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PROGRESS IN FOOD GRAIN RESEARCH AND PRODUCTION IN SEMI-ARID AFRICA

Edited by

J.M. Menyonga
TAYE BEZUNEH
J. Y. YAYOCK
Idrissa SOUMANA

SAFGRAD

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Proceedings of the SAFGRAD Inter-Network Conference
held at the "Palais des Congrès".
Niamey, Niger, 7 - 14 March, 1991

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Edited by

J.M. MENYONGA
International Coordinator
OAU/STRC-SAFGRAD,
Ouagadougou, Burkina Faso

TAYE BEZUNEH
Director of Research
OAU/STRC-SAFGRAD,
Ouagadougou, Burkina Faso

J. Y. YAYOCK
Director, Institute for Agricultural Research
Ahmadu Bello University
Zaria, Nigeria

IDRISSA SOUMANA
Professeur, Faculté d'Agronomie
Université de Niamey
Niamey, Niger

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Contents

	Page
Foreword	xi
Preface	xii
Contributors	xiv
Introduction	xviii
Acknowledgements	xx
INTRODUCTORY REMARKS ON THE CONFERENCE. *J.M. Menyonga.*	xxi
Part I. STRATEGIES FOR IMPROVED FOOD GRAIN PRODUCTION.	
1. New Frontiers for Food Grain Research for the 1990s. *Jacques P. Eckebil.*	3
2. The SAFGRAD Network Approach and Experience in Strengthening National Agricultural Research Capacity. *Taye Bezuneh and G. Kingma.*	21
3. Germplasm Resources for the Improvement of Sorghum and Millets in Sub-Saharan Africa. *Melak H. Mengesha, S. Appa Rao and K.E. Prasada Rao.*	39
4. ICRISAT Cereals Programme Until the Year 2000. *R.W. Gibbons.*	57
5. Networking of Crop Genetic Resources: The Case for West Africa: *J. Toll and P.M. Perret.*	63
Part II. COWPEA.	
06. Regional Approach to Cowpea Research in West and Central Africa. *N. Muleba.*	71
07. Breeding Suitable Cowpea Varieties for West and Central African Savanna. *B.B. Singh.*	77
08. Evaluation of Some Selected Cowpea Varieties for Grain and Fodder Potential. *G. Atuahene-Amankwa and M.A. Hossain.*	87
09. Effect of Delayed Application of Phosphorus Fertilizer on Nodulation, Growth and Yield of Cowpea. *J.K. Adu.*	95

10. The Role of Guided Spraying in the Management of Cowpea Insect Pests. *Jakpasu V.K. Afun.* 105

11. Comparaisons des Méthodes de Traitement Phytosanitaires de Niébé au Niger. *Germaine Ibro, J. Lowenberg-Deboer, K.C. Reddy et Maliki Kadi.* 111

12. Identification of Cowpea Diseases and Evaluation of Selected Cowpea Varieties to Brown Blotch and Web-Blight Diseases in the Forest Ecology of Ghana. *J.K. Twumasi and M.A. Hossain.* 119

13. Field Evaluation of Seed Treatment Fungicides for the Control of Cowpea Scab, Brown Blotch and Septoria Leaf Spot in Nigeria's Northern Guinea Savanna. *A.M. Emechebe, O. Alabi and M. Tarfa.* 127

14. Economic Importance of the Bean Flower Thrip on Cowpeas with Reference to Economic Injury Level. *A.B. Salifu.* 137

15. Critères d'Evaluation au Champ de la Résistance du Niébé au *Striga gesnerioides. T. J. Ouédraogo, J.B. Tignégré et N. Muleba.* 143

16. Identification et Recherche de Variétés Résistantes aux Principaux Virus du Niébé au Togo. *M.Y. Gumedzoe.* 149

PART III. MAIZE.

17. Regional Approach to Maize Research for the Semi-Arid Zone of West and Central Africa. *J.M. Fajemisin.* 157

18. Overview of Maize Research at IITA. *Mark D. Winslow.* 169

19. Analysis of Daily Rainfall Data and its Application to Maize Production in the Transitional Zone of Ghana. *S. Chemeng-Dapaah.* 173

20. Diallel Analysis of Maize Inbred Lines Evaluated in the Forest-Savanna Transition and Guinea Savanna Zones of Ghana. *S. Twumasi-Afriyie, B. Badu-Apraku and P.Y.K. Sallah.* 181

21. Inheritance of Soft and Floury Endorsperm in some Local Maize Varieties of West and Central Africa. *B. Badu-Apraku, J.H. Mareck and J. Kling.* 189

22. Effects of Six Cycles of Recurrent Selection on the Nitrogen Response of a Lowland Tropical Maize Population. *Peter Y.K. Sallah.* 195

23. Comparaison de Méthodes d'Appréciation de la Stabilité de la Productivité de Variétés de Maïs en Zone Semi-Aride. *Abdou Ndiaye.* 203

24. Contribution à l'Evaluation de la Variabilité des Cultivars Traditionnels de Maïs du Centre de la Côte d'Ivoire. *K. Attiey.* 213

25. Field Evaluation of Nigeria-made Granular Urea on Maize Production in the Semi-Arid Zone of Nigeria. *V.O. Chude, E.N.O. Iwuafor and G. Lombin.* 225

26. Response of Maize to Various Rates of Zinc Fertilizer in the Semi-Arid Zone of Nigeria. E.N.O. *Iwuafor, V.O. Chude and I. Amapu.* 235

27. Determination of Optimum Harvesting Date for Seed Maize Using some Seed Characteristics. *Ernest A. Aseidu.* 245

28. Response of Improved Maize and Sorghum Varieties to Different Seed Treatments on-Station and in Farmers' Fields in the Lowland Savanna of North Cameroon. *H. Talleyrand, A. Ebete, T. Ngoumou and W. Katsala.* 251

29. Incidence of Blights and Races of *Excerohilum turcicum* in Cameroon. *Claude Nankam.* 257

30. Development of *Striga hermonthica* Tolerant Open-Pollinated Maize Varieties in Africa. *Soon Kwon Kim.* 263

PART IV. SORGHUM.

31. Network Approach to Sorghum Improvement in West and Central Africa. *Melville D. Thomas.* 277

32. Sorghum and Millet Improvement in Eastern Africa: Current Status of EARSAM Network Activities and Challenges in the 1990s. *V.Y. Guiragossian and S.Z. Mukuru.* 285

33. Besoins Agronomiques des Génotypes de Sorgho sous Condition de Culture Pluviale au Mali. *D. Sogodogo et S.V.R. Shetty.* 297

34. Estimation du Taux d'Allogamie chez les Sorghos de la Race Guinea. *J. Chantereau et C. Kondombo.* 309

35. Etude de la Qualité des Graines Récoltées des Sorghos de Types Guinea et Caudatum. *C. Luce et Mohamed A.G. Hamada.* 315

36 Distribution, Dégâts et Dynamiques des Populations d'*Eurystylus marginatus* Odhiambo (Heteroptera, miridae), Ravageurs du Sorgho au Mali. *Y.O. Doumbia et G.L. Teetes.* 321

37. Réaction de Variétés de Sorgho aux Attaques de la Punaise des Panicules *Eurystylus immaculatus* Odhiambo (Heteroptera, miridae) en Afrique de l'Ouest. *A. Ratnadass, K.V. Ramaiah, H.C. Sharma et B. Cissé.* 333

38. Chemical Control of Sorghum Stem Borers in the Nigerian Savanna. *Ignatius I. Uvah and Olupomi Ajayi.* 345

39. Identification de Sources de Résistance à l'Anthracnose Foliaire du Sorgho Causée par *Colletotrichum graminicola* au Burkina Faso. *Adama Neya.* 355

40. Utilization of Sorghum in Eastern Africa. *S.N. Mitaru and C.I. Munene.* 365

41. Quality of Composite Wheat-Sorghum Bread and Confectionery. *R.E. Aluko, L.B. Olugbemi and C.C. Nwasike.* 371

PART V. CROPPING SYSTEMS AND STRIGA RESEARCH.

42. Soil Testing as a Tool for Soil Fertility Management in the Semi-Arid Zone of Sub-Saharan Africa. *A.A. Agboola and G.O. Adeoye.* 387

43. Production Agronomy of Sorghum-Based Systems in the West African Semi-Arid Tropics: Present Status and Research Challenges. *S.V.R. Shetty, D. Sogodogo and M.V.K. Sivakumar.* 393

44. Influence des Génotypes de Sorgho et de Niébé sur la Population de l'Association Sorgho-Niébé à Sotuba. *D. Sogodogo et S.V.R. Shetty.* 415

45. Premiers Résultats Obtenus sur des Rotations de Sorgho et Légumineuses en Culture Pure ou Associée et de Cotonnier. *Patrick Salez et Kalifa Traoré.* 421

46. Maize-Sorghum Intercropping in Northern Ghana: Effect of Land Preparation and Fertilizer on Growth and Yield. *G.K.S. Aflakpui, J.E. Ampong, S.A.R. Ziblim and L.W. Chanase.* 429

47. Productivity of Maize-Sorghum Mixture as Influenced by Component Crop Density Arrangement. *K.A. Elemo.* 435

48. Research Towards Integrated Control of *Striga* in West and Central Africa. *A.M. Emechebe, S.T.O. Lagoke and J.K. Adu.* 445

49. Integrated Research Approach to *Striga* Control in Food Grain Production in East Africa. *A.G.T. Babiker.* 465

50. Interactions Between some Cowpea Lines and Two Parasitic Higher Plants *Striga gesnerioides* and *Alectra vogelii. A.M. Emechebe and B.B. Singh.* 479

51. Management of Cowpea under *Striga* Infestation in the Sudan Savanna of Burkina Faso: Response of Daylength Sensitive Cultivars. *N. Muleba and E. Mosarwe.* 487

52. Nitrogen Sources and Levels and the Control of *Striga hermonthica* in Sorghum. *C.C. Nwasike, F. Pancras-Deke, V.O. Chude, E.O. Asiribo, C.A. Kimbeng and F.A. Sowemimo.* 497

53. Etude des Parasites du Niébé en Association avec le Sorgho et le Maïs. *A. Yehouenou.* 507

54. L'Expérimentation sur le Désherbage Chimique du Maïs en Zone Cotonnière au Nord-Cameroun. *J. Martin et E. Gerardeaux.* 513

55. Evaluation of Plant Products for the Control of Cowpea and Maize Storage Insects. *M. Owusu-Akyaw.* 523

56. Evaluation of Cowpea and Pearl Millet Cultivars to Improve and Sustain Yield of the Intercrops. *B.R. Ntare and L.K. Fussell.* 537

57. Effect of Planting Time on Cowpea in Relay Intercropping with Maize. *J.N. Asafu-Agyei and P.B. Allou.* 545

PART VI. NOTES

1. La Production du Maïs et Etat Actuel de la Recherche pour le Développement de la Culture au Niger. *Naino Jika.* 553

2. Identification des Sources de Résistance au Charbon Allongé *(Tolyposporium ehrenbergii)* sur le Sorgho (*Sorghum bicolor* L. Moench) et Effet de la Date de Semis sur la Sévérité. *Issoufou-Kolo Abdourhamane.* 555

3. L'intensification de la Culture du Maïs/Niébé en Zone Mali-Sud CMDT : Quelques leçons. *Abdoulaye Dolo.* 557

4. Effets de l'Association Céréale-Niébé sur la Densité de *Striga* Attaquant le Niébé. *Ouédraogo T.J., J.B. Tignégré et G.R. Zangré.* 559

5. Présentation d'une Méthodologie d'Etude des Plantes Parasites Herbacées des Cultures. *G. Hoffmann et C. Diarra.* 561

PART VII. RECOMMENDATIONS/RECOMMANDATIONS.

Report and Recommandations of the Plenary Session 565

APPENDIX I. OPENING CEREMONY

Allocution du Secrétaire Exécutif Adjoint de l'OUA/CSTR. *P.D. Fall.* 573

Discours d'Ouverture du Secrétaire d'Etat auprès du Ministre de l'Agriculture et de l'Elevage chargé du Développement Coopératif. 577

APPENDIX II. CLOSING CEREMONY.

Allocution de Clôture du Secrétaire Général du Ministère de l'Agriculture et de l'Elevage 583

Foreword

In May 1986, a symposium on "Food grain production in semi-arid Africa" was organized in Nairobi, Kenya by the Semi-Arid Food Grain Research and Development (SAFGRAD) Project. That symposium which brought together many national agricultural policy makers, donors as well as several eminent international and national scientists, marked the end of the first phase of SAFGRAD.

The second phase took advantage of the achievements of the first phase and adopted the principles of networking, geared to promoting indigenous leadership in the development of technologies that would enhance more food production across the semi-arid zones of Africa. The inter-network conference held in Niamey, therefore, gave an opportunity to scientists from West, Central and Eastern Africa to present and discuss achievements of the different networks with one another and to see how these networks can work closer together in the interest of the farmer who is the principal food producer.

The Scientific, Technical and Research Commission of the Organization of African Unity (OAU/STRC) has committed itself to collaborate with the International Agricultural Research Centres, donor agencies and national agricultural research programmes of Member States towards food self-sufficiency for Africa.

Professor C.A. Johnson
Ag. Executive Secretary
OAU/STRC
Lagos, Nigeria.

Preface

The main objectives of the Conference were:

(i) to review the current state of knowledge on food grain research progress and production attained in the 1980's;

(ii) to identify the gaps as well as new thrusts of research needs for the 1990's;

(iii) to facilitate scientific interaction and complementary programme activities between and among the different networks in order to promote the exchange of experiences; and

(iv) to assess the extent of the application of research results through on-farm testing and extension activities.

The invited and contributed papers spanned a broad specimen of disciplines in food grain research and production. The keynote address dwelt on analysis of the current technological gains made, and identified some research gaps and priorities "as new frontiers to food grain research in the 1990's".

The plenary sessions which were devoted to technical papers, addressed the following areas:

(i) experiences of regional research collaboration to build national capacity, within the network framework:

(ii) cropping systems research;

(iii) integrated research approach to control *Striga*,

(iv) on-farm verification trials and technology adoption;

(v) importance of soil testing and mapping for determining soil productivity as a basis for fertilizer recommendations and

(vi) exploitation of indigenous rock phosphates and their mixtures with other available sources of nutrients, such as compost, which will improve phosphorus availability, as discussed in Parts III and V.

The concurrent sessions explored research progress made so far and constraints encountered in the improvement and production of cowpea, maize and sorghum as presented in Parts II, III, IV and V, respectively. On the final day of the conference, discussions were centred around the major technical issues that surfaced in the course of the conference. Recommendations for future areas of research emphasis and the institutional evolution of SAFGRAD, as summarized in Part VI were equally treated.

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Response to the call for this Conference involving the West and Central Africa maize, sorghum, cowpea, and millet networks, the farming systems research network of West Africa and the sorghum and millet network of eastern Africa was overwhelming. Over 70 abstracts were received by the Organizing Committee, although only those papers which met the workshop objectives and technical standards have been published.

Apart from the financial assistance received from the United States Agency for International Development (USAID), other agencies which co-sponsored the conference included:

(i) the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT);

(ii) the International Institute of Tropical Agriculture (IITA);

(iii) "Institut National de Recherches Agronomiques du Niger" (INRAN), and

(iv) Semi-Arid Food Grain Research and Development (SAFGRAD) of the Organization of African Unity's Scientific, Technical and Research Commission (OAU/STRC);

Contributors

Abdourhamane, I.K. INRAN, Kollo, BP 429, Niamey, Niger.
Adeoye, G.O. Department of Agronomy, University of Ibadan, Ibadan, Nigeria.
Adu, J.K. Institute for Agricultural Research, Samaru, Ahmadu Bello University, PMB 1044, Zaria, Nigeria.
Aflakpui, G.K.S. Crops Research Institute, P.O. Box 3785, Kumasi, Ghana.
Afun, J.V.K. Crops Research Institute, P.O. Box 3785, Kumasi, Ghana.
Agboola, A.A. University of Ibadan, Ibadan, Nigeria.
Ajayi, O. Institute for Agricultural Research, Samaru, Ahmadu Bello University, PMB 1044, Zaria, Nigeria.
Alabi, A. Institute for Agricultural Research, Samaru, Ahmadu Bello University, PMB 1044, Zaria, Nigeria.
Allou, P.B. Crops Research Institute, P.O. Box 3785, Kumasi, Ghana.
Aluko, R.E. Institute for Agricultural Research, Samaru, Ahmadu Bello University, PMB 1044, Zaria, Nigeria.
Amapu, I. Institute for Agricultural Research, Samaru, Ahmadu Bello University, PMB 1044, Zaria, Nigeria.
Ampong, J.E. Crops Research Institute. P.O. Box 3785. Kumasi, Ghana.
Asafu-Agyei, J.N. Crops Research Institute, P.O. Box 3785, Kumasi, Ghana.
Aseidu, E.A. Crops Research Institute, P.O. Box 3785, Kumasi, Ghana.
Asiribo, E.O., Institute for Agricultural Research, Samaru, Ahmadu Bello University, PMB 1044, Zaria, Nigeria.
Attiey, K., Institut des Savanes, 01 BP 635, 01 Bouaké, Côte d'Ivoire.
Atuahene-Amankwa, G.A. Nyankpala Agricultural Experiment Station. P.O. Box 52. Tamale, Ghana.
Babiker, A.G.T. Agricultural Research Corporation, Gezira Research Station, P.O. Box 126, Wad Medani, Sudan.
Badu-Apraku, B. Crops Research Institute, P.O. Box 3785, Kumasi, Ghana.
Chanase, L.W., Crops Research Institute. P.O. Box 3785, Kumasi, Ghana.
Chantereau, J. CIRAD, 01 BP 596, Ouagadougou, Burkina Faso.
Chude, V.O. Institute for Agricultural Research, Samaru, Ahmadu Bello University, PMB 1044, Zaria, Nigeria.
Cissé, B. ICRISAT-WASIP, BP 320, Bamako, Mali.
Diarra, C. ICRISAT-WASIP, BP 320, Bamako, Mali.
Dolo, A. CMDT, BP 487, Bamako, Mali.
Doumbia, Y.O. IER/SRCVO, Sotuba, BP 438 Bamako, Mali.
Ebete, A. Institute of Agricultural Research, BP 415, Garoua, Cameroon.
Eckebil, J.P. IITA, PMB 5320, Ibadan, Nigeria.
Elemo, K.A. Institute for Agricultural Research, Samaru, Ahmadu Bello University, PMB 1044, Zaria, Nigeria.
Emechebe, A.M. Faculty of Agriculture, Ahmadu Bello University, PMB 1044, Zaria, Nigeria.
Fajemisin, J.M. OAU/STRC/SAFGRAD/IITA, 01 BP 1783, Ouagadougou 01, Burkina Faso.
Fussell, L.K. ICRISAT Sahelian Centre, BP 12404, Niamey, Niger.
Gerardeaux, E. IRCT-CIRAD, IAR, Garoua, Cameroun.

Gibbons, R.W. ICRISAT Sahelian Centre, BP 12404, Niamey, Niger.
Guiragossian, V. ICRISAT/SAFGRAD, P.O. Box 39063, Nairobi, Kenya.
Gumedzoe, Y.M. Université du Bénin, BP 1515, Lome, Togo.
Hamada, M.A.G. ICRISAT-WASIP, BP 320, Bamako, Mali.
Hoffmann, G. ICRISAT-WASIP, BP 320, Bamako, Mali.
Hossain, M.A. Crops Research Institute, P.O. Box 3785, Kumasi, Ghana.
Ibro, G. INRAN, BP 429, Niamey, Niger.
Iwuafor, E.N.O. Institute for Agricultural Research, Samaru, Ahmadu Bello University, PMB 1044, Zaria, Nigeria.
Jakpasu, A.K. Crops Research Institute, P.O. Box 3785, Kumasi, Ghana.
Kadi, M. INRAN, BP 429, Niamey, Niger.
Katsala, W. Institute of Agricultural Research, P.O. Box 415, Garoua, Cameroon.
Kim, S.K. IITA, PMB 5320, Ibadan, Nigeria.
Kimbeng, C.A. Institute for Agricultural Research, Samaru, Ahmadu Bello University, PMB 1044, Zaria, Nigeria.
Kingma, G. USAID/SAFGRAD, BP 35, c/o American Embassy, Ouagadougou, Burkina Faso.
Kling, J. IITA, P.O. Box 5320, Ibadan, Nigeria.
Kondombo, C. INERA, BP 7192, Ouagadougou, Burkina Faso.
Lagoke, S.T.O. Institute for Agricultural Research, Samaru, Ahmadu Bello University, PMB 1044, Zaria, Nigeria.
Lombin, G. Institute for Agricultural Research, Samaru, Ahmadu Bello University, PMB 1044, Zaria, Nigeria.
Lowenberg-Deboer, J. INRAN, BP 429, Niamey, Niger.
Luce, C. ICRISAT-WASIP, BP 320, Bamako, Mali.
Mareck, J.H. IITA, P.O. Box 5320, Ibadan, Nigeria.
Martin, J. IRCT-CIRAD, IRA Maroua, Cameroun.
Mengesha, M.H. ICRISAT, Patancheru, Andhra-Pradesh, India.
Mitaru, B.N. College of Agriculture and Veterinary Sciences, University of Nairobi, P.O. Box 29053, Nairobi, Kenya.
Mosarwe, E. Department of Agricultural Research, Gaborone, Botswana.
Mukuru, S.K. ICRISAT/SAFGRAD, P.O. Box 39063, Nairobi, Kenya.
Muleba, N. OAU/STRC/SAFGRAD/IITA, 01 BP 1783, Ouagadougou 01, Burkina Faso.
Munene, C.I. College of Agriculture and Veterinary Sciences, University of Nairobi, P.O. Box 29053, Nairobi, Kenya.
Naïno, J. INRAN, Kollo, BP 429, Niger.
Nankam, C. IRA Bambui Station, P.O. Box 80, Bamenda, Cameroon.
Ndiaye, A. Institut Sénégalais de Recherches Agricoles, BP 3120, Dakar Senegal.
Neya, A. INERA, 03 BP 7191 Ouagadougou 03, Burkina Faso.
Ngoumou, T. Institute of Agricultural Research, P.O. Box 415, Garoua, Cameroon.
Ntare, B.R. ICRISAT Sahelian Centre, BP 12404, Niamey, Niger.
Nwasike, C.C. Institute for Agricultural Research, Samaru, Ahmadu Bello University, PMB 1044, Zaria, Nigeria.
Olugbemi, L.B. Institute for Agricultural Research, Samaru, Ahmadu Bello University, PMB 1044, Zaria, Nigeria.
Ohemeng-Dapaah, S. Crops Research Institute, P.O. Box 3785, Kumasi, Ghana.
Ouédraogo, T.J. INERA, 01 BP 476 Ouagadougou 01, Burkina Faso.
Owusu-Akyaw, M. Crops Research Institute. P.O. Box 3785, Kumasi, Ghana.

Pancras-Deke, F. Institute for Agricultural Research, Samaru, Ahmadu Bello University, PMB 1044, Zaria, Nigeria.

Perret, P.M. IBPGR, Rome, Italy.

Ramaiah, K.V. ICRISAT-WASIP, BP 320, Bamako, Mali.

Rao, K.E.P. ICRISAT, Patancheru, Andhra-Pradesh, India.

Rao, S.A. ICRISAT, Patancheru, Andhra-Pradesh, India.

Ratnadass, A. ICRISAT-WASIP, BP 320, Bamako, Mali.

Reddy, K.C. INRAN, BP 429, Niamey, Niger.

Salez, P. ICRISAT-WASIP, BP 320, Bamako, Mali.

Salifu, A.B. Nyankpala Agricultural Experiment Station. P.O. Box 483. Tamale, Ghana.

Sallah, P.Y.K. Nyankpala Agricultural Experiment Station, P.O. Box 52, Tamale, Ghana.

Sharma, H.C. ICRISAT-WASIP, BP 320, Bamako, Mali.

Shetty, S.V.R. ICRISAT-WASIP, BP 320, Bamako, Mali.

Singh, B.B. IITA Kano Sub-station, PMB 3112, Kano, Nigeria.

Sivakumar, M.V.K. ICRISAT Sahelian Centre, P.O. Box 12404 Niamey, Niger.

Sogodogo, D. ICRISAT-WASIP, BP 320, Bamako, Mali.

Sowemimo, F.A. Institute for Agricultural Research, Samaru, Ahmadu Bello University, PMB 1044, Zaria, Nigeria.

Talleyrand, H. Institute of Agricultural Research, P.O. Box 415, Garoua, Cameroon.

Tarfa, M. Institute for Agricultural Research, Samaru, Ahmadu Bello University, PMB 1044, Zaria, Nigeria.

Taye, B. OUA/CSTR/SAFGRAD, 01 BP 1783, Ouagadougou, Burkina Faso.

Teetes, G.L. Department of Entomology, Texas A&M University, College Station, TX 77843, U.S.A.

Thomas, M.D. ICRISAT/SAFGRAD, c/o ICRISAT-WASIP, BP 320, Bamako, Mali.

Tignégré, J.B. INERA, BP 7192 Ouagadougou, Burkina Faso.

Toll, J. IBPGR, c/o ICRISAT Sahelian Centre, BP 12404, Niamey, Niger.

Traore, K. ICRISAT-WASIP, BP 320, Bamako, Mali.

Twumasi, J.K. Crops Research Institute, P.O. Box 3785, Kumasi, Ghana.

Twumasie-Afriyie S., Crops Research Institute, P.O. Box 3785, Kumasi, Ghana.

Uvah, I.I. Institute for Agricultural Research, Samaru, Ahmadu Bello University, PMB 1044, Zaria, Nigeria.

Winslow, M.D. IITA, PMB 5320, Ibadan, Nigeria.

Yayock, J.Y. Institute for Agricultural Research, Samaru, Ahmadu Bello University, PMB 1044, Zaria, Nigeria.

Yehouenou, A. Station de Recherches sur les Cultures Vivrières, INA, BP 03 N'Dali, Benin.

Zangré, G.R. INERA, BP 7192, Ouagadougou, Burkina Faso.

Ziblim, S.A.R. Crops Research Institute, P.O. Box 3785, Kumasi, Ghana

Introduction

Based in Ouagadougou, Burkina Faso, Semi-Arid Food Grain Research and Development (SAFGRAD) is a regional project of the Organization of African Unity's Scientific, Technical and Research Commission (OAU/STRC).

In response to the worsening droughts which hit the African Continent, SAFGRAD was created more than 15 years ago by OAU Heads of State and Government with the principal objective of improving the quality and quantity of the major food grains (sorghum, maize, millet and cowpeas) of the semi-arid region of Africa. It was also to develop appropriate farming systems which could build and maintain the resource base for productive agriculture in this zone.

Evolution of SAFGRAD

During the first ten years of existence, SAFGRAD worked in close collaboration with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) on sorghum and millet, and with the International Institute of Tropical Agriculture (IITA) on maize and cowpea as well as with the national research programmes of its member countries. It was during this first phase that crop varieties and technologies were developed to improve the productivity and economic conditions of resource-poor farmers.

The second phase of SAFGRAD (1987-1992), while still involved in technology development and transfer, the major thrust was directed towards enhancing the capacity of national programmes through networking. Six networks were established; one each for maize, cowpea and sorghum in West and Central Africa, one for sorghum and millet in East Africa and the others for farming systems research and agroforestry in West Africa.

Management of SAFGRAD

Notwithstanding its administrative relationship with STRC and the OAU General Secretariat, the need was felt to involve more African scientists in decision-making and to develop indigenous human capital (capacity building) to assume greater leadership in directing and managing agricultural research and network activities. This resulted in the creation of the Council of National Agricultural Research Directors of all the 26 SAFGRAD member countries. The Council met biennially to review SAFGRAD activities and provide policy guidance.

A seven-member Oversight Committee, directly responsible to the Council of National Directors, oversees the administrative, technical and financial affairs of SAFGRAD and evaluates the performance of the networks. The Committee comprises eminent scientists, research managers and members of agricultural faculties of African universities drawn from West, Central, East and Southern Africa. It meets at least once a year.

The activities of each research network are guided by a Steering Committee composed of 5-8 NARS scientists who are actively involved in research on the particular crop or commodity. It meets twice a year.

The day-to-day activities of SAFGRAD are carried out at the SAFGRAD Coordination Office (SCO) in Ouagadougou, Burkina Faso. The SCO serves as the secretariat for the Council of National Directors and the Oversight Committee. It provides the political and administrative leadership crucial for sustaining network activities. Through its OAU umbrella, the SCO facilitates the movement of scientists, germplasm and research supplies among member countries. It organizes meetings for the various committees and facilitates the arrangement of scientific monitoring tours, training courses, seminars, workshops, etc.

Acknowledgements

This publication would not have been possible without the direct or indirect contribution of several individuals and organizations. The Coordination Office of the Semi-Arid Food Grain Research and Development (SAFGRAD) Project of the Organization of African Unity's Scientific, Technical and Research Commission (OAU/STRC) is greatly indebted to the United States Agency for International Development (USAID) and the African Development Bank for funding the publication of this document; to the International Agricultural Research Centres, IITA and particularly ICRISAT for their technical and logistic support and the National Institute of Agricultural Research of Niger (INRAN) whose assistance, through the Local Organizing Committee, was indispensable for the success of the Conference. The Government of the Republic of Niger deserves special thanks for allowing the Conference to continue its deliberations in the same building where its National Conference was also taking place. All the participants were touched by this gesture of support from the people of Niger.

The award of certificates of recognition to deserving scientists by STRC as an encouragement for scientific excellence is gratefully acknowledged. Thanks are due to Prof. Joseph Y. Yayock and Prof. Idrissa Soumana for their hard work in editing the various papers that make up this publication, and to all the secretarial staff, especially Mrs. Yvonne Toé who spent numerous hours in preparing the manuscript for these proceedings.

Introductory Remarks on the Conference

JOSEPH M. MENYONGA

International Coordinator, OAU/STRC-SAFGRAD Ouagadougou, Burkina Faso

This Inter-Network Conference on food grain research and production marks another significant turning point in the life of the Semi-Arid Food Grain Research and Development (SAFGRAD) of the Organization of African Unity (OAU). The first such conference was the SAFGRAD drought symposium which took place in Nairobi, Kenya, in 1986.

Created by the OAU since 1976, the focus of SAFGRAD has been directed on developing maize, sorghum, cowpea and millet research in the semi-arid regions of 26 member countries. This was in response to the severe drought which devastated the African Continent during the 1970s. SAFGRAD has since worked very closely with national agricultural research institutions as well as with International Agricultural Research Centres (IARCs) and notably the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in respect of sorghum and millet and the International Institute of Tropical Agriculture (IITA) for maize and cowpea. You will, therefore, understand why this conference is being organized by SAFGRAD jointly with the National Agricultural Research Institute of Niger (INRAN), ICRISAT and IITA.

As one of the regional offices of the OAU, SAFGRAD receives legal and administrative guidance through its Scientific, Technical and Research Commission (STRC) based in Lagos, Nigeria. The Assistant Executive Secretary of this Commission will be addressing you also during this conference.

Technically, SAFGRAD is headed by the Council of National Agricultural Research Directors of its member states. The Council, in turn, has appointed an Oversight Committee of seven eminent agricultural research scientists which meets regularly to review SAFGRAD activities.

During the first ten years since from its existence, SAFGRAD used the umbrella of the OAU to work across political and linguistic barriers in assisting and strengthening national programmes through training, information exchange, testing and adaptation of different crop varieties and other agricultural technologies developed by ICRISAT, IITA and some national agricultural research institutions. Since 1987, SAFGRAD has concentrated most of its attention on the development of agricultural research Networks in collaboration with IARCs and NARS. Four of the networks on maize, cowpea, sorghum and farming systems research presently operate in West and Central Africa, while a joint Network on sorghum and millet is for Eastern Africa.

Through the system of networking, SAFGRAD has registered some significant achievements including greater articulation of NARS research needs by ICRISAT and IITA, emergence of NARS scientific and research management leadership as

well as the sharing of research results and germplasm between national programmes.

Before the second phase of SAFGRAD comes to an end towards the end of 1991, this conference has been planned towards bringing together all the partners working separately on the crop commodity Networks with the primary aim to:

i. review the current status of knowledge on food grain research and production and to document the progress made during the last five years;

ii. identify gaps as well as new thrust of research needs for the 1990s;

iii. facilitate scientific interaction and complementary programme activities between and among the different Networks in order to promote exchange of experiences, and

iv. assess the extent of the application of research results through on-farm testing and extension activities.

The conference has brought together scientists from 21 West, Central and Eastern African countries as well as several foreign experts to address the above-mentioned issues as well as find answers to Africa's multitude of agricultural problems. Knowing the spirit of cooperation that has existed within and between the different Networks, I have no doubt that the objectives of this conference will be achieved.

The Honourable Minister of Agriculture and Livestock, Distinguished guests, Ladies and Gentlemen, if SAFGRAD has been successful, it is due mainly to the generous and ready funding from the various donors, and especially the United States Agency for International Development (USAID), the International Fund for Agricultural Development (IFAD), the Ministry of Cooperation of France, the International Development Research Centre (IDRC) of Canada, to mention just a few. While expressing appreciation to these and other sponsoring agencies, it is our desire and hope that we can continue to count on their support and assistance. Special thanks are due to INRAN for its assistance in organizing this conference as well as to ICRISAT and IITA for their valuable contributions. I thank the Government of the Republic of Niger for permitting us to host this conference in this beautiful Palais des Congrès. I thank all of you, Ladies and Gentlemen, for honouring our invitation and wish you all successful deliberations.

PART I

Strategies for improved food grain production

New Frontiers of Food Grain Research for the 1990s

JACQUES P. ECKEBIL.

Deputy Director-General, IITA, Ibadan, Nigeria.

Introduction

As an introduction to this presentation, I would like to share with you an extract from the book "Science in Africa" by Thomas A. Bass, primarily because I feel it expresses particularly well the African dilemma:

"Photographs supposedly don't lie, but the images we see of African crisis seem unreal. Farmers standing in fields blasted by drought. Mothers in feeding camps sheltering hungry children. Then we hear on the nightly news that European and American farmers are suffering, too from over production. Wheat farmers in Europe have trebled their yields per acre since 1960. Rice yields in Asia have doubled. The green revolution of genetically improved crops -resistant to diseases, pests, and drought - has worked its miracle around the world. Everywhere, that is, except in Africa, which stands alone in suffering a per capita decline in food production. How has a continent that was self-sufficient until the 1960s slipped so disastrously behind? And what can be done to reverse the trend?"

Table 1. Selected economic indicators in sub-Saharan Africa (%).

Indicator	1965-73	1973-80	1980-87
GDP[1]	5.9	2.5	0.5
GNP per capita	2.9	-0.1	-2.6
Agriculture	2.2	-0.3	1.3
Inflation rate	7.5	6.8	15.2
Population growth	2.6	2.8	3.1

Source: Sub-Saharan Africa: From Crises to Sustainable Growth. The World Bank, Washington, D.C., 1989.

Note: 1. Average annual percent.

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Many authoritative studies have dealt with food situation in Africa. This paper will, therefore, not attempt to address in any detailed manner the crisis situation of food production in Africa. Rather, it will only set the stage by recalling the basic indices of food production in Africa.

With a total number of 45 countries in west, central, eastern and southern Africa, sub-Saharan Africa has a total population of 450 million people and covers an area of approximately 22 million square kilometres. It has been estimated that about 800 million hectares are potentially arable, although only 215 million hectares are actually cultivated, with 9.5 million hectares being under irrigation. (Grall, 1986).

With an annual population growth rate of 3.1%, (Table 1), the basic indices stand as follows for the periods 1965/73 and 1980/87:

a) the per capita GNP declined from 2.9 to 2.6%;
b) average annual growth rate of agriculture commodities declined from 2.2 to 1.3% while inflation rate doubled from 7.5 to 15.2% and
c) maize, millet and sorghum production grew at 2.3, 0.8 and 1.2% annually (Table 2) compared with 2.3 and 2.0% for rice and wheat, respectively.

In terms of total cereal production, the rate of annual growth between 1965 and 87 was only 1.7%, from 33 to 47.7 million tons of grain (Table 3). Knowing the importance of cereals in the food consumption of the peoples of Africa, it is no wonder that cereals

Table 2. Average annual production of some major food crops in sub-Saharan Africa (%).

Commodity	1965-73	1973-80	1980-87	1965-1987
Maize	3.3	-0.2	3.7	2.3
Millet	1.2	-1.2	2.5	0.8
Sorghum	0.2	2.3	1.3	1.2
Rice	3.7	2.6	2.7	3.0
Wheat	3.9	1.1	1.0	2.0
Total Cereals	2.0	0.9	2.3	1.7
Pulses	-2.1	1.2	3.4	2.5

Source: Sub-Saharan Africa: From Crises to Sustainable Growth. The World Bank, Washington, D.C. 1989.

Table 3. Production statistics of some major food crops in Sub-Saharan Africa (million metric tons).

Commodity	1965	1980	1987
Maize	9.9	12.9	15.6
Millet	8.1	9.2	10.1
Rice	3.7	6.3	7.6
Sorghum	8.4	11.1	10.7
Wheat	1.0	1.5	1.5
Total Cereals	33.0	43.7	47.7
Pulses	3.5	4.5	3.9

Source: *Sub-Saharan Africa: From Crises to Sustainable Growth. The World Bank, Washington, D.C. 1989.*

imports doubled between 1974 and 86, from 4.1 to 8.1 million tons. In addition, food aid for the same period more than trebled, from 0.9 to 3.1 million tons of grain.

The production of legumes during the same period was estimated at 3.5 to 4 million tons, with an average annual growth of 2.6%. Overall, the per capita average food production index remained relatively unchanged between 1979/81 and 1985/87, while the average annual consumption of basic food staples grew at a steady annual rate of 2.5% and the per capita food production dropped by 1% annually. The consistent short-fall in legume and cereal grain production provides a plausible explanation for the over 100 million under-nourished people in Africa and representing about 30% of the population of the sub-Saharan region or 93 poor individuals per square kilometer of real agricultural area.

According to World Bank projections (Table 4), food deficits world-wide are likely to grow to as high as 50, 115 and 245 million tons of maize equivalent in 1990, 2010 and 2020, respectively. From such projections, it is postulated that the food gap can be eliminated only when population fertility rate declines by 50% to 3.3% whilst food production grows at 4% annually -- a task that implies trebling the present growth rate of food output. The food situation thus appears quite gloomy.

Table 4. Population and food security in Sub-Saharan Africa, 1990-2020.

Assumptions	1990	2000	2010	2020
Case - 1				
Population (millions of people) (with constant fertility rate)	500	700	1.101	1.500
Food production (mtme* at current-trend growth rate of 2% per year)	90	110	135	165
Food requirement (mtme, for universal food security by 2020)	100	160	250	410
Food gap (mtme)	10	50	115	245
Case - 2				
Population (as in Case - 1)	500	700	1.010	1.500
Food production (at 4% annual growth)	90	135	200	300
Food requirement (as in Case - 1)	100	160	250	410
Food gap (as in Case - 1)	10	25	50	110
Case - 3				
Population (millions of people) (with total fertility rate declining 50% to 3.3% by 2020)	500	680	890	1.110
Food production (mtme, at 4% annual growth)	90	135	200	300
Food requirement (mtme)	100	150	220	305
Food gap (mtme)	10	15	20	5

Source: Sub-Saharan Africa: From Crises to Sustainable Growth. The World Bank. Washington, D.C. 1989.
* mtme = millions of tons of maize equivalent.

Major Constraints to Food Grain Production in Semi-Arid Zones

Among major technical constraints to food grain crop production in the semi-arid zones of sub-Saharan Africa are recurrent drought, desertification, low and erratic rainfall, low soil fertility, poor crop management practices, as well as attacks by insect pests, diseases (including parasitic flowering plants) and vertebrates.

Rainfall constitutes the most limiting factor to crop production in semi-arid Africa. Historical, long-term rainfall studies show a consistent decrease in total amounts, with dry periods alternating with wet periods (Farmer and Wigley, 1985). More

recent studies of rainfall fluctuations show striking features over the last 40 years. For about 15 years starting in 1950 (Fig. 1), rainfall was on the average abnormally higher than the average. But since 1968, a period of below average rainfall has taken place and has led to the persistant dry spell being experienced by all sub-Saharan African countries and particularly those in the Sudan zone. Table 5 clearly shows that the mean rainfall for the period 1970 is about half of that received from 1950-59. But beyond the total amount of rainfall is the unreliability, unpredictability, as well as their year-to-year variability that has come to characterize the semi-arid zone.

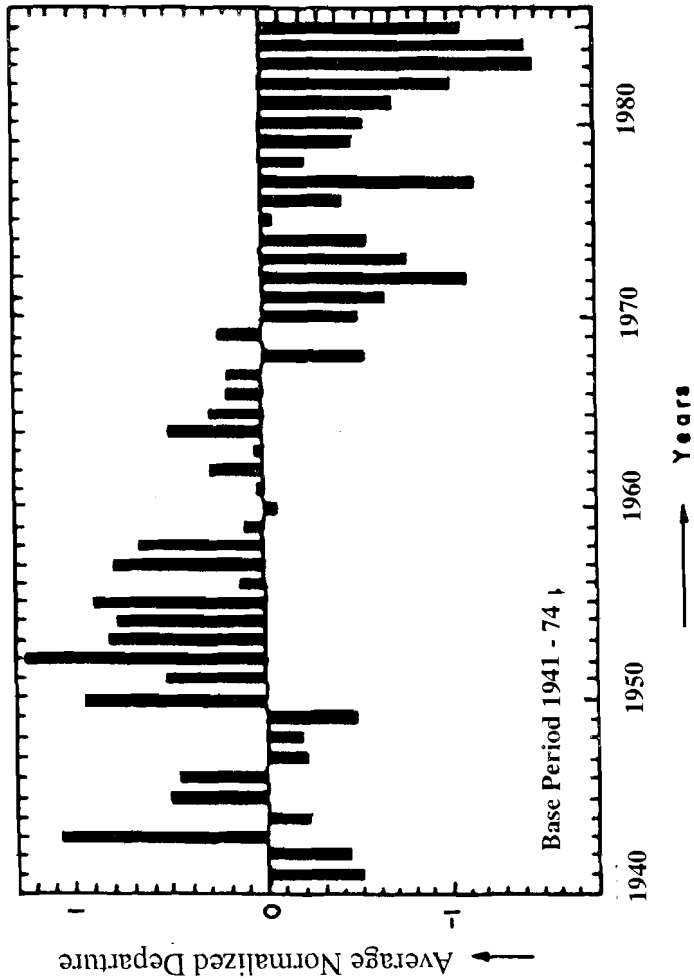

Fig.1. Sub-Saharan rainfall index averaged over 20 locations

Table 5. Rainfall at nine Sahel stations in various years (mm/year).

Location	1950	1972	1983	1950-1959	1970-1984
Bilma	40	21	0	20	9
Atbara	166	55	15	92	54
Nouakchott	183	103	66	172	51
Khartoum	178	135	86(15)	178	116
Agadez	262	74	94	210	97
Tombouctoo	230	106	74	241	147
Nema	345	245	43	381	210
Dakar	797	130	159	609	308
Banjul	1489	583	358	1409	791

Virtually all of sub-Saharan Africa is subject to drought although the severity is greatest in the Sahel zone. It is estimated that one third of Western Africa is arid. All countries in the Sahelian zone were severely affected by the droughts of the late 1960s and early 1970s when cereal production was a mere 15% of normal yearly harvest (Sasson, 1990). Another round of drought occurred in the early 1980s, resulting in food shortages in some 22 African countries (Farmer and Wigley, 1985).

The manifestation of persistant drought over prolonged periods leads to desertification, a situation in which dry ecosystems lose the capacity to revive or repair themselves (Hare, 1985). It is estimated that between 1935 and 85, the Sahara desert had invaded about 100 million hectares of previously productive land and continues to encroach at the rate of 2 millions hectares per year in the Sahel or 7 to 10 km per year in Senegal (Zecchini, 1985 b).

Among documented causes of drought and desertification are the extension of crop cultivation to marginal lands where rainfall is increasingly uncertain, overgrazing of large flocks as a consequence of increasing settlement of pastoralists and deforestation of wooded land for fuel purposes. But beyond these and similar human activities is the global process of atmospheric circulation which has direct implication on drought condition (Hare, 1985; Nicholson, 1989).

Crop resistance/tolerance to soil moisture stress and high soil temperatures are important adaptation traits for successful agricultural production in the semi-arid tropics. In terms of fertility, most soils of the semi-arid zone are poor, both physically and chemically. Decades of cultivation without soil amendments or adequate crop rotation, the removal of natural vegetation, overgrazing, bush burning, indiscriminate cutting of trees have all combined to hastened the erosion and degradation of the fragile soils of the arid and semi-arid zones (Ibrahim and Modibo, 1989; Spikens and Nabila, 1989).

Whereas in the past, resource-poor farmers traditionally restored soil fertility by long periods of bush fallow, this is no longer feasible mainly due to rapidly increasing population pressure. At the same time,the high costs of inorganic fertilizers limits the extent and intensity of their use, thus resulting in a steady decline in soil productivy with the consequent reduction in yields (Sasson, 1990).

Crop damage by pests and diseases is yet another serious constraint in the production of virtually all crops. Among the multitude of important pests of dry environments are termites, army worms, stem borers, migratory locusts, birds and especially *Quelea quelea* (IITA/SAFGRAD, 1986; Doggett, 1988).

Perhaps the most serious disease problem that cuts across crops and ecologies is *Striga*. While *Striga hermonthica* attacks maize, sorghum and millet, the species *Striga gesnerioides* and *Alectra vogelii* both attack cowpea (Emechebe *et al.*, 1988). With the rapid expansion of maize into the relatively dry savanna areas of Africa, *Striga* is rapidly becoming a very serious constraint to maize as it is for cowpea production.

Specific to sorghum, the shootfly (*Atherigona soccata*) is regarded as the most important field insect in both east and west Africa, while sorghum midge *(Contarinia sorghicola)* and the head bugs complex seem more important in west Africa. Other important insect pests in east Africa are armyworms, borers, grain weevils and moths (Gebrekidan, 1987). Diseases considered important in the semi-arid zones of sub-Saharan Africa are ergot (*Claviceps purpurea*), grain molds, anthracnose *(Colletotrichum graminicola)*, smuts, charcoal rot (*Macrophomina phaseolina*) and downy mildew.

Downy mildew remains the main millet disease in west Africa while blast (*Pyricularia grisea*) and ergot seem more prevalent on finger millet in east Africa.

Apart from the virus complex of maize (maize streak, maize chlorotic mottle and maize stripe), a major but often ignored maize disease is the root and stalk rot complex induced by various species of *Macrophomina, Fusarium* and *Botryodiplodia.* In addition, localized epidemics of various types of downy mildew occur is some parts of the dry savanna zones of Africa.

Cowpea is attacked by a large number of important pre flowering insect pests, including *Aphis craccivora* and *Ootheca mutabilis*. Among the flowering pest of cowpea are *Thrips* while the post-flowering pests include Maruca pod borer and a complex of pod sucking bugs. The major diseases of cowpea in the arid and semi-

arid zone include bacterial bligth (*Xanthomonas campestri* pv. *vignicola*) and *Septoria* leaf spot. The last three of these diseases, together with a scab (*Sphaceloma* stage of *Elsinoe phaseoli)* are very destructive especially in the more humid Northern Guinea than in the Sudan savanna and Sahel zone where bacterial blight and macrophomina blight attain epidemic proportions. Of the two major virus diseases of cowpea in the arid and semi-arid tropics, cowpea aphid-borne mosaic virus (CAbMV) is a lot more important than cowpea golden mosaic virus (CGMV) because the latter causes occasional epidemics only in local, prostrate cultivars while CAbMV causes successive epidemics in both local and improved cowpea varieties. A recently recognized problem on cowpea in the sandy soils of the Sudan savanna zone is the root knot nematode complex *(Meloidogyne incognita, M. arenaria & M. javanica)* which is prevalent following successive cultivation of cowpea.

Research Achievements in Food Grain Crops.

Scientists and institutions have devoted much time and resources in addressing these and other constraints of crop production with mostly encouraging results and achievements. One area where substantial progress has been made is in the genetic development of crop varieties with improved adaptation to bio climatic conditions of semi-arid ecologies and particularly in their resistance/tolerance to diseases and insects. Table 6 lists a number of crop varieties identified or developed through SAFGRAD Networks and which are cultivated in 12 countries of West and Central Africa.

More specifically, SUVITA-2 cowpea shows a good level of resistance to strains of *Striga gesnerioides* which is prevalent in Burkina Faso and Mali.Similarly, VITA-7 and TVx 3236 are also popular in the region for their resistance/tolerance to important cowpea diseases and insects, particularly thrips.

Early breeding efforts in maize had concentrated on improving varieties for resistance to lowland rust and blight. These efforts led to the release of TZB and TZPB varieties, which are still popular in the region. Later, the combined efforts of IITA and CIMMYT led to the development and release of several streak resistant maize varieties like TZESR-W, IKENNE 8149-SR (POZA RICA 43-SR).

Table 6. Crop varieties identified through Network activities for production in various countries in West and Central Africa.

Country	Cowpea	Sorghum	Maize
Burkina Faso	KN1, Suvita-2 TVX 3236, TVX 396-4-4	ICSV-1001 (Framida) E-35-1 ICSV 16-5, BE ICSV 1049 BA.	EV 8422-SR KPB (EV 8430SR) KPJ (EV 8431SR)
Guinea Bissau	IT 82E-9		Aburotia
Ghana	IT 82E-16 IT 82E-22	Composite-4	Aburotia Golden Crystal Kawanzie Mexican-17-E
Mali	Suvita-2 TN-88-63		SAFITA-2 TZE-Y
Nigeria	TVX 3236	ICSV 1007 BF	TZESR-W
Benin	TVX 1850-01 F, IT 82E-32 IT 81D-1137		Sekou 81TZSR-W-1 EV 8443-SR Pirsaback 7930 SR
Cameroon	IT 81D-985 (BR1), IT 81D-994	S-34, S-35	Mexican 17E SAFITA-2
Togo	IT 81D-985 (B-Togo)		Poza Rica 43-SR Ikenne 8149-SR Pirsaback 30-SR KPB (EV 8430-SR)
Niger	TN-5-78, KVx 1002	ICSV 1007 BF	
Côte d'Ivoire			CD IRAT-178 MTS FERKE-7622
Senegal	58-57 and IS 86-275		Synthetic-C JDB SM-10
Chad	TVx 3236 IT 81D-985		TZESR-W

Several sorghum varieties exhibiting good levels of resistance to drought, anthracnose and ergot have been identified by EARSAM for Rwanda, Ethiopia and Sudan. In Kenya, the sorghum cultivar IS76 which is resistant to long smut has been released, while in West Africa varieties like E-35-1, ICSV-1007 BF, ICSV 1001 (Framida) which have a measure of resistance to *Striga hermonthica* are widely cultivated in many of the countries.

An important characteristic emphasized in the development of improved varieties for semi-arid regions is earliness in growth and maturity. Motivated by the short growing season and the relative unpredictability of rainfall, IITA scientists have developed a number of 60-day erect and photo-insensitive cowpea varieties for sole cropping as well as minimum insecticidal regime. More recently, extra-early varieties of maize have been developed by the SAFGRAD Maize Network and which are particularly popular because they mature during the "hungry period" in the Sahel and well before the sorghum crop reaches maturity.

Achievements relating to crop management include optima sowing dates, plant populations and fertilizer requirements principally for sole cropping situations. Since rainfall is a major constraint to food crop production especially in the Sahel ecology, mention must be made of the tied-ridging technique developed by SAFGRAD to reduce runoff losses and to improve water infiltration.

Research Agenda for Next Decade

a) The Main Crops

i) **Maize Research**. All available data suggest that the moist savanna presents a priority research ecology for maize relative to the Sudano-Sahelian zone, even if early and extra-early maize will continue to play some role as the "hungry crop". It is in this ecology that the parasitic plant Striga represents the major threat to maize production, hence the emphasis in breeding for resistance/tolerance to this pest. Since little progress has been made until now by using routine conventional plant breeding methods, it is imperative that the approach must be re-oriented towards more basic research aimed at better understanding of the host-parasite relationships as well as the mechanisms for resistance/tolerance.

The high potential of the moist savanna must be exploited using hybrid maize varieties. In this context, inbred lines will have to maintain a high level of resistance to streak virus, downy mildew, stem borer, rust and blight. Other abiotic breeding objectives will need to also include high nitrogen use efficiency as well as resistance to drought.

ii) **Sorghum Research**. With plans well underway to hold a world-wide symposium on sorghum research and production, I will rather not anticipate the outcome of such a highly distinguished forum in defining a research agenda for sorghum in the nineties. Rather, I will only highlight in this presentation some of the researchable issues that are likely to continue to attract the attention of sorghum scientists especially in sub-Saharan Africa.

Foremost among issues of major interest in sorghum research are those relating to abiotic factors limiting production and particularly environmental stress. In the semi-arid tropics where rainfall is problematic in amounts and distribution, resistance/tolerance to drought in relation to continuous changes of the environment will, of necessity, continue to be a major issue for research. This will thus call for a better characterization of the sorghum agro-ecologies as well as multi-disciplinary studies relating to the physiological mechanisms of drought resistance.

Among the biotic factors, insects, diseases and Striga will necessarily constitute researchable issue of high priority. Even though some work has already been done on the biological control of some of the important sorghum pests, it is more than likely that host-plant resistance and cultural methods will continue to be the best management strategies towards effecting their control. Since the five major sorghum diseases (grain molds, charcoal rot, downy mildew, anthracnose and virus diseases) are likely to continue to constitute serious constraints to production, the best management strategy in the next decade, especially keeping in mind the resource-poor farmers, is host resistance. Fortunately, there is a large germplasm collection assembled and managed by ICRISAT much of which have been screened for disease resistance and many promising lines identified (Mengesha and Rao, 1981).

Specific to *Striga* research, extensive laboratory screening of more than 15,000 accessions of the sorghum germplasm has been made and over 600 lines identified as holding some promise for *Striga* resistance, but the understanding of resistance mechanisms is presently lacking or is incomplete. What is more, field screening techniques have proved largely unreliable. Future research efforts on *Striga* control must necessarily be well coordinated and multi-disciplinary in approach if major break-throughs are to be achieved.

iii) **Cowpea Research.** The major re-orientation of cowpea research in the next decade will be the translation into research objectives of the belated acceptance by scientists generally that cowpea is essentially intercropped in the semi-arid region of Africa. Unlike in the past when the breeding objectives were directed towards the creation of determinate and erect cowpeas suitable for sole cultivation, the challenge now is to breed for new types which are photosensitive, with morphological and physiological characteristics which make them suitable for intercropping.

Another research area which will need urgent attention is that of resistance to post-flowering pests. Since the regular screening of germplasm for identification of sources of resistance has thus far not yielded good results, attention must necessary be turned to wild *Vigna* species in the search for resistance genes for post-flowering pests. The transfer of such genes from wild *Vigna* to cultivated *Vigna* will involve wide crosses combined with bio technology research for which little capacity exists presently in Africa. To this end, effective linkages must be developed with advanced laboratories in other parts of the world.

With regard to *Striga*, much has been achieved recently in the identification of sources of resistance to *Striga gesnerioides* and *Alectra vagelii* in the cowpea line B-301. An active crossing programme to transfer this resistance gene to all cultivated cowpea varieties should receive the highest priority attention during the coming

years. These and similar research objectives are intended to be achieved by the combined effort of IITA and other IARCs with national agricultural research institutions and notably Nigeria's Institute for Agricultural Research (IAR) in Samaru.

iv) **Millet.** The overall objectives of millet improvement in the next decade will be to combine high yield potential and acceptable grain quality with resistance/tolerance to drought, to seedling emergence and to diseases and insects. Research priority is to continue on the important millet diseases of the region, including downy mildew (*Sclerospora graminicola*), smut (*Tolyposporium penicillariae*) and ergot (*Clavicep fusiformis*). With regard to pests, stem borer remains one of the most important.

v) **Soyabean.** Although soyabean is not among SAFGRAD mandated crops, it is more than likely that the crop will assume increasing importance in the semi-arid zones of sub-Saharan Africa. Apart from sharing the same agro-ecologies with maize and sorghum where its ameliorating effect on the soil physical and chemical properties is well known, soyabean has already received considerable research attention towards resolving such production constraints as nodulation, seed viability, pod shattering, resistance to insect pests and diseases as well as its potential to human nutrition, including such high-risk social categories like lactating mothers and children. With the overcoming of these and other production constraints by the joint effort of IITA and Nigerian scientists, the two major research priorities in the coming years will be the adaptation of improved cultivars to the farming systems of the different ecologies and the utilization aspects of the crop. Following a workshop held in January of 1991 involving soyabean researchers from IARCs, NARS as well as sponsoring agencies, participants endorsed the creation of an African Network on Soybean Production and Utilization. When operational, such a Network may serve to provide the necessary framework and leadership for the promotion and development of soybean in Africa.

b) Common Research Priorities

By reviewing the research priorities identified for each of the important crops of the semi-arid tropics, it is evident that some of these, including drought, Striga, intercropping and post-harvest technology, are common to all the crops and, consequently, of importance for inclusion in the research agenda over the next decade.

i) **Drought.** Drought has been and will continue to be the most common natural phenomenon agriculture will have to cope with in the semi-arid regions of the world. The climatic factors of rainfall and temperature which influence drought offer little or no direct control by man. The challenge for scientists and farmers is, therefore, to manipulate the crops cultivated in such a way as to adjust their life cycle to the particular conditions or temporal patterns of these factors. In this regard, what solutions are proposed for adoption must be sustainable by the resource-poor small-scale farmers of the region.

Plant breeding remains the most effective tool for the search for low cost solutions especially when pursued in a multi-disciplinary approach involving agro-climatologists and plant physiolo-gists. Already, simple models have been developed which

allow the prediction of the length of the growing season and its variation in a particular region based on soil-water balances and climatic data such that the breeder is able to select varieties which fit, on the average, the growing season (Landsberg, 1988). In addition to or in combination with breeding for varieties with special characteristics for drought-proned environments, agronomic practices will also need to be pursued towards modifying the soil structure in such a way as to decrease water run-off, increase water infiltration and, therefore, increase water availability to the crop.

ii) ***Striga.*** The dismal achievements recorded thus far in *Striga* research is generally perceived to be the result of the piecemeal approach employed in tackling this gigantic problem. To effectively address the *Striga* problem in all its ramifications, it is suggested that research be pursued in a concerted and coordinated manner towards tackling all the facets of the problem, including such basic and strategic research areas as the better understanding of resistance/tolerance mechanisms of crops against *Striga*, the development of laboratory screening techniqes, the study of mechanisms which influence seed germination, attachment to host and emergence, the development of bio-technological and molecular techniques in *Striga* research like inter generic transfers of genes, and the study of the possibilities offered by biological control in combating *Striga*. Also to be pursued as part of the coordinated approach to *Striga* research are such applied research areas as the development of simple and reliable laboratory and field screening methods, identification of sources of resistance by systematic screening of germplasm, as well as the development of stable and high-yielding varieties.

iii) **Intercropping** is the basic production system in the semi-arid tropics of west Africa (Steiner, 1984; Norman, 1974), with food security as the main reason. Proven advantages of crop associations over sole cropping include efficient resource use, particularly for crop mixtures which maximize spatial and temporal complementarity (Fussell and Serafini, 1987).

For all practical purposes, it is important to assume that intercropping will remain the main production system of this ecological zone over the next decades. With the proven erroneous assumption that varieties developed for mono-cropping are also readily suitable for intercropping situations, future research must necessarily seek to develop crop varieties and other improved technologies that are specific for mixed cropping systems. In the specific case of cowpea research, for example, the IITA Research Station in Kano, Nigeria, has been mandated to work closely with the IAR, Samaru, to develop locally adapted genotypes for mixed cropping systems with millet and sorghum and incorporating stable resistance to insects pests and diseases and to *Striga*.

iv) **Post-harvest technology** as an essential component for food security has thus far received relatively little research attention in sub-Saharan Africa. This is rather surprising, considering the enormous post-harvest losses reported especially in developing countries. If the food gap has to be met in the next decade, urgent steps must necessarily be taken to protect what food grains are produced.

Although resolutions of post-harvest problems are largely institutional in nature and require governmental policy decisions, it is considered essential that each national research systems should maintain a minimum capacity for post-harvest research especially relating to the handling, drying, storing and processing of crop produce at the farm level. Other research areas which need to be pursued relate to resistance to cowpea bruchids and storage pests of maize, especially the larger grain borer (Prostephanus truncatus. Losses due to this borer is presently checked by using synthetic pyrethroid insecticide, but good prospects exist for its control by classical biological control techniques - an aspect that should retain adequate attention in the next decade.

v) **On-Farm Research**. Many studies have shown the significant yield gap that exists between improved crop varieties developed and managed under research conditions and when grown under farmers conditions. Such differences, often as high as 60%, are explainable on the basis of the little attention paid to understanding the conditions and the environment under which the farmer operates, the many constraints which hamper his operations and the difficult decisions he has often to make when presented with a new or improved technology. It is in this realisation that on-farm research should receive increased attention in the next decade towards assisting on-station research to focus on the real problems and needs of the farmer and improving on the dismal record of low adoption of technologies.

Strengthening Agricultural Research Institutions

The effective implementation of the agricultural research agenda in the coming decades is predicated on the availability of strong and effective national research systems. The need for the strengthening of NARS in sub-Saharan region is, therefore, an issue of utmost importance which cannot be overlooked in the overall strategy of food security in Africa. Even with the presence of international and regional research agencies in the region, experience elsewhere clearly demonstrates that productive interaction occur only when the national system is substantially strong to pursue true partnership.

Among problems identified and which deter the effective operation of NARS are related to organizational set us, insufficient management capacity, obsolete or inadequate research infrastructures and facilities, inadequate linkage mechanisms both upstream with political sphere of influence and downstream with direct users of research results, insufficient number of scientists, lack of experienced scientists partly due of high attrition rate, and insufficient level of funding. Ordinarily, economic crises as presently faced by most countries in sub-Saharan Africa should constitute an incentive for the adequate and effective funding of agricultural research especially in the fact that the survival of economies are directly related to the capacity to revive and boost agriculture. Unfortunately, this is presently not the situation such that the national agricultural research system seems more and more dependent on external support. It is not only a matter of national pride for national research systems to be effectively sustained through national effort, but it should also be a matter of national strategy for African governments to avoid possible distortion of national priorities by heavy reliance on external funding and, therefore, influence.

Conclusion

In the light of the present African food crisis, the paper has briefly reviewed the main constraints and past major achievements of agricultural research in sub-Saharan Africa, with emphasis on the semi-arid ecologies and the mandated crops of SAFGRAD. The main priority research areas have been highlighted for each of five crops, including soybean which will assume increasing importance in the decades to come. Common research priority themes which cut across crops have been reviewed, including drought, *Striga*, intercropping, post-harvest technology and on-farm research. The necessity to strengthen the national agricultural research systems has been reaffirmed.

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The SAFGRAD Network Approach and Experience in Strengthening National Agricultural Research Capacity.

TAYE BEZUNEH and G. KINGMA.

Director of Research, OAU/STRC and Senior Project Adviser, USAID/SAFGRAD, respectively, Ouagadougou, Burkina Faso.

Summary

Agricultural research and training are essential in bringing about technological changes, for the enhancement of economic development. A critical mass of research scientists is necessary to effectively support a viable agricultural development programme. The SAFGRAD contribution, through Network linkages, has been substantial in mobilizing available research resources, including manpower, for resolving particularly biotic and climatic constraints to the production of food grains. The SAFGRAD Network model is comprised of 26 OAU member countries (as beneficiaries and building units of the Networks); two collaborating IARCs; and the SAFGRAD Coordination Office which provides the necessary political, legal and administrative support.

Under the administrative umbrella of OAU/STRC, SAFGRAD's role has been to promote the continuous flow of technology and information to and among national research programmes through networking, improve the indigenous research management capability of member countries and enhance the diffusion of agricultural innovations through on-farm testing programmes. The geographic mandate of SAFGRAD covers the semi-arid regions of member countries in West, Central, East and Southern Africa.

Short and long-term training courses as well as specialized seminars provided to nearly 400 NARS researchers and technicians have yielded positive results in upgrading skills and improving the execution of field experiments, data analysis and management. Project monitoring tours by NARS and IARC inter-disciplinary teams in different countries had also enhanced effective interaction among more experienced and younger researchers. The extensive exchange of germplasm and related improved technologies among NARS and between IARCs and NARS has contributed to the adoption of suitable crop varieties in several countries.

Introduction.

The fact that population in sub-Saharan Africa is expected to reach one billion inhabitants by the early part of the 21st Century, the resulting food and agricultural production requirements, the already heavy dependence of the human population on agriculture, the progressive decline in per capita food and agricultural output, the problems of erosion losses as well as the decline in soil quality and its productive capacity, all point to the urgent necessity to develop relevant technologies towards a more productive and sustainable agriculture. Thus, in the harsh environment of sub-

Saharan Africa, region-specific research is necessary. The National Agricultural Research Systems (NARS) alone cannot be expected to cope with the enormity of the problem. In fact, the effective development of the NARS is commonly identified as the principal constraint to agricultural development in sub-Saharan Africa.

In the West and Central Africa semi-arid region, food grains constitute about 70% of the staple food. In East Africa, maize and sorghum cultivation predominate, with millets constituting 10-15% of the production. FAO statistics indicate that sorghum and millet production in West and Central Africa cover approximately 8.5 and 10 million hectares (ha), respectively (Annex 1 and 2). In Eastern Africa, 4 million tons of sorghum grain is produced annually on about 6 million ha (Annex 3). Finger millet is the dominant millet type grown in this sub-region, particularly in the dry areas which are usually unsuitable for sorghum production. There is also limited production of pearl millet in this region. The total area devoted to the production of millets approximates 2 million ha, with total annual grain yield of just over a million tons.

Maize is the most important crop in Eastern and Southern Africa where it constitutes the major staple food crop. There has been a steady increase in maize production in West and Central Africa during the last two decades, mainly by the expansion of production areas rather than improvement of average yield due to the use of better technologies and management (Annex 4). West and Central Africa account for only 15% of total production of maize in the continent. Most of the maize (over 50%) is produced in the Northern Guinea savanna. However, maize cultivation is also expanding in the Sudan savanna, which zone presently produces about 20% of the total output.

Cowpea is extensively grown in West and Central Africa. About two thirds of world production (close to 8 million tons) comes from this sub-region. Nigeria and Niger are the major producers. The average grain yield of cowpea in the region is less than 0.33 t/ha, contrasting with potential yields of 0.5-2.5 t/ha. As a common ingredient in the diets of most inhabitants of the sub-region, cowpea provides about 50% of the daily quality protein requirements.

Agricultural research, as the prime mover of agricultural and institutional development, has been seriously neglected by most governments and donor agencies alike. And yet agricultural research is fundamental in bringing about the sort of technological and policy changes that are necessary for enhancing agricultural productivity and the attainment of self-sufficiency in food, fibre and shelter. At present, most member countries have weak NARS and only a few possess the number of qualified scientists that could sustain viable research programmes.

Realizing the research strengths and weaknesses of the NARS of member countries, SAFGRAD has adopted the collaborative mode (Networking) to be central to its activities, since the "critical research mass" necessary to sustain agricultural development could be more easily attained at the regional level. Networking as a regional strategy should, thus, be perceived as a mechanism for

sharing resources and scientific talent and the exchange of technical know-how for attaining common goals.

Purpose and Objectives of Networking.

The main purpose of Networking among Semi-Arid Food Grain Research and Development (SAFGRAD) member countries is to solve common problems of food production by judiciously pooling together scientific resources. Networking transcends linguistic and political barriers. Such effort is expected to lead to the strengthening of national research programmes. More specifically, the objectives of Networking include:

i. to facilitate the exchange of technical information and interchange among participating member countries;

ii. to identify research priorities of common interest based on constraints of regional dimension and ensuring that research remains focused to solving farmers' problems;

iii. to enhance the generation, evaluation and exchange of germplasm and also to facilitate mobility of scientists.

iv to coordinate research activities in order to avoid duplication or overlapping of efforts;

v. to efficiently utilize existing research talents and facilities to attain a "research critical mass" at regional level towards enabling NARS solve widely-shared problems of agricultural production and sustain viable national programmes, and

vi. to explore the potential for complementary activities among member countries in addition to the evaluation and adoption of technologies across a wider range of conditions.

Collaborative research Networks among NARS for the development and improvement of maize, sorghum, millet and cowpea as well as for the generation of related technologies, have been the major focus of SAFGRAD activities, in cooperation with the International Institute for Tropical Agriculture (IITA) for maize and cowpea and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) for sorghum and millet.

Since the last decade, the major thrust of SAFGRAD has been to increase the productivity and production of food grains in the semi-arid ecology, by enabling NARS to generate and identify suitable technologies to the environmental and socio-economic conditions of farmers. Since 1987, SAFGRAD's major mechanism for strengthening national research programmes is through collaborative research Networks. Four of the Networks, namely maize, sorghum, cowpea and farming systems research, are operational in West and Central Africa whilst the fifth, Network on sorghum and millet improvement, is operational in Eastern Africa. In

addition to the five Networks, the SAFGRAD Coordination Office, in cooperation with the International Council for Research in Agro-forestry (ICRAF), is also providing administrative management services to the agroforestry research network for the semi-arid lowlands of West Africa.

Network Model.

The SAFGRAD Network model involves the partneship and mobilization of resources of NARS, International Agricultural Research Centres (IARCs) and the Scientific, Technical and Research Commission of the Organization of African Unity, (OAU/STRC) through the SAFGRAD Coordination Office (SCO) (Table 1). Each partner has its own entities with specific responsibilities.

a) **Network Management Entities.** The OAU/STRC provides the political umbrella and legal framework under which Networks and other SAFGRAD activities are facilitated across geo-political boundaries. The management entities of the Networks include:

i. The Council of National Agricultural Research Directors (NARD) which comprises directors of agricultural research of the 26 SAFGRAD member countries. The Council provides policy input into SAFGRAD programmes and activities from the perspectives of its member countries.

ii. The Oversight Committee of seven members is directly responsible to the Council of NARD and charged with the monitoring of the implementation of Network activities and other projects of SAFGRAD. In addition, the Oversight Committee provides guidance in the management and appraisal of Network performance as well as in policy and administrative issues related to Network development.

Table 1. Components of SAFGRAD network model

Network partners	Network entities	Responsibilities
I. NARS i) 18 countries in West and Central Africa. ii) 8 countries in Eastern Africa.	i) The Directors of Agricultural Research of National Programmes. ii) The Oversight Committee. iii) Network Steering Committees	- Policy guidance, addressing research and development issues. - Monitoring the implementation of SAFGRAD project activities. - Management of SCO and appraisal of networks. - Technical management of networks.
II. IARCS IITA ICRISAT ICRAF	i) Maize Network Coordinator ii) Cowpea Network Coordinator i) Sorghum Network Coordinator in West and Central Africa. ii) Eastern Africa Sorghum and Millet Network Coordinator. Semi-Arid Lowlands Agroforestry Network in West Africa.	All the Network Coordinators undertake technical execution of network programmes.
III. OAU/STRC The Scientific, Technical and Research Commission of OAU-Political and administrative support.	The SAFGRAD Coordination Office.	i) Coordinate research activities among NARS and with relevant government bodies. ii) Provides legal and logistic framework for network operation. iii) Serves as secretariat to network entities. iv) Facilitates the review of policy issues through regular channels of OAU. v) Promotes the adaptation and transfer of network technologies to farmers in different national programmes.

N.B.: The West African Farming Systems Research Network, administered by SCO, also executes technical programmes of the Network.

iii. The SCO provides research coordination and serves as the administrative and legal entity for the Networks as well as facilitating the development of scientific and management leadership among NARS. In addition, SCO functions to smoothen and strengthen linkages among NARS institutions and governments and between NARS and IARCs.

iv. The Steering Committee of each Network, comprising 7-8 members, sets research priorities, plans programmes, ensures the attainement of set objectives, disburses funds for programme support, and monitors the implementation of Network activities. Steering Committees report to the Oversight Committee through the SCO.

v. The IARCs provide technical, training and management support for their respective mandate crops.

b) **Network Strategy**. The organization of SAFGRAD Networks took into account the different levels of research strengths and weaknesses among NARS. Based on a thorough inventory of food grain production constraints, participating countries committed available resources, including scientific manpower, towards utilizing optimum ecological sites or "hot spots" for the screening of crop cultivars towards alleviating biotic and physical stress factors. Furthermore, a systematic identification of research priorities and acceptance of regional responsibilities by certain NARS as well as the ability to assess research needs of the relatively weaker and smaller national programmes, resulted in the categorization of some specific NARS institutions as follows:

i. "Lead NARS Centres" are specific research institutions or universities which are endowed with requisite numbers of qualified and experienced research staff, with adequate infrastructure as well as optimum environmental conditions to research into specified biotic, abiotic or physical stress factors/aspects to complement the technological back-stopping provided by IARCs;

ii. "Associate Centres" are endowed with less than optimum capabilities and environmental conditions but which are sufficient to enable them sreen crop materials for resistance to major biotic and abiotic factors; and

iii. "Technology-Adapting NARS" are relatively smaller and weaker research systems with limited capabilities and infrastructural facilities but which have minimum capacity for the verification and validation of improved technologies for adoption in their environments.

Essentially, therefore, "Lead Centres" focus on priority constraints in specific ecological zones and, in close association with "Associate Centres", intensify the evaluation and validation of results. "Technology-Adapting NARS" benefit through the verification and validation of elite germplasm to their specific environmental and socio-economic conditions. The NARS in this caterogy also take advantage of the technical research and training support provided through IARCs.

c) **Collaborative Research Projects.** Even in the face of the limited resources at their disposal, "Lead NARS" have come to accept responsibilities to undertake research of regional application. However, lack of adequate funding and qualified research manpower have constrained the full development of the 25 collaborative research projects started since 1988. Nevertheless, Lead and Associate NARS of the respective Networks have made substantial improvement in the conduct of adaptive research especially in developing technologies and screening for such biotic and abiotic stress factors as Striga, drought, soil fertility, moisture stress, control of pests and diseases as well as agro-industrial and food utilization.

Through the concept and practice of collaborative research, there has been extensive exchange of germplasm and related improved technologies among NARS and between IARCs and NARS. For example, Togo has adopted the maize streak virus screening technology developed at IITA for the mass-rearing of viruliferous vectors, leading to the successful selection of streak-resistant maize varieties. Early and extra-early maturing maize varieties as well as new varieties of cowpea and sorghum suitable for cultivation in semi-arid zones have also been developed and distributed to NARS and farmers. In the Eastern Africa region, sorghum varieties with satisfactory resistance to Striga, long smut disease and ergot have also been identified and the seeds widely distributed to NARS for further evaluation.

The Network approach has enabled NARS and IARCs to streamline the various (germplasm) nurseries and regional variety trials in such a way as not to overburden particularly the weak national programmes. The strategy has enabled technology adapting countries to concentrate their efforts on adaptive research.

Sorghum.

Collaborative projects were initiated to alleviate food grain production constraints of common interest. For example, to improve sorghum production, several resistant cultivars to anthracnose, Striga, long-smut and headbug have been identified. With regard to Striga resistance, the most promising sorghum cultivars are SAR-24, Gambella 1107, ICSV-1006, ICSV-1007 and N-13 in Eastern Africa. Results of the West and Central African Sorghum Striga Resistance Trials have indicated IS9830 and ICSV 1007 BF as promising.

Sorghum headbug is an important economic pest in West and Central Africa. Mali, as the "Lead NARS" for this particular project, has reported that the insect is more abundant towards the end of September and early October. Thus, early planting of sorghum is a possible control measure. Furthermore, 25 sorghum lines resistant to headbug have been identified.

Among the various sorghum elite varieties evaluated in West and Central Africa, the Nagawhite variety from Ghana gave the highest yield among the early maturity sorghum varieties in 1987, 1988 and 1989; its grain yield varied from 2.8-3.5 t/ha. ICSV 1063 yielded highest (2.6-3.3 t/ha) among the medium maturity varieties. Among the hybrids, ICSH 567 ranked first in 1988 and 1989, with mean yields of 3.3 and 3.7 t/ha, respectively (SAFGRAD/ICRISAT, 1989/90, Sorghum Network Report).

A number of improved sorghum varieties have been released for production. For example, cultivar S-35 is grown by more than 5,000 farmers in the Far-North Province of Cameroon, while the same variety is cultivated by more than 15,000 farmers in the Sahelian zone of Chad (NCRE/IRA Report 1990). The Framida variety, introduced in 1980s for its Striga resistance trait, has been cultivated in Burkina Faso (Manga region), Northern regions of Ghana, and Togo.

In Mali, ICSV 1063 BF and ICSV 1079 BF were tested on farmers' fields, with the former producing superior grain yields over the local variety. Cultivars ICSV 11 IN and M 66118 have received greater attention in Ghana; ICSV 1063 BF and Mali Sor 84-1 were included in on-farm tests by extension agencies in Côte d'Ivoire. Promising sources of resistance to the prevalent leaf diseases and to Striga have been identified through disease observation nurseries and Striga trials.

In Eastern Africa, among low-dryland elite varieties, Seredo produced the highest mean yield (3.37 t/ha) across locations, followed by ICSV 112, CR 35-5 and KAT/369 which averaged 3.42, 3.39 and 3.31 t/ha, respectively. The promising sorghum cultivars at the intermediate altitude zone were IS9302 (from Ethiopia), Nyirakkabuye and Amasugi (both from Rwanda) which yielded 3.33, 2.61 and 2.54 t/ha, respectively, across location (ICRISAT/SAFGRAD Annual Report 1990).

Of the entries in the Elite Finger Millet Trials, the variety, Gulu, (from Uganda) was the highest yielder across locations, with an average of 2.6 t/ha.

With regard to sorghum varieties grown by farmers in Eastern Africa, the variety Seredo has been released in and widely grown by many farmers in Uganda, Kenya and Ethiopia. Other varieties such as Serena, Lulu and Tegemeo are largely cultivated in Tanzania. The varieties Melkamash, Gambella 1107 and Dinkmash are the major improved cultivars grown by farmers in Ethiopia.

In the Sudan, a number of improved sorghum varieties have been released. In the early 1980s, the development and release of the sorghum hybrid Hageen Dura-1, through the collaborative effort of ICRISAT and the National Research Programme of Sudan, brought new hopes for substantial increase in sorghum production in the country. On-farm verification trials of sorghum variety SRN-39 (since 1986), in collaboration with the Sudanese-Canadan project, expanded the production of this cultivar by farmers on about 45,000 ha in the Sim Sim and Gedarif regions. Farmers were convinced of the superiority of SRN-39 over local varieties in Striga-infested fields (SAFGRAD/ICRISAT 1991 Report on Striga). The cultivar SRN-39, having short stature, fits into mechanized farming in the Sudan. It is expected that an increasing number of Sudanese farmers will continue to grow this cultivars in Striga infested fields.

Evaluation of sorghum for nutritional quality and for industrial use, such as brewing, has also been pursued. For example, in Nigeria the sorghum varieties are used for malting (brewing) while the local variety, "Farafara", and the improved Kenyan cultivar KAT 369 have been found suitable for wheat-sorghum composite bread and confectionery.

Cowpea.

Cowpea is an important grain legume as a common ingredient in the daily diet for over 100 million people in West and Central Africa. The challenges of cowpea production are to improve its yields and control insects and diseases at various stages of the crop development, including storage. A number of cowpea cultivars resistant to Striga, drought and pests have been developed by researchers of the Cowpea Network in collaboration with IITA.

Cowpea production statistics with respect to improved varieties in various countries are virtually lacking. During the last decade, some countries (notably Nigeria, Ghana, Senegal, Mauritania, Mali and Burkina Faso) have expanded the production of improved cowpea. For example, in Northern Ghana, the variety Vallenga (released since 1987) is cultivated on more than 20,000 ha with a yield of 800-1200 kg/ha under farmers' conditions. (IITA/SAFGRAD Report 1990/91). In Southern Ghana, the variety Asontem is largely cultivated on about 29,000 ha, with an average yield of 1 ton/ha under farmers' conditions. The varieties, II8ID-1137 and II83S-818, are cultivated in the savanna zones of Ghana.

In Burkina Faso, the cultivars TVx3236, KN-1, and SUVITA-2, are grown by a large number of farmers. Varieties of cowpea of recent introduction to farmers include KVx61-1, KVx396-4-4, KVx396-4-5, and KVx396-18-10.

Nigeria and Niger (with annual cowpea grain production of 850,000 and 271,000 t/ha, respectively) are known to produce about 50% of world cowpea production. However, it has not yet been established to what extent improved cowpea cultivars are utilized in these countries. In the savanna and forest zones of Nigeria, the production of variety SAMPEA-7 is known to cover an estimated area of 75,000 ha with an average yield of 600 kg/ha under farmers' conditions (IITA/SAFGRAD Report 1989/90). In the Sudano-Guinea savanna zone, cowpea varieties TVx 3236 and II8I-D994 are also cultivated.

Cowpea production in Senegal, estimated to cover an area of 30,000 ha, is largely made up of improved cowpea cultivars such as IS86-275 with an average yield of 600 kg/ha under on-farm test conditions. The cowpea variety 58-146 from Senegal is produced in most regions of Togo. In Mauritania, improved varieties such as SUVITA-2, KVx 256-K17-11, and IT83S-343-5-5 are grown on about 3000 ha (IITA/SAFGRAD Report 1989/90).

In Mali, a number of cowpea varieties have been found suitable for production by farmers in various regions. For instance, in the Seno plain, early-maturing varieties such as SUVITA-2, Gorom-Gorom and TN-8863, are increasingly cultivated by farmers. Furthermore, suitable packages of technologies for intercropping systems involving, for example, millet/cowpea, maize/cowpea, sorghum/groundnut and sorghum/millet, have been developed.

Affordable technologies have been developed by Cameroon and Ghana NARS for the control of storage insects of cowpea. Results have shown that local plant products such as neem seed oil, groundnut oil, black peper powder, and ash could control storage insects.

Maize.

The SAFGRAD Maize Network has taken a pragmatic approach, to concentrate its effort in developing early and extra-early maize cultivars for production in semi-arid ecology, primarily to fill food gaps. Some drought tolerant and several early and extra-early maize cultivars have been developed by the Networks in the Cameroon and Burkina Faso "Lead NARS". Various populations of maize of different maturity groups and purposes have also been developed at the Ghana "Lead NARS" (Table 7). Capability in maize streak-resistance conversion technology has been strengthened in Togo and Ghana.

The short cycle varieties that have been developed by the Network are targeted to short growing seasons in which the crop could be harvested as green maize two months after planting. Agronomic research in the Cameroon has indicated that the extra-early varieties could also fit into the farming system of hydromorphic soils (vertisols) where it was reported to yield 5-7 t/ha at recommended plant density and soil management levels (Annual Report, 1990, IITA/SAFGRAD).

Several maize varieties evaluated through the Network have enhanced the release of improved maize varieties in various countries. For example, in Cameroon, the variety TZB/TZB-SR, covers 15% (or 75,000 ha) of the maize production area with an estimated yield of 90,000 tons (IITA/SAFGRAD, 1990 and CIMMYT, 1990). In the Far-North Province of Cameroon where sorghum and millet are the major staple food crops, the area planted with maize has nearly doubled (about 35,000 ha) due to the availability of short cycle maize varieties (e.g. CMS 8704, CMS 8806 and Pool 16 DR) cultivated by more than 1000 families. The positive acceptance of the short cycle maize cultivars has been attributed to their earliness and good "taste" of the green maize.

In Burkina Faso, maize is the third most important crop. The variety EV 8442-SR occupies 60% of the maize area (about 123,600 ha), with an estimated annual production of 120,600 tons. SAFITA-2, one of the earlier introduced varieties, is reported to occupy 5% of the maize area (10,300 ha), with an estimated annual output of 10,000 tons (IITA/SAFGRAD, 1991). The variety, KPB (TZESR-W) occupies about 3% of the maize area with total production of about 6000 tons. Other varieties currently evaluated on-farm include KPJ (EV 8431-SR) and Pool 16 DR.

In Ghana, maize is the most important food crop. Maize grain production has increased from 560,000 tons in 1986 to 750,000 tons in 1989 (Fajemisin, unpublished data, 1991). Among improved maize cultivars, Okomasa is planted to approximately 35% of the total maize area, with an estimated annual production of 400,000 tons. The second important improved maize variety, known as Abeleehi, covers 15% of the maize area, with an estimated annual production of 50,000 tons. The variety SAFITA-2, which was released in Ghana as an early white dent cultivar, is cultivated by 12% and 3% of farmers in the Volta and Eastern regions, respectively. According to Global 2000 survey, SAFITA-2, a short cycle maize cultivar, is cultivated predominantly in the Denu District of Ghana. At the national level, SAFITA-2 covers only 2% of the maize area, with an estimated annual production of 16,000 tons (Global 2000 Report 1989).

In Benin, the variety TZB/TZB-SR occupies 25% of the total maize area (about 119,749 ha), with an estimated production of 106,000 tons. The variety Poza Rica 7843-SR constitutes 10% of the total maize production (47,900 ha), with an estimated production of 42,404 tons. Two other varieties that occupy 10% of the total maize production area are TZ SR-W and TZESR-W, each with an estimated total production of 21,202 tons. The variety Pirsaback 79 30-SR is cultivated on 3% of total maize area (14,370 ha), with an estimated production of 12,720 tons. The variety, DMR-ESRW was recently released while Across 85 Pool DR is being evaluated on-farm. Farming System Research in Northern Benin has shown that the improved maize variety TZB fits well into the sorghum/maize intercrop system due to the different growth patterns of the crops which minimize competition (OAU/STRC-SAFGRAD, 1989). Regarding cereal/legume associations, Crotalaria spp., as green manure, increased the yield of maize by 45% when incorporated into the soil. The practice has been recommended for pre-extension tests as it involves minimal additional labour.

In Mali, through the Maize Network Regional Uniform Variety Trials, promising extra-early varieties have been identified. The varietie, TZESR-W and SAFITA-2 are released cultivars which occupy 10 and 3% of the maize area, with an estimated grain production of 22,000 and 6740 tons, respectively (IITA/SAFGRAD, 1991). DMR-ESRY and TZEF-Y, both short cycle cultivars, are currently undergoing on-farm testing in the country. Improved maize varieties, including Tuxpeno and Tiementié, have been adopted by farmers in the Sudano-Guinean zone of Mali where more than 50% of the crop is produced. At Kita, where average rainfall is above 650 mm, top yielding short cycle maize cultivars include DMR-ESRW, Across Pool 16 SR, and DMR-ESRY, with average grain yields of 4.8, 4.7 and 4.6 tons/ha, respectively (OAU/STRC-Food Grain Production Technology Verification Project Report 1990/91).

In Mauritania, maize production through irrigation covered 11,303 ha in 1990. The Maka and Capinopolis 8345 varieties occupy 35% and 10% of the area under maize, respectively. Pool 16 DR, a short-cycle maize cultivar, is currently undergoing on-farm testing.

In Senegal, total maize output has increased to 144,000 tons from about 105,000 ha. Improved varieties, such as Pool 16 DR and Maka, constitute 10% of the total maize production.

During the last 20 years, maize production in Togo has increased to about 245,000 tons from a cultivated area of 258,000 ha. Improved streak resistant cultivars, Ikenne 8149 SR and EV 8443-SR, constitute 12% of maize production (IITA/SAFGRAD, 1991).

A number of short-cycle maize varieties are being tested on-farm in Chad, Guinea, Niger, Central African Republic, Côte d'Ivoire, and Cape Verde.

Conclusion.

The strategy of regional Networks has been effective not only in forging linkages between scientists of national institutions and IARCs, but also in accelerating the flow and availability of agricultural technology.

Through the Network Strategy, significant building of research capacity of NARS has taken place during the last two decades.

A large number of improved crop varieties and related technologies have been developed and are currently being utilized by NARS. Relatively weak NARS have benefited from Network Strategy not only by taking full advantage of training activities, but also in the resulting "spillover" of transfer of technology from Lead Centres and IARCs. This has reduced costs for technology generation by small national programmes.

The regional trials have been a focal point and an important mechanism for the direct exchange and evaluation of food grain production technologies.

Among the major indicators of positive impact of the SAFGRAD Network on NARS institution building are:

i) the assumption of regional research responsibility by "Lead Centres" has enhanced their capabilities to generate and evaluate technologies and the results shared among Network participating countries;

ii) the improvement of research skills as demonstrated in the amount and quality of research projects implemented both at national and regional levels;

iii) NARS increased contribution of elite germplasm and related technologies to Network regional trials; and

iv) the evolvement of several national research leaders and managers.

Annex 1. Total sorghum production trends in SAFGRAD member countries in West and Central Africa.

	Area harvested (1000 ha)				Yield (kg/ha)				Production (1000 MT)			
Country	1979/81	1987	1988	1989	1979/81	1987	1988	1989	1979/81	1987	1988	1989
Benin	90	118	133	139	650	806	733	786	59	95	97	110
Burkina Faso	1051	1176	1295	1362	589	721	779	728	620	848	1009	991
Cameroon	374	250F	253	270F	805	900	909	889	301	225F	230F	240F
Centr. Afr. Rep.	57	47*	40*	45F	673	828	1225	1111	39	39*	49*	50F
Chad	114	500	530	500F	570	586	623	578	227	293	330*	289*
Côte d'Ivoire	40	37	38	40F	600	622	632	575	24	23	24	23*
Gambia	6	9	10	14*	795	778	700	1071	5	7	7*	15*
Ghana	223	272	226	284	639	758	786	863	140	206	178	245
Guinea	20	24F	24F	24*	1250	1417	1417	1417	25	34F	34F	34*
Guinea Bissau	28	60F	60F	60F	637	617	583	633	18	37	35	38*
Mali	434	491	624F	600F	785	1045	1139	1193	341	513	711*	716*
Mauritania	102	116	164	149F	272	776	665	517	28	90F	109	77*
Niger	822	1100F	1470	1566F	432	333	381	289	347	366	560	452
Nigeria	3050	3182	4247	4200F	1092	1851	1165	1092	3341	5890	4948	4587
Senegal	130	128	130	127*	996	869	846	866	131	111	110*	110*
Sierra Leone	7	8F	8F	8F	1571	2250	2375	2375	11	18F	19F	19F
Togo	122	136	181	200*	715	717	658	811	87	98	119	162

Source: FAO Production Yearbook, Vol.43, 1989
Note: a) F = FAO estimate
b) * = Preliminary data

Annex 2. Total millet production trends in SAFGRAD member countries in West and Central Africa.

Country	Area harvested (1000 ha)					Yield (kg/ha)				Production (1000 MT)			
	1979/81		1987	1988	1989	1979 /81	1987	1988	1989	1979 /81	1987	1988	1989
	M	S + M	M	M	M	M	M	M	M	M	M	M	M
Benin	13	103	31	35	31F	504	641	635	677	7	20	23	21*
Burkina Faso	803	1957	1168	1277	1278	486	541	640	508	390	632	817	649
Cameroon	130	503	100 F	110F	110F	753	750	727	909	98	75F	80F	100F
Centr. Afr. Rep.	16	73	10*	10*	13F	680	976	971	1154	11	10*	10*	15F
Chad	360	790	450	460	400*	525	500	798	642	182	225	367*	257*
Côte d'Ivoire	64	104	68	70	72F	582	603	600	549	37	41	42	41*
Gambia	28	28	44	60*	59*	916	1136	800	949	26	50	48*	56*
Ghana	182	405	235	228	244	648	737	844	738	117	173	192	180
Guinea C.	35	41	40F	40F	40*	1429	1500	1500	1500	50	60F	60F	60*
Guinea Bissau	16	44	30F	30F	30F	600	900	833	833	10	27	25	25F
Mali	643	1077	782	1000F	980F	716	887	965	880	461	694	965*	862*
Mauritania	12	117	20	13	15F	290	350	538	533	3	7F	7	8*
Niger	3011	3811	3000F	3526	3385F	435	340	501	382	1311	1020	1766	1293
Nigeria	2836	5929	3705F	3874	3400F	857	1187	985	1029	2420	4397	3816	3500F
Senegal	932	1062	946	898	977*	587	729	539	687	555	690	484*	671*
Sierra Leone	9	9	15F	16F	16F	1343	1333	1375	1375	12	20F	22F	22F
Togo	121	243	128	118	120*	384	552	479	649	44	71	56	78

Source: FAO Production Yearbook, Vol. 43, 1989
Note: a) F = FAO estimate
b) * = Preliminary data.

Annex 3. Total sorghum production trends in SAFGRAD member countries of Eastern Africa.

Country	Area Harvested (1000 ha)				Yield (kg/ha)				Production (1000 MT)			
	1979/81	1987	1988	1989	1979/81	1987	1988	1989	1979/81	1987	1988	1989
Burundi	53	63F	77*	58*	1000	1000	1465	1514	53	63	113	88
Ethiopia	1048	900*	800*	900F	1372	1056	1205	1071	1419	950F	964*	964F
Kenya	168	138	140	146*	984	803	1029	979	160	111	144	143*
Rwanda	159	160F	170*	173F	1129	1175	1041	948	178	188	177*	164F
Somalia	478	516	570	550F	347	472	412	529	167	244	235	291
Sudan	3163	3360	5577*	3682*	731	410	793	523	2361	1379	4425*	1924*
Tanzania	713	758	514	514F	763	875	817	979	543	663	420	503
Uganda	175	185	199*	180F	1788	1550	1452	1444	312	286	289*	260F

Source: FAO Production Yearbook, Vol. 43, 1989
Note: a) F = FAO estimate
b) * = Preliminary data.

Annex 4. Total maize production trends in SAFGRAD member countries in West and Central Africa.

Country	Area Harvested (1000 ha)				Yield (kg/ha)				Production (1000 MT)			
	1979/81	1987	1988	1989	1979/81	1987	1988	1989	1979/81	1987	1988	1989
Benin	407	395	486	480	711	677	884	949	289	267	430	455
Burkina Faso	123	176	277	221	880	741	819	1162	108	131	227	257
Cameroon	495	400F	408*	420*	852	1025	1029	1024	418	410F	420F	430F
Cape Verde	11	29	25F	12F	365	719	639	600	4	21	16	7*
Centr. Afr. Rep.	108	65	69	68F	372	1020	1019	1029	40	66	70	70F
Chad	32	60F	62F	35F	836	567	548	457	27	34*	34*	16*
Gambia	7	13	13F	11*	1460	1154	1231	1455	10	15	16*	16*
Ghana	390	548	540	567	982	1091	1391	1320	380	598	751	749
Guinea C.	87	90F	90F	94	1000	1000	889	1150	87	90F	80F	108
Guinea Bissau	13	25F	25F	25F	687	800	600	800	9	20	15*	20F
Mali	52	118	114*	125F	1221	1512	1882	1824	61	179	215*	228*
Mauritania	8	2F	11	5F	573	500	636	600	5	1	7	3*
Niger	14	5F	3	5F	708	600	1867	1600	10	3	5	8
Nigeria	443	1137	1556	150F	1350	1193	1170	1067	599	1357	1821	1600F
Senegal	75	99	112	113*	876	1149	1097	1097	66	114	123	124*
Sierra Leone	13	18*	18*	17F	974	704	711	706	13	12*	13*	12F
Togo	147	225	267	258	1024	765	1109	950	150	172	296	245

Source: FAO Production Yearbook, Vol. 43, 1989
Note a) F= FAO estimate
b) * = Preliminary data.

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Germplasm Resources for the Improvement of Sorghum and Millets in Sub-Saharan Africa.

MELAK H., MENGESHA, S. APPA RAO and K.E. PRASADA RAO.

International Crops Research Institute for the Semi-Arid Tropics, Patancheru, A.P., India.

Summary

Sorghum (*sorghum bicolor* (L.) Moench), pearl millet (*Pennisetum glaucum* (l.) R. Br.), and finger millet (*Eleusine coracana* (L.) Gaertn.) were domesticated in Africa. To conserve the fast-vanishing genetic resources of these crops, ICRISAT has undertaken several collection missions in collaboration with national, regional, and international organizations and assembled 32,890 sorghum, 21,919 pearl millet, and 3.220 finger millet samples. Of these, 21,670 sorghum, 9,880 pearl millet and 2,015 finger millet samples are from Africa. All the accessions are evaluated at the ICRISAT Centre in India for morphological and agronomic characters. Several traits of economic importance have been identified for use in crop improvement programmes. Timely assembly and proper evaluation of landraces will help identify suitable genotypes to develop improved cultivars for sustainable crop production in sub-Saharan Africa.

Introduction

The enormous genetic diversity assembled from the gene-rich sub-Saharan Africa is considered very valuable in crop improvement programmes. Germplasm originating from these areas possess early-maturity, drought tolerance, and superior grain quality, besides many desirable agronomic traits. This germplasm is often valued for its adaptation and as sources of resistance to prevailing biotic and abiotic stress factors. Zerazera, Hegari, Feterita, and Milo types of sorghum have offered several desirable characters and are extensively used in sorghum improvement programmes. Similarly, the early-maturing, large grain types of Ghana and Togo; white grain types of Central African Republic and Cameroon; and large spike characters of Tanzania are some of the important traits for utilization in the pearl millet improvement programme. Sub-Saharan Africa is an important area for wild relatives of sorghum and millets whose potential is yet to be fully realized.

Crop improvement scientists need to base their germplasm requirements on indigenous landraces for varietal adaptation purposes. However, they must not limit their choice to local material as some of the exotic material may be the only source for certain specific, desirable genetic and agronomic traits. That is why the world collections of various crops are regarded as a rich source of diverse material for crop improvement programmes around the world (Mengesha, 1974 and 1988; Mengesha and Appa Rao, 1988).

Potentials of indigenous germplasm are realized through collection, evaluation, and utilization. Maintenance, documentation, and conservation of germplasm are necessary activities to safeguard the material for present and future use.

Origin and Distribution

Sorghum that originated in the Sudan-Ethiopian border region has since spread to all parts of the world (Snowden, 1936; de Wet and Harlan, 1971; Harlan and de Wet, 1972; Harlan, 1975; de Wet, 1978). Considerable diversity is also found in Ethiopia (Mengesha, 1974). It reached India some 3000 years ago (1000 B.C.) and is now cultivated almost throughout South Asia. Distribution of different races of sorghum, their assembly, evaluation, and utilization are described by Brhane (1982), Prasada Rao and Mengesha (1987).

Pearl millet originated in West Africa in a diffuse belt from Sudan to Senegal (Brunken *et al.*, 1977). Finger millet had originated in the highlands of eastern Africa (de Wet *et al.*, 1984). Sub-Saharan Africa is the primary centre of origin and diversity for sorghum and millets, but grain and fodder yields are the lowest here. This may be due to our inability to realize and properly utilize those natural and abundant resources. This presents a challenging reality to all of us.

Germplasm Assembly and Collection

To feed the ever-increasing population, we need to accelerate crop improvement programmes, starting with the collection and conservation of the vanishing germplasm. Fortunately, enormous diversity of sorghum and millets still exists in nature. But the continued availability of diverse germplasm in nature cannot be guaranteed in view of the alarming genetic erosion that is taking place around the world. A good example of such genetic erosion is the extinction of Zerazera and Hegari sorghum landraces in the Gezira Province of Sudan and their replacement by newly bred cultivars (Mengesha and Prasada Rao, 1982 and 1985; Mengesha *et al.*, 1988; Mengesha, 1989). Also, the once-popular pearl millet landrace, 'Gullisita', is now almost extinct in Punjab, India (Appa Rao et al., 1986c). Hence, the need for the accelerated collection of germplasm, especially from remote areas.

ICRISAT has acquired most of the world germplasm collections for its mandate crops through exchange and by launching joint collection missions. Collection missions were carried out for special types such as the Zerazera sorghum landraces from Ethiopia (Prasada Rao and Mengesha, 1987), Kaura and Farafara sorghum landraces from Nigeria (Prasada Rao *et al.*, 1985) and the early-maturing, bold-grain types of pearl millet from Ghana (Appa Rao et al., 1985) and Togo (Appa Rao *et al.*, 1990).

To date, ICRISAT has launched 58 expeditions in 37 countries, and assembled 102,209 samples of all mandate crops consisting of 32,890 sorghum, 21,919 pearl millet, 3,220 finger millet (Table 1) and 46,852 samples of other crops. All germplasm accessions have been equally shared with national programmes after completion of every collection mission. Also, the material is always available for free distribution and exchange. Many of the germplasm exploration and collection mis-

sions in Africa were supported by or undertaken in collaboration with the International Board for Plant Genetic Resources (IBPGR). Concerned crop scientists and experts contribute by identifying priority areas for collection. Such areas are further studied in collaboration with national scientists. New collection areas are determined as a result of fresh information received about genetic erosion, diversity, and the extent of representation in the world collections maintained in ICRISAT's genebank. In terms of germplasm collections and subsequent utilization, the first beneficiaries are those countries where the collections are made. This is because promising cultivars that are developed by hybridizing local landraces are likely to be well adapted in their original habitat (Mengesha, 1984).

Current priority areas for cereal germplasm collection are shown in Table 2. New priority areas are determined annually in close consultation with national, regional, and international programmes.

Table 1. Sorghum, pearl millet and finger millet germplasm accessions conserved in ICRISAT genebank.

Continent	Sorghum		Pearl millet		Finger millet	
	N°	%	N°	%	N°	%
Africa	21670	65.88	9880	45.08	2015	62.58
Asia	8247	25.07	11426	52.13	1121	34.81
Europe	201	0.61	34	0.16	28	0.87
America	2327	7.08	180	0.82	7	0.22
Oceania	42	0.13	7	0.03	-	-
Unknown	403	1.23	392	1.79	49	1.52
TOTAL	32890	100	21919	100	3220	100

Table 2. Priority areas for sorghum and millets germplasm collection in Africa

	Present status		
Prority area	Sorghum	Pearl millet	Minor millets
Angola	4.5	4.5	6
Benin	4	4	7
Burkina Faso	2	2	6
Cameroon	1	1	7
Central African Republic	2	1	4
Chad	3	3.8	6
Côte d'Ivoire	4	4	6
Egypt	7	4	7
Ethiopia	1.8	7	3
Ghana	2	1	4
Kenya	2	4	2
Lesotho	1	7	4
Mali	2	3.8	6
Mauritania	2	4.8	6
Morocco	7	7	7
Mozambique	5	5	5
Namibia	4	4	6
Niger	1	1.8	6
Nigeria	1	2.8	6
Senegal	2	1.8	6
Swaziland	1	7	6
Tanzania	1	1.8	6
Togo	1	1	6
Uganda	2	5.8	4.5
Zaïre	4	4.8	6

1. Well collected.
2. Partly collected.
3. Poorly collected.
4. Not collected.
5. Presently inaccessible.
6. Unexplored.
7. Nonpriority areas
8. For wild relatives

a) Status of Sorghum Germplasm. So far, ICRISAT has assembled 32,890 sorghum germplasm accessions from 87 countries, of which 21,670 (66%) are from Africa (Table 1). In view of the diversity of the areas yet to be explored, the number of samples collected is relatively small compared with what is available in nature (Mengesha and Prasada Rao, 1982 and 1985). However, it represents the largest collection of diverse sorghum germplasm assembled and conserved at any one place. Several genetic stocks with desirable genes have been identified, many of which have already been incorporated in current breeding programmes in several countries.

The sorghum germplasm conversion and introgression programmes have made it possible for breeders to utilize tropical germplasm. Conversion activites have generated a good source of new material to breeders in the semi-arid tropics. The wide and growing range of germplasm variation maintained at ICRISAT looks promising (Table 3).

Table 3. Range of variation in sorghum germplasm evaluated in rainy season at ICRISAT Centre.

Character	Range of variation	
	From	To
Time to 50% flowering (days)	36	199
Plant height (cm)	55	655
Pigmentation	Tan	Pigmented
Midrib color	White	Brown
Peduncle exsertion (cm)	0	55.0
Head length (cm)	2.5	71.0
Head width (cm)	1.0	29.0
Head compactness and shape	Very loose stiff branches	Compact oval
Glume color	Straw	Black
Glume covering	Fully covered	Uncovered
Grain color	White	Dark brown
Grain size (mm)	1.0	7.5
100-seed mass (g)	0.58	8.56
Endosperm texture	Completely starchy	Completely corneous
Threshability	Freely threshable	Difficult to thresh
Luster	Lustrous	Nonlustrous
Subcoat	Present	Absent

See IBPGR/ICRISAT sorghum descriptors, 1984.

b) Status of pearl Millet Germplasm. The present status of pearl millet germplasm shows 21,919 samples collected from 44 countries, of which 9,880 (45%) are from Africa (Table 1). All the accessions are maintained in ICRISAT's genebank. As pearl millet is cross-pollinated, we follow cluster bagging method for maintainance and rejuvenation. Besides evaluation at ICRISAT Centre, Patancheru, diverses lines were evaluated in Bobo-Dioulasso and Kamboinse, Burkina Fas, and Maradi, Niger. Also, all Cameroonian landraces were evaluated in Maroua, Cameroon.

c) Status of Finger millet Germplasm. Finger millet is known to have its origin in eastern Africa (de Wet et al., 1984). In view of the importance of this crop mainly in eastern, central, and southern Africa, more efforts should be made to collect germplasm before it is too late (Prasad Rao and Magesha, 1988 ; Gupta et al., 1989). Of the 3,220 finger millet germplasm accessions conserved at ICRISAT, 2,015 (63 %) are from Africa (Table 1). Though the number of accessions is small, they show considerable diversity for head, finger and seed size as well as in shape and color. In general, African types mature late and produce larger heads compared with those collected from India. In addition to what is conserved at ICRISAT, large germplasm collections of finger millet are also maintained at SADCC/ICRISAT Centre, Bulawayo, Zimbabwe, and the All-India Co-ordinated Small Millets Improvement Project (AICSMIP), Bangalore, India.

Evaluation

The greatest potential of any world germplasm collection is the diversity it offers, which is realized through evaluation and documentation (Murty et al., 1967). Such vast and diverse genetic resources of sorghum and millets are available at ICRISAT. They need to be closely studied and evaluated in sub-Saharian Africa for utilization.

At ICRISAT, the material collected from various sources is evaluated according to standardized descriptors (IBPGR/ICRISAT, 1981 and 1984). The work is carried out in the rainy and post-rainy seasons at the ICRISAT Centre, patancheru, Variation in important morphological and agronomic characters is considerable, as shown in Table 3 (for sorghum) and Table 4 (for pearl millet collections were evaluated at five different locations in India, Burkina Faso and Niger. Indigenous germplasm are evaluated by ICRISAT in western, eastern and southern Africa in collaboration with national programmes.

World collections could be used to identify new traits (Mengesha and Appa Rao, 1989). We found dwarfing (Appa Rao *et al.*, 1968 b), glossy genes (Appa Rao *et al.*, 1987) and early maturity (Appa Rao *et al.*, 1988). Pearl millet with high sugars in the stalks (Appa Rao et al., 1982) can be used to produce syrup and alcohol.

Utilization

The potential of a germplasm sample is largely unknown at the time of its collection. Examples of sorghum utilization were described by Quinby (1975), Brhane (1982), Doggett (1982), Prasada Rao and Mengesha (1987 and 1988a), Prasada Rao *et al.*, (1989), Vidyabhushanam *et al.* (1989); and millet utilization by Harinarayana *et al.* (1988). However, we have seen that a number of desirable characters is iden-

Table 4. Range of variation in pearl millet germplasm evaluated in rainy season at ICRISAT Centre.

Character	Rainy (Kharif) season	
	From	To
Plant height (cm)	18	475
Flowering (days)	33	140
Tillers (no.)	1	210
Stem thickness (mm)	2.8	15
Leaf/node number	6	25
Leaf length (cm)	25	120
leaf width (mm)	11	78
Hairiness	Glabrous	Villous
Pigmentation	Green	Purple
Spike exsertion (cm)	-45	39.5
Spike length (cm)	5	165
Spike thickness (cm)	11	64.5
Spike density	V. loose	V. compact
Grain n°/spike	489	3337
1000-grain mass (g)	2.54	19.32
Grain shape	Obovate	Globular
Grain color	White	Purple
Endosperm texture	Corneous	Starchy
Bristle length (mm)	2	60
Bristle color	Green	Purple

tied whenever a diverse group of germplasm samples are evaluated and screened. A large number of promising genetic stocks were assembled at ICRISAT which were used in breeding for disease resistance and yield in pearl millet (Andrews et al., 1985). In sorghum, we have genetic stocks that are early-flowering and have resistance to pests and diseases (Table 5). At times, even those lines that show susceptibility to a disease or pest offer a rare source of breeding material for other agronomically desirable traits. For example, sorghum accessions IS 1082, 2122, 2145, 4663, 4664, 5470, 5484, 5566, 18551 and others have been identified as having promosing shoot fly *(Atherigona soccata)* sorghum germplasm lines such as IS 620, 621, 5959, 7237, 8219, 93,8, 9482, and 11234 have promising grain mold resistance; but they are susceptible to shoot fly and stem borer *(Chilo* sp.). In pearl millet, we have sources of resistance to pests and diseases (Table 6). Such accessions as sweet-stalk pearl millet are not only useful for grain and fodder (Appa Rao *et al.*, 1982) but are also useful for the production of syrup and alcohol.

Much emphasis is presently placed on multilocational evaluation of germplasm, specially at or near the place of origin. This will enhance the identification and utilization of new and useful germplasm accessions in different agro-climatic conditions.

Table 5. Sorghum genetic stocks collection maintained at ICRISAT Centre as of June 1988.

Type	Number of Accessions
Promising lines for pest resistance	
Shoot fly (*Antherigona soccata*)	60
Stem borer (*Chilo partellus*)	70
Midge (*Contarinia sorghicola*)	14
Head bug (*Calocoris angustatus*)	6
Promising lines for disease resistance	
Grain mold	156
Anthracnose (*Colletrotrichum graminicola*)	15
Rust (*Puccinea purpurea*)	31
Downy mildew (*Peronosclerospora sorghi*)	155
Striga low-stimulant lines (lab screening)	
Striga-resistant lines (field screening)	24
Other characters	
Glossy lines	501
Pop sorghum lines	36
Sweet-stalk sorghum lines	76
Scented sorghum lines	17
Twin-seeded lines	131
Large-glume lines	71
Bloomless sorghum lines	207
Broomcorn sorghum lines	52
Cytoplasmic A & B lines	240

Table 6. Pearl millet germplasm evaluation/screening results

Screened for	N° of accessions screened	N° of promising lines	Identified and described in collaboration with
Disease resistance			
Downy mildew	2748	1220	Millet Pathology*
Ergot	2524	151**	"
Smut	941	161**	"
Rust	2670	392	"
Insect resistance			
Mythimna spp.	100	0	Millet Entomology*
Shoot fly	424	45	"
Aphids	100	14	"
Shoot bugs	100	8	"
Thrisps	29	3	"
Spider mites	234	31	"
Drought resistance	509	2	"
Other characters			
High protein lines	3523	100	Biochemistry *
Sweet-stalks	8	4	"
Male sterility	16968	5	Genetic Resources
Glossy leaf	16968	8	"
Dwarf lines	15388	6	"
Genetic stocks	15388	692	"
Viable chlorophyll mutants	16968	11	"

* Courtesy of the sub programmes indicated.
** Less susceptible plants.

Collaboration with national programmes in multi locational evaluation has helped to identify locally adapted lines for direct use or as parents in hybridization programmes. Sources of resistance to biotic and abiotic stress factors have been identified through such joint efforts. Several sorghum germplasm landraces from sub-Saharan Africa were found useful elsewhere (Table 7). For example, the Ethiopian sorghum germplasm E 35-1 (IS 18758) did well in Burkina Faso. A pure-line selection of E 1966 (IS 30468), a Zerazera landrace from Ethiopia, was released in India. Red Swazi (IS 29185) and Framida (IS 8744) are still popular in southern Africa. Some cultivars such as Dobbs (IS 18519) from the Nyanza region of Kenya, Framida from southern Africa, Serena (IS 18520) and dwarf Lulu (IS 18515) are very popular. Karper's nursery selections are basically developed from Kauras of Nigeria

and one of the selections (Karper 1597) has contributed towards the development of Hageen Durra-1 hybrid in Sudan. Muskwari (transplanted) sorghums from northern Cameroon are contributing as source material in the postrainy (rabi) season programme in India. Two Kafir germplasm lines from southern Africa (IS 9302, IS 9323) were released in Ethiopia as ESIP 11 and ESIP 12.

In pearl millet, several landraces were released directly or after mass selection (Table 8). For example, early-maturing germplasm with large grain from Ghana (Appa Rao et al., 1985) was released as 'Pusa Moti' in India, ICTP 8203 in India and Namibia and several Serere Composites are still popular in Africa.

Table 7. Important sorghum landraces for utilization in sub-Saharan Africa.

Type	Source	Major characteristics
Zerazera (Caudatum)	Ethiopia	Tan plant Semicompact panicle Straw-colored grain High-yield potential Good grain quality Resistant to leaf diseases
Kaura (Durra-caudatum)	Nigeria	Pigmented plant Semicompact to compact panicle Yellow endosperm grain High-yield potential Good grain quality Tolerant to *Striga*
Farafara (Durra-caudatum)	Nigeria	Pigmented plant Semiloose panicle Chalky white grain High yield Good grain quality Subcoat absent
Hegari (Caudetum-Kafir)	Sudan	Pigmented plant Semicompact panicle Chalky white grain Subcoat present Short duration
Feterita Caudatum)	Sudan	Pigmented plant Semicompact panicle White grain High yield Large size grain Subcoat absent

(continued)

Table 7 (continued)

Type	Source	Major characteristics
Yadasi 5durra-caudatum)	Yemen	Pigmented plant Semicompact oval panicle Recurved peduncle Yellow endosperm grain High yield Good grain quality
Oubali (Durra)	Yemen	Pigmented plant Semicompact panicle Yellow endosperm grain High yield Good grain quality
Segaolane (Durra-kafir)	Botswana	Pigmented plant Semiloose panicle Straw-colored lustrous grain High yield Superior grain quality
Maldandi (Durra)	India	Pigmented plant Semicompact panicle Straw-colored lustrous grain Superior grain quality Moderately resistant to shoot fly
Dalassi (Durra)	Cameroon	Pigmented plant Transplanted type Compact oval panicle High yield Large grain size Superior grain quality
Safrari (Durra-caudatum)	Cameroon	Pigmented plant Transplanted type Compact elliptic panicle High yield Yellow pericarp Superior grain quality

Table 8. Prominent landraces of pearl millet and their characteristics.

Name of landrace	Origin	Characteristics
Early-maturing (70-85 d)		
Ignati	Benin, Togo	Large grain
Nara	Togo, Ghana	Large grain
Iniadi	Burkina Faso	Large grain
Boudouma	Niger	Compact spikes
Thiotande	Senegal	Large, starchy grain
Medium-maturing (90-110 d)		
Souna	Mali, Senegal	Compact spikes, Large grain
Gero, Zongo	Niger, Nigeria	Large spikes
Mouri	Cameroon	Compact spikes
Tiotioni, Gaouri	Mali	Compact spikes
Late-maturing (120-180 d)		
Amala	Benin	Large grain
Sanio	Senegal	Long bristles
Maiwa	Nigeria, Niger	Large spikes & grain, Good quality grain
Dauro	Nigeria	Transplanted
Yadiri	Cameroon	White grain

The World Composite developed in Nigeria, which was improved at ICRISAT (Andrews et al., 1985), is still popular in southern Africa. Finger millet, which is an important crop in eastern and southern Africa, needs to be collected and evaluated. One of the finger millet germplasm lines from Malawi (IE 2929) was released in Zambia as 'Lima'.

Germplasm Exchange

Considering the world-wide crop improvement programmes and in view of the Plant Breeders' remarkable success in developing high-yielding cultivars, it is obvious that there are significant advantages associated with international germplasm exchange (Mengesha, 1984). With careful handling, imaginative methods, and more specific research on seed pathogen and pest relationships, man should be able to save and exchange his valuable seeds for present and future use. Use of indigenous germplasm for crop improvement should be emphasized in sub-Saharan Africa where the greatest germplasm diversity exists (Mengesha, 1984 and 1988). However, we should not fail to realize the importance of exotic material for specific

traits. For example, some of the all-time great African genetic resources exchanged are the Zerazera sorghums from Ethiopia and Sudan, Farafara and Kaura sorghums from Nigeria, Hegari from Sudan, and kafirs from southern Africa. In pearl millet, some of the excellent examples are Gero from Nigeria, Souna from Senegal (Appa Rao *et al.*, 1986a; Mengesha and Appa Rao, 1986) and Mali, Nara from Ghana and Togo, Mouri from Cameroon (Table 8). Indo-African crosses in finger millets have contributed to the development of 'INDAF' lines which are being utilized in finger millet improvement in India and Africa.

Regional Germplasm Conservation and Evaluation

Regional germplasm conservation and multi-locational evaluation should be further expanded, particularly in sub-Saharan Africa, as it is the original home of sorghum and millets. Regional approaches will provide more economical, meaningful and more complete evaluation data for documentation and utilization. In this regard, the establishment of SADCC Regional Gene Bank is a commendable and most promising task. Similar genebanks should be planned and established for western, central and eastern Africa. Such regional genebanks will ensure a safe conservation and mutually beneficial germplasm exchange.

Duplicate Germplasm Conservation Centres

Another important role for regional genebanks is that they could serve as alternate base conservation centres for selected world collections of germplasm. For example, base or long-term conservation of sorghum and minor millets could be carried out in esatern Africa where the crops have originated. Likewise, a base collection of pearl millet could best be maintained in the Sahelian region.

Duplicate germplasm conservation centres are necessary for safe and reliable conservation and utilization. Nowadays, the development and implementation of such centres are being emphasized. Although there have been broad international discussions on the need for such centres, very little progress has been made so far in Africa. Perhaps it may be more appropriate for SAFGRAD to take the initiative and leadership to implement such programmes of fundamental and strategic importance in close collaboration with national, regional, and international organizations such as the Food and Agriculture organization of the United Nations (FAO), and IBPGR.

Wild Relatives

It is known that wild relatives are good sources of desirable genes for resistance to certain biotic and abiotic stress factors (Hawkes, 1977; Hanna, 1987). For example, shoot fly resistance in sorghum is found in one of its wild relatives, S. dimidiatum. With the recent advances in biotechnology, it may be easier to transfer desirable genes from wild relatives to cultivated species. Accordingly, more emphasis should be placed on the collection and conservation of wild relatives, since their full use and potential is still to be realized. So far, only 345 accessions of 19 species of Sorghum and 348 accessions of 20 species of Pennisetum have been assembled in world collections. There is hardly any wild relative of minor millets conserved in any genebank, hence, the need for an accelerated effort in this area.

Documentation

Documentation is a vital activity in the proper maintenance and subsequent utilization of germplasm. The basis of germplasm documentation is the accurate evaluation and screening of the collected material. A computer-based data management and retrieval system has become an essential tool for documenting and selecting material for germplasm distribution and utilization. Passport and evaluation data of the world collections of sorghum and millets maintained at ICRISAT are fully computerized. This has increased our capability to supply germplasm accompanied by basic information. The sorghum and millet germplasm from sub-Saharan Africa make up about 45% of the world collection of these crops maintained in the ICRISAT genebank.

Conclusion

Evaluation, screening, and identification of new and useful genetic traits of sorghum and millets are carried out in close collaboration with crop improvement scientists in and outside ICRISAT. Some of the most encouraging results are the fruits of such inter-disciplinary efforts. In this respect, collaborative germplasm collection programmes in Africa are commendable. In the future, more concerted efforts have to be made in Africa in the areas of germplasm evaluation and identification of indigenous landraces for utilization in more dynamic crop improvement programmes. ICRISAT has attempted to augment such efforts at the ICRISAT Sahelian Centre, Niger, SADCC/ICRISAT Centre, Zimbabwe, and OAU/SAFGRAD/EARCAL, Kenya.

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ICRISAT Cereals Programme Until the Year 2000

R.W. GIBBONS.

Executive Director, ICRISAT Sahelian Centre, West African Programmes. Niamey, Niger.

Introduction

This presentation is based on ICRISAT's Strategic Plan "Pathway to Progress in the Semi-Arid Tropics". It is emphasised that this plan is still in draft form and a final version will be presented to the Governing Board of ICRISAT during the last week of March in Bulawayo, Zimbabwe. The new draft incorporates changes suggested by the external review committees, national programmes from Africa and Asia, the Governing Board as well as ICRISAT programmes. After the ICRISAT Board endorses the final draft, it will be sent to TAC and the CGIAR for comment. This plan will take ICRISAT to the year 2000.

The Centre Programme will move towards more strategic research but the programmes in East, Southern and West Africa will remain largely applied in nature. The medium term plan (1989-93) endorses the shift of resources from Asia to Africa. Up to 1993, the staffing position has been approved by the CGIAR, but new posts are dependend on funding. All projects under special project funding are, of course, dependend on continued funding, including SAFGRAD.

Crops Research

a) *Goals for Crops Research.* ICRISAT's research strategy is founded on two institutional benchmarks: the area mandate of the SAT and the emphasis on dryland agriculture. These requirements cannot be modified without fundamentally altering the intent of the founders, but the crop commodity component of the mandate does have flexibility. ICRISAT's mandate crops include three cereals (sorghum, pearl millet and finger millet) and three legumes (groundnut, pigeonpea and chickpea). Changes in this mandate are not presently envisaged, but it may be reviewed before the year 2000 to accommodate possible shifts in commodity demands and NARS capabilities.

b) *Yield Improvement.* New cultivars of ICRISAT mandate crops with higher yield potentials have been produced, and further advances are achievable. Our goals are to continue to increase the yield potential of new cultivars, reduce fluctuations by adapting cultivars to specific environments, and to help stimulate sustained production in farmers' fields so that gaps between yields on research station trial plots and those on farmers' fields are reduced.

c) *Quality Improvement.* Improvements in physical crop yield translate into improved crop value only if commodity characteristics valued by processors and consumers are maintained or enhanced. Food quality characteristics must be maintained for traditional consumers. The importance of quality characteristics in new

uses of mandate crops will be determined so that more diversified demand can be met.

d) *New Crop Uses.* Growth in income and market integration lead to more diversified market demand. At the same time, the enclosure of uncultivated lands in many SAT countries means that biomass previously harvested from these areas must now be produced on cultivated land. Thus, subsistence crops like pearl millet, sorghum, and pigeonpea will need to meet these demands to enable farmers to earn income. Our cereal and legume crops can provide biomass for fodder and soil amelioration to sustain the farming systems of which they are an integral part.

e) *Imperatives for Crops Research.* Detailed long-term planting of crops research may not be useful in a fluid research environment. The appropriate response to fluidity and instability in the external environment is not rigid and over-detailed planning, but to establish principles for research that define a flexible strategy and its limits. Such a strategy should ensure the relevance of research projects that are able to exploit new opportunities while maintaining continuity in research direction.

Our crops research should maintain its international character by being internationally relevant, by linking research in high-income and low-income countries, and by drawing on the world germplasm collection. At whatever level it is conducted, crops research should satisfy disciplinary standards of excellence.

The scope of ICRISAT's crops research encompasses the whole commodity system from crop production to end-use. Research attention, however, will focus on the intersection between the commodity systems of the mandate crops and farming systems in the SAT. Economically important commodity problems outside this focus will receive attention only when ICRISAT has a comparative advantage.

Focusing on Problems

Problem-oriented research is not confined to applied problems, but encompasses strategic research problems whose solution helps solve those of applied research. Research problems tend to transcend disciplinary boundaries and solving them efficiently requires a multi-disciplinary approach.

Research responsibilities will be distributed among ICRISAT's centres, programmes, teams and networks to exploit their locational advantages and to make efficient use of resources. ICRISAT Centre has global responsibilities; it supports all the regional programmes through strategic and basic research, while also serving as a regional programme for Asia. Techniques developed at the Centre are adapted to regional needs and conditions by regional teams and programmes. Networks ensure the transfer to national programmes of regionally developed research products.

Modus Operandi for Crops Research

Crop improvement comprises three broad domains of activity, each requiring the expertise of different disciplines.

a) *Genetic Resources.* ICRISAT's extensive collection of germplasm accessions is an important source of genetic variation to be exploited through breeding. If this germplasm pool lacks the required genetic material, appropriate methods of bid engineering will be considered.

b) *Breeding.* The initial emphasis of ICRISAT's breeding programmes was to overcome the yield constraints that were important over considerable areas of the SAT. This resulted in many new cultivars being released, primarily in India, and in segragating material being made available to breeders in both public and private sectors. We expect the demand for such material to increase as NARSs improve their capabilities to use it.

Improved understanding of production conditions in SAT regions, changing requirements of national programmes and new types of demands for our crops require that we make our material more genetically diverse. In particular, breeding material will have wider environmental adaptation (e.g., through photoperiod insensitivity). It will be better tailored to fit into specific cropping systems and will have a wider range of valuable characteristics. This broader diversity will be exploited by integrating improved genotypes with sustainable management practices. To accomplish this, considerable knowledge of crop production conditions and constraints in different countries is required. We will need to re-define screening objectives, adapt techniques and modify the balance of breeding responsibilities between ICRISAT and the national programmes.

We will undertake strategic research to better define agro-ecological zones and to understand the mechanisms of adaptation of our crops. We will ask NARS to provide such specific information as the needs of farmers, the characteristics of environments and production constraints at specific locations towards guiding our breeding research. The expected partial shift in the use of our mandate crops (from food to animal feed, forage and for industry) will require adjustments in breeding emphasis and screening techniques. The scope of screening will be widened to include the bio-chemical composition and nutritive value of whole plants.

To ensure the sustainability of packages of management practices using new cultivars, the stability of the cultivars themselves must be ensured by screening them for resistance to a range of abiotic and biotic constraints.

Our breeders will give more emphasis to studies of the genetic factors leading to increased production and to the nature and inheritance of the traits involved. They will continue to evaluate early-generation breeding material and make it available to NARS with strong breeding programmes. We shall, however, continue to produce finished products for countries that have not yet developed adequate research capacities. Many of our partners already have the capacity for identifying farmers' needs for new cultivars and evaluating those cultivars in farmers' fields.

The ultimate success of any breeding strategy depends on the capability to produce seed of improved varieties in sufficient quantity and quality. Stimulating countries to develop efficient seed industries will be an important component of our technology transfer.

c) *Bio-technology*. It is well realised that bio technology cannot be an independent research area in a crops research institute. ICRISAT's capacity to fully exploit new techniques is constrained by market conditions in the recruitment of excellent bio-technologists and by the discipline's high demand for capital investment. These constraints can be mitigated by collaborating with private or public mentor institutes with location advantages. ICRISAT's advantage in the applied aspects of bio-technology research lies in its facility to test the effects of introducing new genes into breeding populations in different environments. The long-term benefits to ICRISAT will ultimately depend on our ability to exploit their locational advantages.

d) *Commodity Utilization*. The value of crops research is derived from the value of a crop's utilization and the market demand for commodities derived from that crop. Food technologies and biochemists can provide guidance to breeders by quantifying a cultivar's characteristics. The scope of this research will be expanded from characteristics of our crops when used as human food to feed, fodder, or industrial processing. Economists will determine the economic value of specific quality characteristics and identify demand prospects for commodities derived from our crops.

Strategies for Mandate Crops

a) *Sorghum*. Two important lessons from the past and anticipated changes in demand shape the strategy for sorghum. The first lesson is that high-yielding single stem material is ill-suited to the conditions of farmers in unfavorable locations where crop recovery from stresses depends on the crop's ability to tiller. The second lesson is that location-specific yield reducers cannot be effectively addressed by centralized applied research.

The structure of sorghum demand will change significantly. For instance, in India it is expected that demand for food sorghum will remain high and demand for sorghum fodder will increase as bullocks continue to be the main source of draft power on small farms. The demand for sorghum grain as animal feed will increase throughout the SAT, with the increasing demand for milk. Industry's demand for sorghum will rise from its presently low levels and the sorghum processing industry could become a major catalyst for sorghum production toward the end of the 1990s.

Our strategy in applied sorghum research is to breed for specific abiotic and biotic constraints rather than for broad adaptation and to assist NARSs breed for specific uses rather than for multiple or non-specific uses. Our objective is to increase crop value and increasing yield stability will take preference over maximizing yield potential. Important constraints that will attract research attention in both Indian and African sorghum-growing areas are grain molds, shoot fly and stem borer in rainy-season sorghum as well as lodging under terminal drought stress in post rainy season sorghum. Research on fodder sorghum will be conducted in western and southern Africa.

With the increasing dispersion and regional diversification of applied sorghum research, ICRISAT Centre will focus on breeding methods and techniques, the study of the biology of mechanisms providing resistance to physical and biotic stress, the

heritability of these triats and the effects on agronomic crop performance of introducing them into advanced breeding lines.

b) *Pearl Millet.* Yield increases in pearl millet hybrids have been more than three times higher than those of other cereals and genetic gains in yield of pearl millet varieties have been on a par with gains in other cereals. Fodder yield, disease resistance, average and grain quality have also been improved. Advances in breeding methods will allow even more dramatic progress in the future. High-yielding cultivars based on ICRISAT material or produced by ICRISAT are widely grown by farmers.

Pearl millet success in India is due to both the close integration of disciplinary research and the full collaboration of public and private sector breeding programmes. The private sector has lately been more successful in delivering hybrids based on ICRISAT material and investment in pearl millet breeding by private industry is likely to grow so long as ICRISAT continues to supply germplasm for new hybrids.

The prospects for pearl millet improvement are not matched by prospects for its demand. Production of pearl millet for food will be largely restricted to dry regions, such as Rajasthan in India, the Sahel and parts of southern and eastern Africa. However, the demand for pearl millet for fodder will increase throughout the SAT and to meet this, we have started to work on pearl millet/napier grass hybrids in southern Africa.

The strategy for applied pearl millet improvement is to breed open pollinated cultivars of specific maturity for specific regions and agro-ecosystems; to concentrate on the genetic diversification of parents for pearl millet hybrids to provide broad-based resistance to downy mildew, and to emphasize the cultivation of top-cross hybrids. Applied breeding will be complemented by research on stresses limiting millet production, including seedling emergence, temperature and drought stress. Pearl millet entomologists will identify resistance to earhead caterpillar and stem borer towards transfering it to breeding lines.

Networking of Crop Genetic Resources: The Case for West Africa.

J. TOLL and P.M. PERRET.

IBPGR Coordinator for West Africa, c/o ICRISAT Sahelian Centre, Niger. and IBPGR Crop Networks Coordinator, IBPGR, Rome, Italy.

Plant Genetic Resources and Crop Improvement

West Africa has a rich heritage of plant genetic resources by virtue of its ecological and agricultural diversity. There are strong cultural traditions in the use of a large variety of plants which is reflected in the high level of concern expressed within the region for the preservation of its plant resources.

Plant genetic resources have a crucial and direct part to play in the region's development. Increasing and sustaining production under West Africa's varied, often unfavourable and fragile environments, and in its complex and low-input farming systems, makes heavy demands on genetic variation. Scientists need access to a diversity of species, genotypes and genes to manipulate to improve the region's production systems. Central to this is local germplasm which is the source of varieties and characters for adaptation to local growing conditions and farmer and consumer preferences.

Germplasm Collection in West Africa

It was the severe droughts of the late 1960's and early 1970's that heightened the awareness of the risk of crop genetic erosion in the Sahel and mobilised action to preserve this diversity so vital to future efforts to provide sustainable increases in agricultural production. On the initiative of the FAO, a programme of germplasm collection was launched in the West African Sahel with funding from UNEP. Emphasis was on the evidently endangered major cereals, sorghum and pearl millet, and the missions were undertaken mainly by ORSTOM under contract, initially to FAO, but subsequently to IBPGR, in collaboration with ICRISAT and jointly with the national programmes. From 1975 to 1984, 17 missions explored eleven countries and collected about 2,500 samples each of millet and sorghum, including wild and weedy forms (Achaempong et al., 1984; Clement, 1985). Samples were left in the country of collection and deposited with ORSTOM, at ICRISAT which maintains the global collection of sorghum and millet germplasm, and in the other genebanks which have agreed with IBPGR to maintain base collections (the National Plant Germplasm with IBPGR in the USA and Plant Gene Resources, in Ottawa, Canada.

During this period IBPGR also worked with IITA, IRAT/IDESSA, ORSTOM and WARDA and significant collections of cowpea, rice and other cereals, food legumes and vegetable crops were assembled. Samples were left in the country of collection and deposited in the genebanks assuming responsibility for the base collection -- for example, IITA for cowpeas and African maize.

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From the early 1980s, as genetic resources capabilities within the region have developed, the trend has been for collecting missions to be initiated and carried out by national institutions, with attention on a wider range of crops of importance in local breeding efforts. In the same period, the focus of international institutions has shifted to targeting specific parts of the crop variation and to the wild and weedy related species.

Among the nationally executed missions that IBPGR has assisted, the systematic, country-wide collecting and characterisation of traditional millet varieties by the University of Ouagadougou and INERA, Burkina Faso, can be cited as an example. Between 1984 and 1987, the project collected 333 samples from all regions of the country. The accessions have been characterised and evaluated for a number of traits following the IBPGR/ICRISAT Descriptor List. Diversity within this collection has been analysed and sources of disease resistance located (Wilson et al., 1989 and 1990). An example of the shift in focus in international activities is the collecting and study of wild pearl millet from throughout its geographical distribution in the Sahel by ORSTOM geneticists in Niamey in collaboration with the ICRISAT Sahelian Centre and national programmes.

Development of Crop Genetic Resources Programmes

From the earlier collecting missions, little of the germplasm is now available in the country of origin. It has invariably all been used in breeding programmes with little maintained largely because of non-existent or inadequate conservation facilities. However, the growing realisation amongst the region's scientists of the importance of local germplasm to crop improvement programmes and the need to have access to reference collections of local varieties has spurred efforts to conserve genetic resources at the national level and link-up with genebank and the international genetic resources community. In many countries of the region, a germplasm conservation unit or some sort of genetic resources programme is now under development. In West Africa, as elsewhere in the world, IBPGR promotes and tries to assist these national efforts and encourages regional initiatives where they emerge. IBPGR recognises national programmes as essential operating units for successful genetic resources activities. They form the backbone to regional and global genetic resources programmes.

Generally, the training of key scientists is the first step in getting activities started in a country, followed by assistance with the development of seed conservation facilities. The priority for most agricultural research institutes is a better way of conserving and managing their working collections, which typically are a mixture of local landraces and exotic germplasm. Longer storage life means fewer grow-outs, which releases funds, labour, land and time for the primary research activitiy of breeding for improved production. Furthermore, the better the methods of documenting collections and the more the exchange of data and germplasm worldwide, the easier it would be to locate materials to meet specific improvement objectives.

This valuable support function provided by a germplasm conservation programme to crop improvement research is often not appreciated. Consequently, within national research systems and donor projects, the manpower and financial resources allo

cated to germplasm management tends to be inadequate and institutional arrangements for the programmes invariably poor. Also of concern is the tendency for genetic resources to be considered as an aside and sometimes institutionalised away from their utilisation in crop improvement. Since local germplasm is often the starting point of breeding for increased production especially under varied ecologies and farming systems, germplasm conservation must necessarily be integrated with its use in crop improvement for either activity to be viable and sustainable. It is in this context that Networking provides a mechanism by which these constraints can, to some extent, be overcome. Under a Network approach, genetic resources activities can be linked, even integrated, with breeding programmes such that individual country genetic resources capabilities are strengthened through the sharing of tasks, expertise and resources.

Networking of Crop Genetic Resources Activities

Genetic resources Networks on a crop-by-crop basis are thus proposed following the crop genepool concept. Such Networks would provide the framework within which arrangements for the conservation of a genepool can be put into place and a collaborative programme developed for the collection, study, evaluation and use of its genetic diversity. The Network would thus bring together curators of the crop's dispersed collections with users of the germplasm (breeders) and other scientists.

Suggested Activities of Proposed Genetic Resources Network

Activities for the proposed Network are suggested to fall into the three main areas of documentation of crop genetic resources, their conservation and use as described hereunder.

a) ***Documentation***

Of priority in the documentation of crop genetic resources is the need to use common Descriptor Lists such as the ones published by IBPGR for describing characters, specifying their states and for encoding the data. Adoption of common descriptors allows for rapid, reliable and efficient information storage, retrieval and communication which greatly facilitates the use of the germplasm. This is to say that the adoption by such a Network of common descriptors and the creation of a central database would allow for the sharing and comparison of research results, including the evaluation of data among Network members and the building up of profiles for the region's different landraces for their sites of origin, morphology and agronomic traits.

The inventory of all of a crop's accessions held ex situ in the various collections is a prerequisite for the proper planning of all other activities and essential for access to the germplasm and its use in crop improvement.

Through the proposed Network, a comprehensive inventory of a crop's germplasm accessions can be compiled. The Network would coordinate the completion of the data, its standardisation and the analyses of data files prior to the planning of further collaborative activities.

The increased coordination of activities within the proposed Network and the consequential sharing of results requires that passport data be collated in a central database towards assembling information on the accessions for all other documentation categories: characterisation, preliminary evaluation, further evaluation and management. This is to say that the central database would be the hub of the proposed Network, since it provides the basis on which plans for collaborative activities are drawn-up and the mechanism by which results are assimilated and communicated.

b) ***Conservation***

Germplasm collections must, of necessity, be duplicated for security. It is for this reason that a crop's germplasm accessions are typically held dispersed among national collections and in different genebanks within and outside the region of collection. There is, therefore, a need to rationalise collections and consider all existing collections of a particular crop as a part of a single collection. In rationalising collections following the Network approach to the conservation of a crop genepool, ensuring adequate duplication of the accesssions is paramount. Other practical and technical issues which must also be considered towards enhancing the ease and speed of access to the material include the location of the base collections, quarantine regulations and the status of the storage of the original accessions. In the case of the conservation status of the collections, collation in the Network's database of management descriptors such as seed stocks and germination percentage has particular relevance. For wild species which are difficult to maintain and which have low seed numbers, it may be advisable to deliberately keep the accessions replicated and dispersed among different collections.

In order to guarantee the safety of materials collected, it is generally the practice for every original germplasm accession to be held in long-term storage at high viability and in sufficient seed numbers. In addition, it is normal for duplicate samples to be held in another genebank also under long-term storage conditions. Vegetative material are held in two distinct field genebanks or cyro-preserve same in vitro. With the emergence of more and more genebanks that have facilities for long-term storage, arrangements can be made through the proposed Network to ensure adequate duplication of germplasm collections among member countries and in base collections.

In discussing the suggested activities of the proposed Network especially relating to the conservation of germplasm materials, mention must be made about the concern of genetic resources programmes and plant breeders with ex situ conservation of seeds or vegetative materials. For each crop genepool, there is an optimal combination of in situ and ex situ methods for conserving the full range of genetic diversity in economical yet accessible ways. Through the proposed Network, appropriate combinations of in situ and ex situ conservation can be studied and a conservation strategy developed and implemented in a collaborative fashion. For Networks handling vegetatively propagated crops, the value of taking an integrated appraoch to their conservation is readily apparent. The high costs and risk of maintaining material in field genebanks can be offset by the use of seed and in vitro conservation in an appropriate combination and arranged among Network curators.

For seed producing crops, in situ conservation is recognised as an appropriate additional conservation method for wild related species.

c) ***Access to and Use of Germplasm***

Access to germplasm is a prerequisite for its use and this can be greatly improved through a Network approach. Arrangements for the conservation and movement of germplasm within the Network may bring material physically closer to users and, by dealing with the phytosanitary aspects, make access to it safer. Ensuring safe access through the establishment of guidelines for the movement of germplasm and the designation or strengthening of quarantine centres for its transfer, is a major responsibility of the Network. At the scientific level, access is dependent on the comprehensiveness and relevance of the information (evaluation data) on the germplasm accessions and availability of the data and access to it. In this, the central database has a crucial role to play.

The registration of all available evaluation data in the central database allows users to search germplasm collections for accessions with traits that fit their research objectives. The Network arrangement would thus also enable further evaluation of the material to be coordinated, thereby avoiding unnecessary duplicate characterisation, but enhancing potential use through its screening under different conditions in multi-site trials.

Comprehensive and easily accessible evaluation data may not be sufficient to stimulate the use of the germplasm accessions. It may be necessary to first transfer potentially useful characters to a more acceptable genotype. Through the proposed Network, the collaborative research needed to enhance germplasm through wide-crosses and pre-breeding, can be stimulated. Definition and distribution by the Network of core collections can also stimulate use of the germplasm.

Implementing Crop Germplasm Network Activities in West Africa

Whether Networks are global or regional in focus, the suggested activities and objectives described above are the same. However, activities will vary in importance depending on the crop and the region. For crops with relatively old ex situ collections amongst which there has been much germplasm exchange, the rationalisation of the existing collections is the first and priority objective. The first step is the production of an inventory of all ex situ accessions -- a probable difficult task, in view of the likely lack of or incomplete passport data in non-standard formats.

In the specific case of West Africa, the drawing up of inventories and identification of redundancy should pose much less of a problem in view of the fact that documentation during collection and characterisation has largely followed internationally agreed standard formats. However, if steps are not taken to centralise the documentation of the increasing number of separate collections emerging within the countries and across the region, the likelihood of precious resources being wasted in repeated activities will rise.

Goals for the proposed crop genetic resources Network for West Africa are suggested to include the strengthening of individual country capabilities as well as promoting the use of crop germ-plasm. The question remains, however, on whether to implement specific crop germplasm Networks or to incorporate the networking of genetic resources activities into the region's existing crop research Networks. For reasons which have already been touched upon, it would seem that the latter approach is more appropriate at this stage in the development of genetic resources and crop breeding programmes within the national research systems of West Africa. Breeders are already handling germplasm materials and using them in their crop improvement efforts. With the relatively few crop specialists in many of the countries as at present, it would largely be the same breeders who would be called upon to participate in Networks for genetic resources activities. It is, therefore, questionable whether the region can, as at present, sustain an additional tier of Networks. Even more important is to question the appropriateness at separating the networking of germplasm activities from those of crop improvement.

Conclusion

The improvements that the proposed networking would bring towards enhancing opportunities for access to and use of traditional crop varieties would seem to be of direct relevance and benefit to the existing research Networks. It is, therefore, suggested that consideration be given to incorporating the networking of genetic resources activities into the existing West Africa crop research Networks.

PART II

Cowpea

Regional Approach to Cowpea Research in West and Central Africa.

N. MULEBA.

Coordinator, Cowpea Network IITA/SAFGRAD-OAU/STRC, Ouagadougou, Burkina Faso.

Introduction

The Cowpea Research mandate under the first phase of the OAU/STRC-SAFGRAD project was successfully executed in Burkina Faso between 1978-86. From the laudable scientific achievements recorded in that phase, national directors of agricultural research, together with cowpea scientists from SAFGRAD member countries as well as regional and international research centres decided to extend the project into a second phase under the sponsorship of mainly USAID.

Under the second phase of the SAFGRAD project, cowpea research has the primary objective of boosting the capacity of national scientists towards enabling them eventually to direct cowpea research activities themselves in the sub-region. In order to set the stage for the eventual take-over of cowpea research activities by national scientists, the cowpea Network was established in 1987 involving 17 member countries from West and Central Africa. One of the early tasks of the Network was to document the major cowpea production constraints, research personnel, infrastructure as well as the research strengths and weaknesses of each national programme. Also documented were the research needs, researchable topics and the state of art on cowpea research and production in West and Central Africa.

The Network exercise was viewed as the most feasible solution to tackling cowpea production constraints by sharing scientific information and technologies, whether developed by regional and international agricultural centres or by the national agricultural research system. An elected Steering Committee of six national cowpea scientists met in March 1987 to define the agro-ecological zones of major cowpea production as well as recognise those climatic, biological, soil, socio-economic, manpower and financial considerations that constrain cowpea research and production in the region. The relatively strong national institutions were designated Lead Centres and assigned specified researchable topics of regional interest and application.

Network Objectives

In the overall context of developing a capacity for research, the Cowpea Network has the major responsibility of properly identifying production constraints and generating, through networking and in collaboration with IITA and Lead NARS Centres, the appropriate technologies towards overcoming the constraints. The approach to networking is to enable national cowpea programmes of West and Central Africa to pool together their resources to tackle common cowpea production problems in the sub-region and to find appropriate solutions for the benefit of their inhabitants. The

rationale of networking is, therefore, based on the simple but effective adage "united, we stand, but divided, we fall".

Network Programmes and Their Implementation

Based on the commonality of constraints and the wide variation in the relative strength of national programmes within the sub-region and in order to ensure cost effectiveness and the sustainability of networking, the Steering Committee adopted the strategy of assigning technology development research responsibilities to the relatively strong national programmes (Lead Centres). The technological backstopping provided by IITA and its sub-stations continued particularly in terms of both research and training. Cowpea varieties developed by IITA are channelled through Lead Centres for regional and adaptive testing involving all participating national programmes in the Network.

The six (6) relatively strong national programmes were assigned Lead Centre roles as shown in Table 1. In addition to these Lead Centres and owing to recorded variations in *Striga* strains, Benin and Mali were assigned responsibilities in 1990 of selecting and testing for *Striga* resistance.

Achievements

a) *Strengthening National Research Systems*

Capitalizing on the multiple insect pests and disease resistance developed by IITA, the national programme of Burkina Faso is attempting to incorporate the genes into existing varieties that are acceptable to farmers. The ultimate goal is to have drought, multiple disease, *Striga*, aphids and other insect pest resistant cowpea varieties. Nigerian scientists are also attempting to identify new sources of *Striga* and *Alectra* tolerance as well as the mode of inheritance. Scientists in Niger are looking for new and stable sources of cowpea resistance to *Striga gesnerioides* strains, including the ones parasitizing weeds such as *Ipomeas* sp.. Scientists in Cameroon are working on cowpea storage methods acceptable to farmers.

b) *Resistant Varieties*

Specific to *Striga* research, the cowpea varieties shown in Table 2 have been identified to be resistant to *Striga* gesnerioides and their genes are in the process of being appropriately incorporated into acceptable cultivars.

Table 1. Assignment of of Lead Centre roles to relatively strong national programmes.

Lead Centre	Breeding	Agronomy	Protection
Burkina Faso	Drought, *Striga*, Inect pests and disease resistance/tolerance.	-	Entomology and Panthology for, Sahel, Sudan savana and Northern Guinea savana.
Cameroon	-	-	Entomology with emphasis on storage pests
Ghana	Adaptation to transition zones.	-	Entomology for transition zones
Niger	Drought, *Striga* and *Macrophomina* disease resistance/tolerance	Millet-cowpea intercropping.	Pathology for Sahel zone, especially *Macrophomina* spp.
Nigeria	Drought, *Striga*, *Alectra*, Insect pests and disease resistance/tolerance.	Management covering Sahel, Sudan and Northern Guinea.	Pathology, including scab, brown blotch, *Septoria* leaf spot, *Striga* and *Alectra* ; Entomology for Sahel, Sudan and Northern Guinea with emphasis on mode of inheritance of diseases. *Striga* and *Alectra*.
Senegal	Drought, Insect pests and disease resistance/tolerance	-	Entomology for Sahel-Sudanian zones

Other resistant cowpea varieties identified through the coordination efforts of the Cowpea Network are:

i. For drought resistance -

Gorom Local (SUVITA-2), KV 30-309-6G and KVX 396-4 in Burkina Faso, 58-57 and IS 86-275 in Senegal, andTN 88-63 in Niger.

ii. Adapted to drought and excess moisture conditions are KVx 396-4-2, KVX 396-4-4, KVX 396-4-3 and KVX 396-18 in Burkina Faso

iii. For Aphid resistance -
IT 82E-25, IT 83S-742-2 and IT 85D-3577 in IITA, Ibadan, Nigeria.

iv. For Bruchid resistance -
IT 84S-275-9 and IT 84S-2246 in IITA, Ibadan, Nigeria, and KVx 30-6467-5-10K in Burkina Faso._p2X7

c) ***Regional Trials***

In 1987-88, the regional testing trials numbered seven (7) at 92 locations and with 56 feedbacks at the end of the season. With the same number of trials in 1989, the feedbacks were only 44 out of 63 locations.

Table 2. *Striga* resistant cowpea varieties in West and Central Africa

Name of variety	Origin	Pedigree	Country in which it is resistant to *Striga*	National programme incorporating it in good agronomic background
Gorom local (Suvita-2)	Burkina Faso	A selection from a landrace,	Burkina Faso, Mali, Senegal,	Burkina Faso, Mali
B301	Botswana	-	Burkina Faso, Mali, Senegal, Niger, Nigeria, Benin.	Burkina Faso, Mali, Niger, Nigeria.
IT82D-849	IITA-Ibadan	-	Burkina Faso, Mali, Senegal, Niger, Nigeria, Benin	Burkina Faso.
TN93-80	Niger	Landrace	Burkina Faso, Mali, Senegal, Niger, Nigeria.	-
TN121-80	Niger	Landrace	Burkina Faso, Mali, Senegal, Niger, Nigeria.	-
KVx61-1	Burkina Faso	-	Burkina Faso, Mali	Burkina Faso
KVx61-74	Burkina Faso	-	Burkina Faso, Mali.	Burkina Faso
IT81D-9[illegible]	Burkina Faso	-	Burkina Faso, Nigeria.	Burkina Faso

d) ***On-farm Testing***

Although the Cowpea Network is not directly involved in multi- locational trials and on-farm testings, it is significant that through the effort of the Network, including its regional trials, there have been renewed interests in cowpea research activities in all participating countries. The cultivars shown in Tables 3 and 4 obtained through Cowpea Network activities have been released or are about to be released in the various countries shown.

e) Training

In 1988, a monitoring tour was organised involving six (6) national scientists. Similarly, in 1990 the monitoring tour involved eight (8) scientists. Such tours are of value in enabling scientists from IITA, Lead Centres and technology adapting NARS to interact, to observe production constraints first hand and to compare experimental methodologies and approaches.

Table 3. Cowpea varieties released since 1987 to date

Country	Variety
Benin	IT82E-32 ; IT81D ; TVx 1850-01F
Burkina Faso	TVx 3236, Suvita-2 ; KVx 396-4-4 ; KVx 396-4-5
Cape Verde	KN-1 ; Local Santiago
Ghana	Vallenga (IT82E-16) ; Asontem (IT82E-32)
Guinea Bissau	IT82E-9 ; Bambey 21
Guinea Conakry	IT85F-867-5 ; IT83D-338-1 ; IT84S-2246-4
Mali	Suvita-2
Mauritania	IT83S-343-5-5 ; Suvita-2 ; KVx 256-K17-11
Nigeria	Sampea-7 (IAR-48)
Senegal	IS86-275
Togo	58-146

Table 4. Cowpea varieties accepted by NARS.

Country	Variety
Benin	IT84S-2246 ; IT84D-513, TVx 1999-01F, IT81D-1137
Burkina Faso	KVx 30-309-6G, KVx 61-1, KVx 396-4-4 ; KVx 396-4-5 ; KVx 396-18-10 ;
Cameroon	IT81D-994
Cape Verde	IT83D-444 ;
Ghana	IT81D-1137 ; IT83S-818 ;
Guinea Bissau	IT85D-3516-2 ; IT86D-498 ; IT87S-1390 ; IT85D-3577 ; IT83D-889 ; TVx 309-66 ; IS86-275N ; IS87-416N
Guinea Conakry	IT84S-2246-4 ; IT82E-32 ; IT86D-104B ; IT86D-1056 ; IT85F-867-5
Mali	TN93-80 ; TN121-80
Mauritania	IT86D-472 ; IT82D-544-4 ; IT81D-897 ; IT82ED-716 ; IT82D-927 ; TVx 1948-01F
Niger	A18-1-1 ; A73-1-2 ; KVx 30-309-6G ; KVx 100-2
Nigeria	TVx 3236 ; IT81D-994
Togo	TVx 1850-01E ; IT81D-985 ; 58-146 ; IT83S-818 ; IT82E-66 ; KVx 396-4-4.

In 1988, a seminar was organised at IITA, Ibadan, for 12 scientists from Lead Centres, including breeders, agronomists, pathologists and entomologists and covering the subject of appropriate research methodologies.

A group training course was organized in 1989 at Kamboinse/Ouagadougou in cooperation with the national cowpea programme of Burkina Faso and involving scientists and technicians from seven (7) countries. The subject matters covered mainly technology development and transfer.

Future Thrust of Network Activities

Future research emphasis by the Cowpea Network must necessarily continue on such constraints as drought, heat, *Striga, Alectra* as well as pests and diseases. Specific to pests and diseases, the use of chemicals for their control is hardly a viable option, especially considering the poor economic state of the farmer. Thus, the future challenge rests on finding relatively cheap controls of pests and diseases requiring minimum or no inputs. With this challenge, the most feasible approach would be to embark on a mass breeding programme, incorporating all genes and conferring resistance/tolerance to all major physical, chemical and biological cowpea production constraints into acceptable varieties.

Breeding Suitable Cowpea Varieties for West and Central African Savanna.

B.B. SINGH.

International Institute of Tropical Agriculture, Kano sub-Station, Kano, Nigeria.

Abstract

Cowpea is an intergral component of various cropping systems prevalent in the Central and West African savanna. It is grown in mixture with millet and/or sorghum and provides food as well fodder. However, the average grain yield of cowpea is low, ranging from 100 to 200 kg/ha. The major yield-reducing factors are diseases, insect pests, parasitic weeds, drought and competetion due to the cereals for moisture, nutrients and light. With the establishment of IITA sub-Station in Kano, Nigeria, work has been initiated to develop improved cowpea varieties for traditional cropping systems. Already, local varieties have been crossed with selected donor parents and segregating populations are being evaluated with a view to select breeding lines with resistance to aphid, bruchid, thrips, bacterial blight, *Striga* and *Alectra* and reduced maturity periods, keeping the plant types of traditional varieties. Work is also underway to develop varieties for double intercropping. Several advanced breeding lines have been developed which combine multiple disease and insect resistance but which look very similar to local varieties in plant type and seed quality. Also, the genes for *Striga* and *Alectra* resistance have been incorporated into superior agronomic background. These have now been crossed with improved local type breeding lines to develop a range of resistance to aphid, bruchid, thrips and multiple diseases. A few local lines have been identified which show field tolerance to insect pests and give reasonable yield in pure crop without insecticides.

Introduction

The International Institute of Tropical Agriculture (IITA) has global mandate for developing improved cowpea varieties in collaboration with national programmes. During the last two decades, IITA has made considerable progress in the collection, evaluation and utilization of world cowpea germplasm totaling over 15,000 accessions and has developed and distributed a range of improved breeding lines combining multiple disease and insect resistance with early maturity and preferred seed types to over 60 countries. About 45 countries have systematically evaluated the improved materials received from IITA, identified superior lines and released them for general cultivation. Among the numerous lines released, IT84S-2246-4 combines resistance to aphid, bruchid, thrips and 10 diseases, including viruses and root knot nematode. However, all of these varieties require 2-3 sprays of insecticides for protection against flower thrips, *Maruca* pod borer and pod bugs. Most traditional farmers do not use chemical protection due to socio-economic and infrastructural constraints. Consequently, the improved varieties are being cultivated by only those farmers who have easy access to chemicals and thus, the spread of improved varieties is limited. The majority of small farmers continue to cultivate traditional cowpea varieties in intercropping systems involving millet and sorghum.

New Research Initiatives

In recognition of the fact that most farmers in West and Central Africa grow cowpea as intercrops and without the use insecticides, IITA has launched two major initiatives in cowpea improvement strategy for the 1990s. These include collaborative research with advanced laboratories towards exploiting new bio- technological advances in the transfer genes for insect resistance from wild cowpea relatives and other sources into cultivated cowpeas. Drawing from experiences of other crops in bio-technology research, there are good possibilities of developing cowpea varieties that would be resistant to such insects as thrips, *Maruca* pod borer and pod bugs.

The second IITA, initiative relates to the establishment of a sub-Station in Kano, Nigeria, with the major objective to improve the productivity of traditional cowpea varieties normally grown without insecticides and in mixtures with millet and sorghum. With agro-ecological conditions similar to those found in the savanna region of most of West and Central Africa, research results obtainable at the Kano Station will be of direct relevance to the whole region.

Research Strategy

The general research strategy is intended to involve the following approaches:

a) Survey of cropping systems involving cowpea as a component crop and identifying production constraints.

b) Collection and evaluation of local varieties and selection of suitable parents for hybridization.

c) Systematic incorporation of resistance to major diseases like bacterial blight, brown blotch, *Septoria*, scab and insect pests such as aphid, bruchid and thrips as well as resistance to parasitic weeds like *Striga* and *Alectra* into improved cowpea varieties.

d) Development of a range of cowpea varieties with desired plant types and maturity to suit the needs for pure cropping, mixed cropping and dual purpose varieties which will provide grain as well as fodder.

e) Evaluation of the new improved cowpea breeding lines in pure crop as well as in mixed crop systems with and without insecticides at various locations and selecting the best lines.

f) Development of improved agronomic-cropping systems packages in collaboration with national programmes to ensure the most efficient use of moisture, light and nutrients and to maximize production.

Research Achievement

a) ***Varietal Improvement***. During the last two years (1989 and 90), over 700 new breeding lines generated from planned crosses in previous years were evaluated in

different sets of trials and 67 of these were distributed to various national programmes in the form of 9 different Cowpea International Trials. Some of the most promising breeding lines were also evaluated in All-Nigeria Cowpea Trials. The yield data in respect of these trials are presented in Tables 1 and 2. The trials were sprayed twice with insecticides. It is evident from the results that varieties IT86D-721, IT86D-719, IT86D-715 and IT87D61629 compared favourably with such recommend cultivars like IAR-48 and Ife Brown. The varieties will be extensively tested in the 1991 season, including on-farm adaptive trials. Another variety, IT84S-2246-4, is also very promising, having combined resistance to aphid, bruchid, thrips and 10 diseases, including nematodes and scab. The variety has performed well in all parts of Nigeria and was recommended for pre-release multiplication in 1990.

b) ***Varieties for Mixed Cropping.*** All breeding lines included in advanced and preliminary trials were also evaluated as intercrop planted in alternate rows with millet 1 m apart and giving 2 m distance between millet-to-millet and cowpea-to-cowpea. No insecticide was applied. Mean yields of millet and cowpea over all the trials are presented in Table 3. The mean millet grain yield was 672 kg/ha and mean cowpea yield was 93 kg/ha, with a range from 0 to 328 kg/ha. The best varieties are mostly determinate and semi-determinate types which are good for pure crop as well as for mixed crop. These data indicate good possibility of improving cowpea yield in mixed cropping by using improved varieties.

Table 1. Performance of cowpea varieties evaluated in All-Nigeria short duration trial - Kano 1990.

Variety	Yield kg/ha
IT86D-719	1784
IT86D-721	1743
IT86D-1010	1543
IT84S-2246-4	1461
IT86D-880	1127
I-59	1054
IT65D-3577	1000
LSD 5%	683
C.V. %	33

c) ***Dual Purpose Varieties.*** Commendable progress has been made in improving local cowpea varieties with respect to insect resistance. From crosses involving local varieties and IT84S-2246-4, several breeding lines have been developed which combine resistance to aphid, bruchid and thrips but look very similar to local varieties, both in plant and seed types. Preliminary data on grain and fodder yields of these varieties are presented in Table 4. Most of the varieties gave about 1 ton grain and 1 to 2 tons dry fodder, which is as good or better than the local varieties.

Table 2. Performance of cowpea varieties evaluated in all-Nigeria medium duration trial - Kano 1990.

Variety	Yield kg/ha
IT87D-1629	1620
Ife Brown	1557
IT86D-715	1542
IAR-48	1509
L-80	1398
IAR 11/48-2	1347
IT87D-1134	1345
K-28	1245
IT87S 1462	1188
12AK	1165
L-72	1026
K-39	964
IT86D-975	912
IT87S-1463	569
IT 133-4	531
IAR-48W	387
LSD 5 %	410
C.V. %	25

d) ***Varieties for Double Intercropping.*** In order to exploit the wide gaps left between the millet and cowpea rows under traditional intercropping systems, several early-maturing erect cowpea varieties were planted as an extra row in between intercropped millet-cowpea rows. The millet-to-millet rows were 2 m apart and within this gap one row of erect early cowpea variety and one row of local spreading cowpea variety were planted 50 cm away from the millet rows. Varieties IT86D-1055,

IT86D-880, IT82D-889 and IT84S-2246-4 yielded between 400-600 kg/ha grain yield without any insecticides and without significant effect on the yield of millet and traditional late cowpea variety. This was because the early-maturing cowpeas were harvested within 65 days when the local varieties had not even started flowering. The total 2 m gap was then covered by the local variety which looked similar to traditional intercropped plot. This cropping system has a good potential for increasing local cowpea productivity and needs more research attention.

Table 3. Mean millet and cowpea yields in different intercropped variety trials 1990 (no insecticide used).

		MEAN YIELD KG/HA			
Trial		Millet	Cowpea	Cowpea Range	Best varieties
Advance	1	700	81	10-195	IT86D-721, IT84S-2246-4
	2	800	97	0-247	IT87S-1423, IT87D-697-2
	3	644	98	0-244	IT88DM-361, IT88DA-398
	4	589	59	15-102	TVX1948-01F, IT88S-496-5
	5	731	90	0-216	IT88DM-352, IT88DM-398
	6	752	139	72-238	IT84S-2246-4, IT875-1399
	7	505	113	7-252	IT89KD-188, IT89KD-338
Prelim	1	606	69	0-134	IT88D-133-4, IT88KD908-5
	2	753	48	0-157	IT89KD-358, IT89KD-299
	3	726	158	66-226	IT88D-133-4, IT89KD-216
	4	589	126	11-328	IT88D-906-5, IT88D-911-3
	5	634	84	0-186	IT89K-434, IT89KD-260
	6	699	49	0-258	IT89KD-211, IT89KD-418
	7	631	84	0-193	IT82D-889, IT88D-77-2
Local Cowpea-		-	95	68-126	Kano Early
Local TVX3236		-	55	40-77	Ad 2, 3 5 6 7
Local IAR-48		-	85	37-142	PM-1, 2, 3, 5, 6, Ad-6
Means		672	93		
LSD		NS	71		
C.V. %		11	35		

Table 4. Grain and fodder yields of dual-purpose cowpea varieties.

Variety	Yield kg/ha		
	Grain	Fresh Fodder	Dry Fodder
		Prelim 2	
IT89KD-275	1306	4773	1443
IT88D-249-3	1120	7548	2442
IT89KD-260	955	3330	1199
IT89KD-245	761	6105	1776
IT89KD-355	977	3552	1110
IT89KD-288	847	4773	1332
Kananmado	254	2220	610
		Prelim 5	
IT89KD-275	1057	3496	2142
IT89KD-387	1004	5106	1165
IT89KD-299	765	3219	832
Kano local late	851	3330	1110
IT89KD-433	528	10656	2886

e) ***Resistance to Insect Pests.*** Systematic work on incorporation of resistance to aphid, bruchid and thrips has identified improved lines which combine resistance to all the pests mentioned. In addition, all the breeding lines included in advanced and preliminary trials were also evaluated without insecticide protection in pure crop at Kano, Samaru and Gumel. Most of these varieties did not give any grain yield at Samaru while yields were low at other locations due to combined damage by thrips, *Maruca* pod borer and pod bugs. However, such lines as IT88D-913-10, IT88D-345, IT89D-455 and IT89K-291 appeared quite promising and gave reasonable yield at all locations (Table 5). Cowpea varieties IT88KD-345 and IT89D-455 are spreading types and very early (55-60 days) in maturity.

f) ***Resistance to Diseases.*** All the improved breeding lines were screened for resistance to bacterial blight, *Septoria* and scab under natural infestation. Lines IT86D-782, IT85D-3850-1, IT81D-1228-14, IT81D-994, IT86D-1010, IT86D-719 and IT86D-715, IT86D-843 were highly resistant to bacterial blight and these are being used in breeding the programme. A number of cowpea lines were also found resistant to *Septoria* and scab as well as bacterial blight (Table 6). Breeding lines IT88S-T01-8, IT88D-345-2 and IT88D-584-1 appeared completely resistant to *Septoria* and scab under field conditions.

e) ***Resistance to Striga and Alectra.*** Through collaborative work with IRR, Samaru, commendable achievements have been recorded in breeding for resistance to *Striga* and *Alectra*. The genes for *Striga* and *Alectra* resistance from cowpea line B-301 were transferred to improved genetic background of IT84S-2246-4 such that

there are presently several advanced breeding lines which look similar to IT84S-2246-4 but which have combined resistance to *Striga, Alectra*, aphid, bruchid, thrips and over 10 diseases. While these lines are being evaluated, they are also being crossed with improved local types to develop a range of varieties with different plant types, maturity and seed types and combining resistance to *Striga, Alectra,* aphid, bruchid, thrips and multiple diseases.

Table 5. : Performance of some cowpea varieties with and without insecticide spray tested at three different locations in 1990.

	Yield kg/ha					
	Kano		Samaru		Gumel	
Activiry	Spray	no Spray	Spray	no Spray	Spray	no Spray
It88D-913-10	1081	485	1117	161	881	67
IT86D-721	1142	271	1219	9.1	553	509
IT88D-345	1447	497	1450	528.5	969	83
IAR-48	715	0	655	0.0	202	79
IT84S-2246-4	590	159	945	0.0	647	139
IT88D-377	589	458	671	0.0	593	113
IT89KD-455	1824	957	1154	46.0	340	279
IT88S-524-7	1034	239	1623	0.0	703	276
IT87D-1134	610	253	569	0.0	516	155
IT89K-291	642	217	972	123	607	199
Oveall mean	955.4	270.5	1162	48.0	587.1	199.8

Table 6. Cowpea varieties resistant to Septoria and scab diseases.

	Reaction to diseases*		
	Septoria	Scab	Bact. Blight
IT88S-501-8	1	1	1
IT88D-345-2	1	1	4
IT88D-345-4	1	1	4
IT88D-584-1	1	1	2
IT87D-555-6	2	2	3
IT87D-453-2	2	2	1
IT88S-524-7	2	2	1
IT89K-291	1	2	1
IT86D-1056	1	2	4
IT88D-962	1	2	2
VITA-7	1	2	
IT84S-2246-4	3	2	3
TVX-3236	4	1	2
IT87D-879-1	3	2	1
IT87D-885	2	2	1
IT87D-670-2	3	2	1
IT89KD-245	3	2	2
IT89KD-260	3	2	2
IAR-48	4	4	4

* 1 = Resistant; 2-3 = Moderately resistant; 4-5 = Highly susceptible

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Evaluation of Some Selected Cowpea Varieties for Grain and Fodder Potential.

G. ATUAHENE-AMANKWA and M.A. HOSSAIN.

IITA/GGDP Project, Kumasi, Ghana.

Abstract

The study reported was undertaken to evaluate 12 selected cowpea varieties for both grain and fodder production and to identify specific agronomic characters that could be used as criteria for selecting dual-purpose cowpeas. The experiment was conducted at Kwadaso, Ghana, in 1987 and 88. Data were recorded on grain yield, haulm weight, days to maturity, pod yield and dry shoot weight at flowering and maturity.

Results indicated that the varieties TVX 1948-10F, IT82D-927 and GH438-76-1 combined high grain and fodder (haulm) yields. Haulm weight showed positive correlation with days to maturity and dry shoot weight at both flowering and maturity. Grain yield was positively correlated with pod yield. However, no specific trait showed significant correlation with both grain and fodder yields, although it was evident that relatively long-duration varieties with high shoot weight at flowering and maturity may be of value in breeding for high fodder yield.

Introduction

In the savanna areas of Ghana and of West Africa in general, grain and fodder are both important factors in cowpea cultivation. Traditionally, after the harvest of the grains, farmers feed their livestock with the haulm (the entire plant less mature pods and roots). That cowpea fodder is a valuable nutritious feed is also reported in other places such as USA and India where it is appreciably used to supplement the nutritive value of non-leguminous fodder (Malik, 1953; Poehlman, 1959; Mishra *et al.*, 1985; Pandey and Ngarm, 1985). Generally, excellent grain-producing varieties tend to be poor producers of fodder (Poehlman, 1959). On the other extreme, varieties with excessive vegetative growth habit will tend to produce low grain.

In Ghana, research attention focuses largely on grain production of cowpea which includes its varietal improvement and crop management technologies. So far, no attention has been devoted to research on fodder production in spite of its importance as a livestock feed. With the increasing demand for fodder in the savanna areas of the country, cowpea fodder becomes economically important for livestock production in the dry periods of the year. This problem can be solved partially by developing varieties which can combine high grain yield as well as fodder. In developing such dual-purpose varieties, it is essential for one to look for agronomic traits that are associated with both characters.

This study was undertaken to evaluate the potential of some promising IITA and local cowpea varieties for both grain and fodder production in Ghana. A secondary

objective of the study was to determine the phenotypic correlation of grain and fodder with certain agronomic traits, including days to maturity, dry shoot weight at flowering and maturity and pod yield.

Materials and Methods

The experiment was conducted in the field at Kwadaso, Ghana, in the major season of 1987 and in the major and minor seasons of 1988. Planting dates were 14 May, 1987 and 20 May and 20 September, 1988 for the major and minor seasons, respectively. The cowpeas investigated consisted of eight IITA dual-purpose experimental varieties (grain and tender leaves for use in stew and soup), two recommended cowpea varieties (Boafo = TVX 1843-1C and Asontem = IT82E-32) and two experimental varieties selected on the basis of their grain and fodder yields (Legon Prolific and GH438-76-1). A randomised complete block design with four replications was used. Gross plot size consisted of four rows, 4 m long with 60 cm between rows. Plants were spaced 20 cm within rows. Two seeds were sown per hill and seedlings thinned to one plant per hill after plant establishment. The trial was given a pre-flowering spray with Cymbush 10EC at the rate of 50 g a.i/ha at 30 and 40 days after planting (DAP). A third spray was done using Thionex 35EC at 750 g a.i/ha at 50 DAP. Plants were hand weeded at 3 and 5 weeks after planting.

Data were recorded from the two central rows for days to maturity as well as for pod, grain and haulm yields. Harvested haulms were sun-dried for two days before determining their weights. To take data on dry shoot weights, seven plants were randomly removed from the outer rows at flowering and maturity. Dry shoot weight was estimated from the seven randomly selected plants, after being oven-dried to a constant weight at a temperature of 85° C for 4-5 days.

Both individual and combined analyses of variance were performed for each of the characters from the evaluations. Simple correlation coefficients were computed between grain/haulm yield and the other measured characters.

Results and Discussion

The combined analyses of variance based on a mixed model (varieties considered fixed and environments random) showed significant differences among varieties for all the six characters assessed, except dry shoot weight at flowering (Table 1), which was, however, significant against the error variance. This suggests that selection of desirable trait(s) and/or line(s) could be possible from these genotypes. The main effect of environment was significant in all cases, except for haulm weight. Significant variety x environment interactions were also noted for all characters except for dry shoot weight at maturity.

Table 1. Mean squares from ANOVA of six plant characters of 12 cowpea varieties evaluated for grain and fodder yields.

Source of variation	df	Days to maturity	Dry shoot wt. at flowering	Dry shoot wt. at at maturity	Pod yield (kg/ha)	Haulm yield(kg/ha)	Grain yield (kg/ha)
Environnments E	2	23.9**	3559**	1902**	$3.9 \times 10^{7**}$	$1.1 \times 10^{7**}$	$1.9 \times 10^{7**}$
Rep within (E)	9	3.3	62	504	$6.0 \times 10^{5**}$	$1.2 \times 10^{7**}$	$2.1 \times 10^{7**}$
Varieties (V)	11	382.4**	190	1177**	$2.2 \times 10^{6**}$	$7.3 \times 10^{7**}$	$1.1 \times 10^{7**}$
V x E	22	55.4**	130**	520	$7.8 \times 10^{7**}$	$2.8 \times 10^{7**}$	$3.4 \times 10^{7**}$
Error	99	1.7	55	355	1.2×10^{5}	3.3×10^{6}	4.9×10^{6}

*, ** = Significant at $p < 0.05$ and < 0.01

Mean values for grain yield and haulm weight, averaged over environments, are presented in Table 2 alongside average values from individual environments. In general, grain and fodder yields were highest during the major season of 1988, with means of 1.73 and 5.46 tons/ha, respectively. Mean grain yield of these varieties ranged from 0.55-1.60 tons/ha and no significant differences were noted among the top five grain producing entries, namely: TVx 1948-10F, IT82D-927, Asontem, GH438-76-1 and IT82D-789. Haulm weight was comparatively higher, ranging from 2.84 tons/ha for IT83S-880 to 10.32 tons/ha for TVX 4659-03E.

The relationship between mean grain yield and haulm weight is presented graphically in Fig. 1. Ideally, varieties with relatively high grain and fodder yields will be of much interest to the breeder. To select such genotypes, grand mean values for grain and haulm were employed as reference points. Consequently, the varieties were classified as follows: (i) varieties with high grain and fodder yields; (ii) varieties with low grain and high fodder yields; (iii) varieties with low grain and low fodder yields, and (iv) varieties with high grain and low fodder yields. Three entries showed higher levels of grain and haulm yields. These were IT 82D-927 which ranked second for both characters; TVX 1948-10F which ranked first for grain and fourth for haulm and finally GH438-76 which ranked fourth for grain and fifth for fodder. Therefore, these three varieties appeared to be promising for dual- purpose cultivation.

Table 2. Grain yield and haulm weight of 12 cowpea varieties evaluated at Kwadaso in three different environments (1987 and 88).

	Grain Yield (tons/ha)				Haulm Yield (tons/ha)			
Variety	S1	S2	S3	Mean	S1	S2	S3	S4
TVX 4659-03E	0.25	1.64	1.06	0.98	9.02	17.00	4.94	10.32
IT82D-789	0.38	2.03	1.33	1.25	3.81	3.18	5.63	4.20
IT83S-818	0.34	1.36	0.99	0.92	2.56	2.76	3.54	2.95
Asontem	0.54	2.41	1.15	1.36	2.63	2.50	4.33	3.15
GH438-76-1	0.54	2.02	1.40	1.32	5.84	3.76	5.70	5.10
Legon Prolific	0.57	1.23	0.75	0.85	6.41	9.87	4.60	6.96
IT83S-874	0.40	1.54	0.96	0.97	4.28	1.87	4.31	3.48
IT82D-927	0.47	2.45	1.55	1.49	7.78	13.00	4.77	8.52
TVX1948-10F	0.56	2.71	1.53	1.60	9.34	5.10	4.88	6.44
IT83S-880	0.26	0.66	0.72	0.55	3.63	1.69	3.20	2.84
Boafo	0.38	1.17	0.86	0.80	3.89	2.76	3.37	3.34
IT82D-875	0.65	1.49	1.06	1.06	3.66	1.90	5.29	3.62
Grand mean	0.44	1.73	1.11	1.09	5.24	5.46	4.55	5.08
LSD (.05)	0.25	0.75	0.49	0.49	3.19	3.25	2.90	3.16
CV %	39.7	15.8	18.3	20.3	16.5	41.0	45.1	36.1

S1 = Major Season 1987
S2 = Major Season 1988
S3 = Minor Season 1988

Mean values for four other agronomic characters are presented in Table 3. Days to maturity ranged from 65, recorded on three varieties (IT83S-818, IT82D-789 and Asontem) to 85 for Legon Prolific. The rest of the varieties matured in 68-76 days. The pattern of varietal ratings for dry shoot weight at flowering and dry shoot weight at maturity was quite similar. The former trait ranged from 17 g/plant for IT83S-880 to 37 g/plant for TVX 4659-03E while the latter ranged from 45 g/plant for IT83S-880 to 84 g/plant for TVX 4659-03E. The highest pod yield of 2.39 tons/ha was obtained from TVX 1948-01F while the lowest pod yield of 0.93 tons/ha was recorded with IT83S-880. In general, the trend of varietal ratings for pod yield was also similar to that for grain yield.

Results of correlation analyses are presented in Table 4. The results showed a significant positive correlation between grain yield and pod yield. A significant positive correlation between cowpea grain yield and pod yield had been reported by several authors, including Erskine and Khan, 1978, Tikka and Asawa, 1981; Aggarwal and Haley, 1987.

Hence, the use of a parameter such as pods/plant as an indirect selection criterion for increasing grain yield has often been recommended (Bapna *et al.*, 1972; Singh and Mehndiratta, 1969 and 1970). Grain and haulm yields were not significantly correlated. Haulm yield was significantly and positively correlated with days to maturity and dry shoot weights at flowering

Table 3. Means of days maturity, dry shoot weight at flowering and maturity, and pod yield of 12 cowpea varieties evaluated at Kwadaso during 1987 and 88.

Variety	DM	DSWF (g/plant)	DSWM (g/plant)	Pod Yield (ons/ha)
TVX 4659-03E	79	37	84	1.41
IT82D-789	65	24	63	1.79
IT83S-818	65	23	60	1.24
Asontem (IT82E-32)	65	20	60	2.11
GH438-76-1	70	21	69	1.83
Legon prolific	85	24	68	1.47
IT83S-874	67	21	55	1.47
IT82D-927	72	23	65	2.14
TVX 1948-01F	71	24	58	2.29
IT83S-880	67	17	45	0.93
Boafo (TVX1843-1C)	68	29	71	1.26
IT82D-875	68	21	52	1.68
Grand Mean	70	23	63	1.64
LSD 5 %	6.3	NS	19.3	0.74
CV %	1.9	32.0	30.2	21.4

DM = Days to maturity
DSWF = Dry shoot weight at flowering
DSWM = Dry shoot weight at maturity

Table 4. Simple correlation coefficients (r) among some characters of 12 cowpea varieties.

Correlated Characters	Seed Yield	Haulm Yield
Days to maturity	0.081	0.619*
Dry shoot wt. at flowering	0.042	0.602*
Dry shoot wt. at maturity	0.166	0.681*
Haulm yield	0.321	-
Pod yield	0.980**	0.301

and maturity. Since traits such as days to maturity and shoot weight at flowering and maturity are relatively easy to select, their use in formulating appropriate selection indices for effecting improvement of fodder yields of cowpea appears to be practical. These findings suggest that introduction of gene(s) for greater grain potential to a genotype with greater fodder potential background or vice-versa is essential for the development of a dual-purpose variety. However, it is evident from the study that both factors cannot be improved to the highest levels.

Conclusion

Three genotypes, TVX 1948-01F, IT82D-927 and GH438-76-1 have shown great promise for use as dual-purpose (grain and fodder) varieties. It is evident from the correlation analyses that long duration varieties with high shoot weight at flowering and maturity may be desirable in breeding for high fodder yield, but special efforts are needed to transfer gene(s) for high grain yield to this type of genotype in order to obtain the dual-purpose variety.

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Effect of Delayed Application of Phosphorus Fertilizer On Nodulation, Growth and Yield of Cowpea.

J.K. ADU.

Institute for Agricultural Research, Samaru, Ahmadu Bello University, Zaria, Nigeria.

Abstract

Field experiments were conducted in 1986, 88 and 89 under rainfed conditions to evaluate the influence of delaying the application of phosphorus fertilizer on nodulation, growth and yield of cowpea grown on a sandy loam soil at Samaru in the Northern Guinea savanna ecological zone of Nigeria. Phosphorus fertilizer was applied either at planting, at 2, 4, 6 or 8 weeks after planting or none applied.

Root development and nodulation appeared to be favoured by early application of phosphorus, although the effect was not consistent. However, grain yields were favoured by application at 4 WAP. Generally, except for the plots receiving no P, grain yield was not significantly affected by the delay in P application. Application at 4 WAP averaged over years resulted in the highest grain (1169 kg/ha) and haulm (1706 kg/ha) yields. The relative grain yields were 0.84, 0.87, 088, 0.70 and 0.56 for application at planting, 2 WAP, 6 WAP, 8 WAP and no-P application, respectively. Greater grain yield per plant and bigger sizes of seeds when P was applied at 4 WAP contributed to the increased yield. The delay periods x cultivars interaction was significant for most of the parameters. The significance of these results and the economic implications of the results to cowpea production in the savanna ecological zones of the West African sub-region are discussed.

Introduction

Phosphorus (P) deficiency is one of the important fertility problems limiting grain legume production in the tropics (Fox and Kang, 1977). Application of phosphorus fertilizer to legumes is, therefore, essential. Phosphorus is reported to stimulate root and plant growth, initiate nodule formation as well as influence the general efficiency of the *Rhizobium* - legume symbiosis (Robinson *et. al.*, 1981). It is also involved in reactions involving energy transfer, more specifically ATP in nitrogenase activity (Israel, 1987). Optimum supply of P early in the life of plants is essential for laying down the primordia for the reproductive parts, thus enhancing flowering, fruit and seed formation.

Cowpea (*Vigna unguiculata* (L.) Walp) is a major source of dietary protein in the West African sub-region. In Nigeria, 80% of the cowpea produced is grown mainly in the savanna zones of the country (Emechebe *et. al.*, 1988). Although most farmers in the region grow cowpea in mixture with cereals, sole crop cowpea cultivation is becoming popular. However, soils in this area are inherently low in nitrogen and phosphorus (Jones and Wild, 1975). This necessitates the application of P ferti-

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lizer to ensure proper plant growth and to maximise nitrogen fixation by the crop for eventual improved grain yields.

Kang and Nangju (1983) observed that plants supplied with low or no P gave stunted, slightly chlorofic, earlier flowering and maturing plants with smaller leaves and lower yields as compared to plants given high P.

However, a major problem facing farmers in the sub-region is unavailability of fertilizers at the beginning of the cropping season. Most farmers are, therefore, compelled to plant cowpea without the application of phosphorus or applying the fertilizer late. The present study was carried out to determine how long after planting farmers could apply P fertilizer without significant losses in grain yield.

Materials and Methods

The study was conducted in the 1986, 88 and 89 wet season on the Institute for Agricultural Research (IAR) experimental farm at Samaru (11'11'N 07'38'E, 686m above sea level), Nigeria. Samaru lies in the Northern Guinea savanna ecological zone with a long-term mean annual rainfall of about 1100mm concentrated almost entirely within the five-month period May to September. The soils at the experimental area are mainly sandy loam and classified as Typic Haplustlt in the U.S.D.A. System or Orthic Acrisol in the FAO System (Valette and Ibanga, 1984).

Trials in 1986 and 89 were conducted at the same site whilst a different field was used in 1988. The physico-chemical properties of the soils at the experimental sites were determined and the rainfall received during the period of the study was recorded (Table 1).

Two cultivars of cowpea (SAMPEA-1 and SAMPEA-7, both photo-insensitive) developed at IAR, Samaru, and with maturity periods of 75-90 days were grown. Two seeds were sown per hole on 7 July, 1986, 4 August, 1988 and 22 July, 1989 on ridges 75 cm apart and 20 cm intra-row spacing. Phosphorus (as single superphosphate) was applied at the rate of 23.8 kg P/ha either at planting (0-delay) or at 2, 4, 6 and 8 weeks after planting (WAP). A sixth treatment was included in which no P was applied throughout the life of the crop. Application at planting (0-delay) served as the control, that being the recommended practice for optimum agronomic grain yield. In each case, applications of P was done by side - dressing and the experiment was laid out in a randomized block design with three replicates. The size of each plot was 3.75 m x 6 m. A basal application of 20 kg k/ha as muriate of potash (60% k20) was supplied to all plots.

Sampling for assessment of nodulation and dry matter accumulation was carried out on randomly selected plants at 28, 42 and 63 days after planting (DAP). Plants were sprayed three times after flowering with 100 ml dimethoate (a.i. of 500 gha-1) and 30 g Benlate (0.6 kg/ha) in 20 l of water. Weeding was done manually as needed to keep the plots weed-free. Pods were picked at maturity on three occasions from 4 m of the three centre rows (9m_) of each plot for assessment of grain yield. Plants were cut at ground level after picking the pods in order to assess the yield of haulms.

Table 1. Physical and chemical properties of the soils and rainfall data of the experimental sites at Samaru, Nigeria.

Soil properties/months	**1986**	**1988**	**1989**
Clay (g/kg)	90	100	90
Silt (g/kg)	340	360	340
Sand (g/kg)	560	540	560
pH - H_20	5.1	5.4	5.2
Org. C. (g/kg)	6	4.9	6
Total N (g/kg)	0.42	0.52	0.42
Available P (mg/kg)			
(Bray P-I)	4.39	5.1	4.39
Exchangeable Cations (C.mol/kg)			
Ca			
Mg	1.78	1.44	1.78
K	0.71	0.49	0.71
	0.13	0.1+6	0.13
CEC (Cmol/kg)			
	4.72	4.25	4.72
Rainfall data (mm)			
January	0.0	0.0	0.0
February	0.0	3.5	0.0
March	0.0	0.0	0.0
April	5.8	34.6	15.0
May	59.1	84.4	113.0
June	82.0	133.2	124.4
July	293.6	181.5	154.6
August	322.1	402.5	170.4
September	205.7	192.3	118.3
October	0.0	114.7	52.9
November	0.0	0.0	0.0
December	0.0	0.0	0.0
Total	968.3	1156.7	748.6
Long term mean		1061	

Results

a) Nodulation. Results on nodulation are shown in Tables 2 and 3. Differences among periods of delay were significant for number of root nodules, except in 1986. In 1988, similar numbers of nodules were produced when P was either applied at planting, 4 WAP or at 8 WAP and these differed significantly from the other periods of delayed application. On the other hand, in 1989 application of P beyond 2 WAP resulted in reductions in the number of nodules. Cultivar SAMPEA-1 had significantly more nodules than SAMPEA-7 in all the years.

The period of delay x cultivar interaction was significant in 1986 and 88, but not in 1989. The periods of delay significantly influenced the dry weight of nodules in all the years (Table 2). Apart from the sporadic results obtained in 1986, the trend in nodule dry weight followed that of number of nodules obtained for 1989, except for the application of P at 8 WAP which improved nodule weight in 1988. Differences in dry weight of nodules between cultivars were obtained only in 1988 when SAMPEA-1 had significantly greater dry weight of nodules than SAMPEA-7.

The interaction between delay periods x cultivar was again significant in all the three years.

b) Shoot and Root Dry Weight. Dry weight of shoots sampled at different periods of plant growth was taken as an indication of growth (Tables 3 and 4). There was no significant interaction of delay period x cultivar for plants sampled at 28 DAP (pre-flowering) and only the main effects of treatments are shown (Table 3). Applied

Table 2. Interactive effects of period of delay in P application and cowpea cultivars on number and dry weight of root nodules at flowering.

Cultivar	Period of delay WAP[a]	Number of nodules/plant		Dry weights of nodules (mg/plant)		
		1986	1988	1986	1988	1989
	0	61.3b	65.7bc	215.8ab	471.7c	220.7a
	2	47.0bcde	54.0c	180.7bcd	661.7b	92.3c
SAMPEA-1	4	75.3a	74.3b	200.7abc	404.3cd	164.0b
	6	56.7bc	41.3d	197.0abc	306.0ef	67.7d
	8	52.7bcd	86.0a	97.5e	783.7a	61.0d
	Indefinite	52.7bcd	59.3c	234.2ab	256.7fgh	25.0e
	0	42.0cde46.	42.3d	148.5cde	476.0c	210.3a
	2	7bcde	30.0de	248.2a	176.0i	221.0a
SAMPEA-7	4	34.3e	38.0de	184.2bcd	200.3hi	102.0c
	6	38.7de	34.3de	215.5ab	351.3de	68.0d
	8	37.3e	27.0e	132.7de	274.7fg	27.0e
	Indefinite	47.3bcde	27.0e	195.5abc	215.0ghi	34.3e

[a]: Weeks after planting. Means within a column followed by similar letters are not significantly different from each other at 5% probability by DMRT.

Table 3. Effects of period of delay in P. application and cultivar on number of root nodules, shoot dry weight at 28 DAP and 100-seed weight

Treatments	Number of nodules/plant 1989	Shoot dry weight (g/plant) at 28 DAP[b]			100 seed weight (g) 1988
		1986	1988	1989	
Period of delay WAP[a]					
0	38.3	5.65	2.52	4.15	19.1
2	42.2	4.32	1.53	4.26	18.0
4	32.0	3.90	1.32	5.75	18.1
6	22.9	3.82	1.14	4.05	17.7
8	24.7	5.24	1.21	3.67	18.1
Indefinite	14.3	4.01	0.96	4.30	17.6
S.E. ±	1.40	0.37	0.81	0.31	0.39
L.S.D (P=0.05)	4.1	1.08	0.24	0.90	N.S
Cultivar					
SAMPEA-1	31.4	4.57	1.48	4.48	16.9
SAMPEA-7	26.5	4.41	1.41	4.25	19.3
S.E.±	0.81	0.21	0.05	0.18	0.23
L.S.D. (P=0.05)	2.4	N.S	N.S	N.S.	0.66

a: Weeks after planting
b: Days after planting
NS: Not significant at P=0.05

P at planting favoured dry matter production throughout the period of sampling in all the years, except at 63 DAP in 1986 and at 28 and 42 DAP in 1989 when the dry weight of shoots was enhanced by delaying the P application until 2 WAP and 4 WAP, respectively. In general, the absence of P resulted in the lowest shoot dry weight. However, the mean relative increase in the dry weight of shoots between 63 DAP and 28 DAP (excluding 1988) indicated that growth tended to be higher when application was delayed for 2 WAP and decreased with increasing period of delay beyond 4 WAP.

Differences between cultivars was significant only at 42 and 63 DAP in 1986 and 89, respectively. In all cases, SAMPEA-7 had higher dry weight of shoots. The interaction of period of delay x cultivar was significant at 42 DAP in 1988 and 42 and 63 DAP in both 1986 and 1989 (Table 4).

Application at planting favoured root growth at all sampling dates, except at 63 DAP in 1986 and at 42 DAP in 1989 when the highest root weight was observed on application of P at 2 WAP and 4 WAP, respectively (Table 5). SAMPEA-7 had higher root weight than SAMPEA-1 in 1986 and 89.

c) Grain and Haulm Yields. Grain yield was generally higher in 1988 compared to other years (Table 6). Delaying the application of P until 4 WAP resulted in the highest grain yield in 1986 and 89. Grain yield obtained from the control treatment in 1989 was the lowest and only similar to that obtained when no application was made. However, in 1988 only the application of P at 4 WAP gave comparable yields to the values obtained when P was applied at planting (which was the highest).

When results over the years were pooled, the maximum grain yield (1169 kg/ha) was achieved when P was delayed until 4 WAP. The relative yields followed the order: 4 WAP (1.00) 6 WAP (0.88) 2 WAP (0.87) application at planting (0.83) 8 WAP (0.71) indefinite delay (0.56).

The difference between cultivars was shown only in 1989 when SAMPEA-7 outyielded SAMPEA-1. The delay period x cultivar interaction was significant for all the years (Table 6). In 1986, yield of SAMPEA-1 was higher when P was applied at 4 WAP, but lower for SAMPEA-7 given similar treatments. The reverse was the case when P application was delayed until 6 WAP. In 1989, application of P to SAMPEA-1 at 4 WAP resulted in lower yields while similar treatment to SAMPEA-7 gave the highest yield.

In 1986, dry matter yield at harvest was highest when P application was delayed for 2 or 4 WAP and lowest for indefinite delay in P application (Table 6). However in 1988, application at planting was highest and only P application at 6 WAP resulted in comparable dry matter yield. In 1989, all treatments except application of P at 4 WAP resulted in lower production of dry matter at harvest (compared to application of P at planting). Cultivar SAMPEA-7 outyielded SAMPEA-1 in 1986 and 89 while the reverse was the case in 1988.

The interaction of delay period x cultivar was again significant for all the years.

d) ***Yield Components.*** Seed yield per plant was significantly reduced when P application was delayed beyond 4 WAP in 1986 (Table 7). In 1988, yield per plant was higher when P was either applied at 2 or 6 WAP while lower yields were obtained by applying P at planting, 4 WAP or beyond 6 WAP. Yield per plant in 1989 increased with increasing delay in P application until 6 WAP and indefinite delay had detrimental consequences. SAMPEA-7 outyielded SAMPEA-1 in 1988 and 89 but SAMPEA-1 outyielded SAMPEA-7 in 1986. There was significant interaction of delay in P application x cultivar for all the years (Table 7).

Table 4. Interactive effects of period of delay in P. application and cowpea cultivar on shoot dry weight (g/plant).

Cultivar	Period of delay WAP[a]	1986		1988	1989	
		42 DAP[b]	63 DAP	42 DAP	42 DAP	63 DAP
	0	14.6a	37.9e	11.2bc	15.2bcd	38.7c
	2	11.3bc	38.1e	12.7ab	11.9d	42.7c
SAMPEA-1	4	12.5b	36.4e	13.3ab	15.1bcd	26.7ef
	6	9.3d	33.5e	13.7a	13.9cd	19.4gh
	8	10.1cd	34.2e	11.9ab	18.1b	33.4d
	Indefinite	7.1e	15.5g	6.6e	15.3bcd	16.7h
	0	11.7bc	59.5c	12.8ab	14.8bcd	53.1a
	2	15.4a	70.9a	12.7ab	18.8bcd	28.8de
SAMPEA-7	4	11.9b	64.2b	12.3ab	26.4a	47.7b
	6	11.3bc	37.7e	11.0bc	12.2d	39.5c
	8	12.7b	54.8d	9.3cd	12.2d	25.8ef
	Indefinite	9.3d	27.9f	7.3de	13.7cd	23.1fg

a: Weeks after planting
b: Days after planting
Means within a column followed by similar letters are not significantly different from each other at 5% probability by DMRT.

Table 5. Effects of period of delay in P application and cowpea cultivar on root dry weight.

	1986			1988		1989		
Treatment	28 DAP	42 DAP	63 DAP	28 DAP	42 DAP	28 DAP	42 DAP	63 DAP
Period of delay WAP[a]								
0	1.23	1.43	4.23	1.28	1.21	0.96	2.13	4.66
2	1.07	1.20	5.86	0.70	0.70	1.03	2.26	4.03
4	0.89	1.20	4.66	0.70	0.70	0.80	2.74	5.09
6	0.91	0.99	3.84	0.89	1.04	0.86	2.06	4.00
8	1.17	1.04	5.02	0.93	0.93	0.68	1.35	4.37
Indefinite	0.94	0.97	3.30	0.60	0.99	0.75	1.32	2.91
L.S.D (0.05)	0.18	0.19	0.62	0.20	0.25	0.31	0.25	0.56
Cultivar								
SAMPEA-1	1.07	1.08	3.08	0.91	0.88	0.80	1.84	3.91
SAMPEA-7	1.00	2.00	5.89	0.80	0.98	0.89	2.11	4.44
S.E.	0.04	0.04	0.12	0.04	0.05	0.026	0.05	0.11
L.S.D. (0.05)		N.S.	0.11	0.36	N.S.	N.S.	0.08	0.14

a: Weeks after planting

Table 6. Interactive effects of period of delay in P application and cowpea cultivars on grain and dry matter yields at harvest.

Cultivar	Period of delay WAP[a]	Grain yield (kg/ha)			Dry matter yield (kg/ha)		
		1986	1988	1989	1986	1988	1989
SAMPEA-1	0	763de	1442ab	553fg	115e	2116a	1400c
	2	984b	1311b	811cde	1722c	1628bcd	1418c
	4	1321a	1307b	681ef	1171e	1645bc	1170d
	6	723de	1326b	869bcd	1549cd	1840b	873e
	8	726de	967c	922bc	1460cde	1375def	1314cd
	Indefinite	471f	729d	438g	708f	808h	517f
SAMPEA-7	0	814cd	1467a	743de	1704c	1419cde	1659b
	2	862bcd	1352ab	900bc	2586a	1142fg	1395c
	4	839bcd	1434ab	1433a	2830a	1400de	2020a
	6	911bc	1368ab	999b	1697c	1413cde	1440c
	8	748de	800d	800cde	2244b	1249ef	500f
	Indefinite	636e	800d	823cd	1280de	980gh	795e

a: Weeks after planting.

Means within a column followed by similar letters are not significantly different from each other at 5% probability by DMRT.

Individual seeds (100-seed wt.) were heavier when P application was delayed until 4 and 6 WAP in 1986 and until 2 and 4 WAP in 1989. In both years, applying P either at planting or delaying the application indefinitely resulted in smaller seeds. The delayed periods had no significant effect on seed size in 1988. SAMPEA-7 produced bigger seeds than SAMPEA-1 in all the years. The period of delay x cultivar interaction was significant in 1986 and 89, but not in 1988.

Discussion

Although cowpea is reported to be more tolerant to P stress than such legumes like soyabean, optimum yields are obtained when optimum P levels are applied (Cassman *et al.*, 1981). The data reported in the present study show the importance of applying phosphorus to cowpea at early stages of growth particularly for nodule development as well as vegetative and root growth. Application of P at planting does not always result in higher cowpea grain or haulm yields. The higher grain yields obtained by delaying P application until 2 to 6 WAP was probably due to the higher average grain yield/plant and bigger seeds as compared to when P was applied at planting. Since phosphorus plays a vital role in reactions involving energy transfer, it stands to reason that plants like cowpea which are dependent on fixed nitrogen for growth, may require high levels of P (Israel, 1987).

Table 7. Interactive effects of period of delay in P application and cowpea cultivar on yield components.

Cultivar	Period of delay WAP[a]	Grain yield (g/plant)			100-seed weight (g)	
		1986	1988	1989	1986	1989
	0	13.6b	21.1cde	15.5efg	14.0e	16.5cd
	2	14.8ab	27.1c	18.0de	14.8cde	16.8cd
SAMPEA-1	4	15.4a	19.8e	17.2def	17.0a	16.4d
	6	8.7de	27.1c	17.3def	16.0ab	16.3d
	8	8.5de	22.5de	17.8de	14.8de	16.2d
	Indefinite	7.2de	20.1e	13.5g	14.0e	16.7cd
	0	11.8c	34.5b	19.2cd	15.0bcde	17.3bcd
	2	10.5c	36.0ab	20.6c	15.5bcd	19.7a
SAMPEA-7	4	8.8d	31.7b	34.9a	15.1bcd	19.4a
	6	11.8c	39.3a	37.2a	15.8bc	17.7bc
	8	8.5de	25.1cd	32.4b	15.3bcd	18.5ab
	Indefinite	7.1de	22.1de	14.8fg	14.6de	17.3bcd

a: Weeks after planting.
Means within a column followed by similar letters are not significantly different from each other at 5% probability by DMRT.

Nitrogen fixation is normally at its optimum at between flowering to early pod-fill which period coincides with the energy transfer for the development of reproductive parts and seed formation - hence the demand for high P levels. Phosphorus applied at either 4 WAP (closer to the flowering period) or 6 WAP (flowering stage) is likely to become more effectively utilized for seed formation than when application is made earlier at planting. From the data presented, it is clear that yield was better when P application was made at 8 WAP than when nothing was applied. But considereing that the cowpeas investigated matured in 75-90 days, it may not be advisable to suggest that application of P be made later than 6 WAP.

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The Role of "Guided" Spraying in the Management of Cowpea Insect Pests.

JAKPASU V.K. AFUN.

Crops Research Institute, Kumasi, Ghana.

Abstract

A comparison was made between calendar and "guided" spraying to assess their effect on cowpea insect pest populations and on grain yield. The study also aimed at determing which of the two spraying regimes would require less number of sprays. Whereas the "guided" sprays were applied when an action threshold (ATh) had been reached based on monitoring the pest infestation and/or damage in the crop, the calendar sprays were made at specified (scheduled) days after planting. The trials were carried out at three locations in Ibadan (Forest transition), Mokwa and Bida (both in the Southern Guinea savanna).

The two calendar spray regimes tested (7 and 10 - day intervals) had no significant effect on the number of insect pests nor on cowpea grain yield. The "guided" spraying regime required 50% fewer sprays than calendar spraying, thus making it an attractive management practice for the control of cowpea insect pests.

Introduction

Insecticides play an important role in every viable cowpea production enterprise and shall continue to do so until adequate levels of resistance are found against the large number of insect pests that attack the crop. Without insecticide protection, cowpeas yield only between 12 to 20% of their grain potential. However, insecticide protection cost constitutes a large portion of the production cost. This high protection cost is attributed, among other factors, to the calendar spraying technique, which is the more widely used (Booker, 1965; Raheja, 1976), even though insects show spatial and temporal variations in their incidence and status and when there is an overlap of some of the pests.

Stern et al. (1959) introduced the concept of "economic threshold" (ET), which was modified by Pedigo *et al.* (1986) to guide farmers in applying insecticides only when necessary. In the present study, the term "action threshold" (ATh) (Cancelado & Radcliffe, 1979) is used instead of ET to mean the infestation/damage level at which insecticide would need to be applied to prevent the pest from reaching economic damage levels. The action threshold for the various cowpea insect pests considered during the study had been established earlier as shown in Table 1. The work reported investigated the use of the various action thresholds to compare the guided with calendar spraying for the control of cowpea insect pests and their effect on grain yield.

Table 1. Action thresholds of important field insect pests of cowpea in Ghana.

Pest	Action threshold	Author(s)
A. *craccivora*	A few scattered colonies of four or more individuals per colony, or a score of 3 on a 0-9 scale.	Jackai & Singh (1988).
M. *sjostedti*	3 thrips per receme, or a score of 3 on a 1-9 scale, the initiation of drying and browning of stipules and calyces of flower buds.	Jackai & Singh (1988) ; Salifu (1986)
M. *testulalis*	40 % flower infestation/damage	Jackai (195) ; Li-dao (1985)
Pod *sucking bugs*	2 bugs/metre	Atropo (1983)

Materials and Methods

The trials were carried out at three locations in Nigeria representing two ecological zones: Ibadan for the Forest transisition zone, during the second cropping season from September to November, 1987; Mokwa for the Southern Guinea zone during the main cropping season from August to October 1987, and at Bida (also in Southern Guinea using a rice fallow from December 1987 to March 1988).

Each trial was a two-factor factorial arrangement (insecticide regime and cowpea variety) fitted to a randomized complete block design with four or five replications.

a) *Insecticide Regimes.* Four insecticide regimes were tested as follows:

Unsprayed (no insecticide protection)
Four calendar sprays; applied at intervals of 10 days starting at 25 days after planting (DAP)
Five calendar sprays; at seven-day intervals starting at 25 DAP
Guided insecticide application - sprayed only when the observed infestation/damage reached or exceeded the action threshold earlier established (Table 1). Monitoring was done at intervals of five or six days.

An Electrodyn formulation consisting of a mixture of lambda cyhalothrin and dimethoate (Karate Super-ED) (R) (17 + 35 g.a.i./ha) was used to investigate the insecticide regimes. The application rate was approximately 0.61 l/ha, equivalent to about 10 g.a.i. cyhalothrin and 21 g.a.i. dimethoate per hectare.

b) *Cowpea Varieties.* Two varieties were used at each site: IT84S-2246 and TVx 3236 at Ibadan and Mokwa and IT84S-2246 and Vita 7 at Bida. Variety IT84S-2246 is erect, determinate and matures in about 65 days. It is resistant to aphids and storage bruchids and moderately resistant to flower thrips and matures within 70-75 days. Vita 7 is semi-erect, determinate and matures in 75-85 days with no known pest resistance.

c) *Monitoring Insect Infestation/Damage.* The treatment effects were assessed in relation to the control of four major groups of insect pests: cowpea aphids, flower thrips, pod borers and pod sucking bugs. A scoring system was used for aphids and thrips as described by Jackai & Singh, 1988. *Maruca* pod borer was assessed as percent flower infestation/damage while pod sucking bugs were estimated as number per metre row or crop.

Results and Discussion

Ibadan. There was no guided spray against aphids at Ibadan, since the populations did not exceed the action threshold. Flower thrips reached the action threshold two times (40 and 48 DAP) on IT84S-2246 and once (48 DAP) on TVx 3236 and were sprayed. Maruca population reached the action threshold once on both varieties at 48 DAP, that is on the day that thrips also needed to be controlled. Therefore, both the *Maruca* and thrips were controlled with the same spray. Pod sucking bugs did not require any chemical intervention to keep their populations below economic damage levels. Therefore, at Ibadan, a total of two sprays were applied to IT82S-2246 while TVx 3236 was sprayed only once (Table 2).

Mokwa. A total of two sprays each were applied to both varieties and directed at *Maruca* and pod sucking bugs (Table 2). Calendar sprays applied earlier than 45 DAP were, therefore, not really necessary at this location, since aphids and flower thrip infestation did not reach the action threshold.

Bida. The important pests on the dry season rice fallow cowpea at Bida included the foliage thrips *Caliothrups impurus*, aphids and flower thrips. The crop had to be sprayed at 15 DAP to control a massive invasion by *C. impurus*. The unsprayed treatments were decimated by the foliage thrips, since they were not sprayed. The calendar treatments would also have been damaged but for the spray at 15 DAP. Foliage thrips had to be controlled again on IT84S-2246 at 46 DAP. Aphids did not attack IT84S-2246 but did Vita 7 and needed two sprays at 46 and 56 DAP to keep them below the action threshold. Crop growth was very slow (due to low soil PH, about 3.9) and matured at 100 DAP. Flower thrips reached the action threshold on IT84S-2246 and were controlled at 71 DAP. *Maruca* did not infest the crop at Bida while pod sucking bugs were well below the action threshold.

Table 2. Distribution of guided sprays on two cowpea varieties at three locations in Nigeria and the pests controlled (August 1987-March 1988).

Location	Variety	Spray n°	DAP	Target	N° of sprays applied
	IT84S-2246	1	40	*M. sjostedti*	2
		2	48	*M. sjostedti* + *Maruca*	
Ibadan	TVx 3236	1	48	*M. sjostedti* + *Maruca*	1
	IT84S-2246	1	45	*Maruca*	2
Mokwa		2	55	Pod sucking bugs	
	ITx 3236	1	49	*Maruca*	2
		2	63	Pod sucking bugs	
	IT84S-2246	1	15	*C. impurus*	
		2	46	*C. impurus*	
		3	71	*M. sjostedti*	3
Bida	Vita 7	1	15	*C. impurus*	
		2	46	*A. craccivora*	
		3	56	*A. craccivora*	3

The calendar schedules ended by 56 DAP when the crop had still not flowered. Had Maruca and pod sucking bugs infested the crop, the calendar plots could have been wiped out.

Grain Yield. The unsprayed plots gave significantly lower yields than sprayed plots at all the locations. At Ibadan and Mokwa, yields from the guided treatment (2 sprays) and the calendar schedules (4 and 5 sprays) did not differ significantly. At Bida, the guided spraying (3 applications) gave the highest yield with the calendar schedules (5-6 sprays) lying between the guided and unsprayed treatments (Table 3).

Conclusion

Chemical pest control shall continue to play an important role in cowpea production until and unless suitably resistant varieties are developed. Resistance to one or two field pests only was not enough to eliminate all together insecticide protection. Even though, IT84S-2246 was aphid resistant with moderate resistance to thrips, it still needed to be protected against *Maruca* and pod sucking bugs at some of the locations. The two calendar schedules did not differ significantly in their effects on insect infestation/damage and on grain yield. The final grain yield between guided and calendar programme did not differ significantly. This implies that large num-

bers of insecticide applications *per se* are not the key factor in pest control, but, rather, the necessity and timeliness of the sprays.

Table 3. Effect of four insecticide regimes on cowpea yield at three locations in Nigeria (1988).

Insecticide Regime	Yield (kg/ha) Ibadan	Mokwa	Bida
Control (No spray)	8 b	335 b	166 c
10-day interval spraying 1	397 a	1827 a	480 b
7-day interval spraying 2	425 a	1834 a	588 ab
Guided spraying 3	440 a	1670 a	676 a
Mean	371.4	1416.5	477.6
S.E. (+)	26.8	31.7	58.9
C.V. (%)	23.9	16.5	39.4
n	4	5	4

1) Four sprays at Ibadan and Mokwa but five at Bida
2) Five sprays at Ibadan and Mokwa but six at Bida
3) Two sprays at Ibadan and Mokwa but three at Bida.

Means within the same column followed by the same letter do not differ at P = 0.05. (Duncan's multiple range test).

Guided spraying reduced the number of calendar sprays by about half. For large-scale cowpea production, this is likely to represent enormous savings on production costs.

Fears have been expressed about the feasibility of the guided spraying technology on farmers' fields. It appears such fears are unfounded as farmers are prepared to acquire new techniques which they grasp faster than generally believed. It is, therefore, necessary to put in the required time and extension effort towards promoting guided spraying for insect pest management in cowpea.

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Comparaison des méthodes de traitement phytosanitaires de niébé au Niger.

GERMAINE IBRO, J. LOWENBERG-DEBOER, K.C. REDDY et MALIKI KADI.

INRAN, Niamey, Niger.

Résumé

Les dégâts causés sur le niébé par des insectes constituent une contrainte majeure à la production du niébé. Le présent rapport examine la rentabilité agronomique et économique du traitement phytosanitaire préconisé en l'absence de variétés résistantes. Les essais, conduits en milieu paysan, montrent que le traitement phytosanitaire a un effet positif sur les rendements de grain mais qu'il n'y a pas de différence d'efficacité des appareils ou produits chimiques utilisés, ni de différence sensible entre traitement unique ou double traitement. L'analyse économique suggère l'on n'exclut pas l'utilisation d'un second traitement, 10-15 jours après le premier, si les conditions pluviométriques sont favorables aux insectes nuisibles.

Introduction

Les dégâts causés sur le niébé par des insectes, tels que les pucerons, les thrips de fleurs, les suceuses et les foreuses des gousses, constituent une des principales contraintes àl'augmentation de la production de niébé. (Maïga et Issa, 1988). En l'absence de techniques culturales ou de variétés résistantes aux insectes ravageurs, la lutte chimique est préconisée dans les stratégies d'amélioration de la production du niébé (Reddy *et al.*, 1990).

Pour la production des grains de niébé au moins deux traitements phytosanitaires sont préconisés (Reddy et al., 1990). Si l'agriculteur s'intéresse uniquement aux fanes, le traitement phytosanitaire n'est pas très important car les dégâts des insectes réduisent surtout le rendement en grain. Dans beaucoup de villages du Niger, il y a des brigades villageoises qui ont été formées par les agents du Ministère de l'Agriculture dans le domaine des traitements phytosanitaires et qui ont des appareils de traitement pour l'utilisation de tous les paysans du village (Rep. du Niger, 1989). Donc actuellement dans certains cas les produits phytosanitaires et l'appareil de traitement sont fournis par le gouvernement ou des bailleurs de fonds gratuitement. Dans d'autres cas les paysans paient une partie des charges, soit le produit phytosanitaire, soit l'essence ou les piles pour faire marcher l'appareil de traitement. A l'avenir, la partie payée par le paysan devrait augmenter ; par conséquent, l'efficacité et la rentabilité des traitements seront plus importantes pour le paysan.

L'objectif de ce rapport est de faire une évaluation de la performance agronomique et économique de trois appareils de traitement et de deux doses d'insecticide sur la production du niébé en culture pure.

Méthodologie.

Cette étude est basée surtout sur des données collectées par l'INRAN pendant quatre années d'expérimentation en milieu paysan. Les essais ont été conduits à Kouka dans l'arrondissement de Filingué (1988, 1989), dans le département de Maradi à Maiguèro (1986-1989), Kodarogo (1986, 1987), Tchizon-Kourégué (1986, 1987), et Lili (1986, 1987). Dès le début, l'étude a cerné les aspects agronomiques et économiques, donc l'essai a été fait par le Département de Recherches Agricoles (DRA) en collaboration avec le projet de Développement Rural de Maradi. Les villages de Kouka et de Maiguéro sont des sites d'intervention du DECOR et par conséquent il y a beaucoup d'informations disponibles sur ces villages qui peuvent servir de base pour une analyse économique. La méthodologie est détaillée par Ibro *et al* (1991).

Le protocole d'éssai agronomique a changé légèrement pendant les années d'essai. Au cours des campagnes de 1987, 1988 et 1989, il y avait 7 traitements. Tous les traitements, y compris le témoin, ont été semés en culture pure avec la TN-5-78 et ils ont tous reçu du phosphate super simple à raison de 100 kg/ha. Les traitements phytosanitaires, outre le témoin absolu, sont obtenus par une combinaison d'appareil de traitement (electrodyne, fontan ou ULV), de produit phytosanitaire (cymbush ou décis) et de fréquence de traitement (une fois en début floraison ou deux fois, la seconde intervenant 10-15 j après la première).

Notons que le dispositif utilisé ne nous permet pas de séparer l'effet du produit de celui de l'appareil. Le cymbush est utilisé seulement avec l'électrodyne, le décis avec l'ULV et le fontan mais pas avec l'électrodyne. La situation est rendue encore plus compliquée par le fait que le cymbush est un insecticide systémique, mais le décis est un insecticide qui tue par contact. Donc, dans l'analyse il faut prendre l'appareil et le produit comme une unité.

Le dispositif bloc aléatoire complet a été utilisé. L'essai a été fait en 4 répétitions sur des parcelles élémentaires de 200 m2. Le semis a été fait après la deuxième pluie utile. La densité a été de 60 cm entre les lignes et 30 cm entre les poquets, soit 55.555 poquets par ha. Un sarclage et un démarriage à 2 plants par poquet, deux semaines après le semis ont été prévus. La récolte des gousses a été faite au fur et à mesure qu'elles mûrissaient.

Résultats et Discussion.

Les Rendements. En général les essais montrent que le traitement phytosanitaire a un effet important sur les rendements en grain, mais qu'il n'y a pas de grande différence entre l'efficacité des appareils ou produits, de même la différence des rendements avec un ou deux traitements n'est pas significative (Tableaux 1 - 3).

Plus précisément, les rendements avec traitement phytosanitaire sont presque toujours plus élevés que sans traitement, et dans la moitié des cas l'augmentation de rendement due au traitement est significative au seuil de 5 % dans les contrastes. Cependant, les rendements sur les parcelles traitées une fois, et celles qui ont été traitées deux fois diffèrent rarement, les différences n'ayant été significatives au

seuil de 5% qu'une seule fois, dans la localité de Tchizon en 1987. De même, il n'y a pas de difference systématique liée à l'appareil. Dans deux cas (à Kouka en 1989 et à Maiguéro en 1988) les parcelles avec le fontan ont donné significativement moins que les autres et dans un cas, (à Kouka en 1989) les parcelles avec l'électrodyne ont donné significativement plus que celle avec l'ULV.

Tableau 1. Rendements du niébé en grain, de 1986 à 1988, par nombre et type de traitement phytosanitaire[1].

Village et année	Traitements[2] 1	2	3	4	5	6	7
	Kg/ha						
Kodarogo							
1986	886b	1008ab	1073ab	-	1175a	1169a	-
1987	419b	548ab	594a	566ab	563ab	663a	613a
Lili							
1986	1006	1131a	1235a	-	10338a	1275a	-
1987	213b	344a	316ab	313ab	331ab	303ab	300ab
Maiguéro							
1986	1293a	1519a	1420a	-	1544a	1430a	-
1987	175b	344ab	238b	368ab	550a	318ab	326ab
1988	831ab	944ab	767a	1099ab	963ab	856ab	1157a
1989	622ab	673ab	669ab	605ab	762a	562b	625ab
Tchizon-Kourégué							
1986	486c	1126ab	1012b	-	1392a	1157ab	-
1987	43c	100b	93b	104b	166a	156a	155a
Kouka							
1986	711b	1044a	848ab	804ab	1039a	980ab	939ab
1987	251c	409abc	288c	588a	348abc	308bc	550ab

1) L'analyse de variance a été faite par campagne et par produit. Donc, pour une année et un produit donné, les rendements portant des lettres différentes sont significativement différents au seuil de 5 % avec le test de Duncan.

2) Les traitements sont les suivants : 1) témoin, pas de traitement phytosanitaire, 2) un traitement au début de floraison à l'appareil électrodyne au cymbush à raison de 0,55 l/ha, 4) un traitement au début de floraison à l'appareil fontan au decis àraison de 1 l/ha, 4) un traitement au début de floraison àl'appareil ULV au décis à raison de 1 l/ha, 5) traité deux fois, au début de floraison et 10 à 15 jours plus tard à l'appareil

électrodyne au cymbush à raison de 0,55 l/ha chaque fois, 6) traité deux fois, au début de floraison et 10 à 15 jours plus tard à l'appareil fontan au décis à raison de 1 l/ha chaque fois, 7) traité deux fois, au début de floraison et 10 à 15 jours plus tard à l'appareil ULV au décis à raison de 1 l/ha chaque fois. Tous les traitements, y compris le témoin, ont été semés avec la variété TN-5-78 et ont reçu 100 kg/ha de SSP. En 1986 les traitements 4 et 7, comprenant l'appareil ULV, n'étaient pas dans le protocole.

Tableau 2. Contrastes orthogonaux pour le nombre et type de traitement phytosanitaire, grain de niébé à Maiguéro et Kouka 1988 et 1989.

	1988		1989	
Contraste	F	Prob	F	Prob
Maiguéro				
Témoin contre les autres (1)	1.49	0.2386	0.20	0.6606
1 ou 2 fois (2)	0.45	0.5111	0.00	0.9915
Electrodyne contre (3) ULV	3.00	0.1005	3.25	0.0884
Fontan contre les autres (4)	6.84	0.0175	1.08	0.3131
Kouka				
Témoin contre les autres (1)	5.48	0.0309	4.07	0.0588
1 ou 2 fois (2)	1.37	0.2570	0.18	0.6748
Electrodyne contre '3) ULV	3.45	0.0796	6.34	0.0215
Fontan contre les autres (4)	0.29	0.5963	7.26	0.0148

1) Les coefficients du contraste " témoin contre les autres " ont été les suivants : 6 -1 -1 -1 -1 -1 -1.

2) Les coéfficients du contraste " 1 ou 2 fois " ont été les suivants: 0 1 1 1 -1 -1 -1.

3) Les coefficients du contraste " électrodyne contre ulv " ont été les suivants : 0 1 0 -1 1 0 -1.

4) Les coéfficients du contraste " fontan contre les autres " ont été : 0 1 -2 1 1 -2 1.

Tableau 3. Contrastes orthogonaux pour le nombre et type de traitement phytosanitaire, grain de niébé à Maradi, 1986 et 1987.

	1986		1987	
Village et contraste	F	Prob.	F	Prob.
Kodorogo				
Témoin contre les autres (1)	10.63	0.0068	9.75	0.0059
1 ou 2 fois (2)	4.74	0.0503	1.08	0.3120
Electrodyne contre ulv (3)	-	-	0.45	0.5090
Fontan contre les autres (4)	0.24	0.6308	1.60	0.2216
Lili				
Témoin contre les autres (1)	2.61	0.1319	6.79	0.0179
1 ou 2 fois (2)	0.09	0.7744	0.17	0.6870
Electrodyne contre ulv (3)	-	-	0.70	0.4142
Fontan contre les autres (4)	3.55	0.0841	0.15	0.7040
Maiguéro				
Témoin contre les autres (1)	2.98	0.1102	3.95	0.0624
1 ou 2 fois (2)	0.03	0.8552	1.38	0.2554
Electrodyne contre ulv (3)	-	-	1.39	0.2535
Fontan contre les autres (4)	1.24	0.2880	2.62	0.1229
Tchizon-Kourégué				
Témoin contre les autres (1)	35.15	0.0001	58.79	0.0001
1 ou 2 fois (2)	3.95	0.0703	51.12	0.0001
Electrodyne contre ulv (3)	-	-	0.11	0.7394
Fontan contre les autres (4)	2.85	0.1170	0.56	0.4648

1) Les coefficients du contraste " témoin contre les autres " ont été 4 -1 -1 -1 pour 1986 et 6 -1 -1 -1 -1 -1 -1 pour 1987.

2) Les coefficients du contraste " 1 ou 2 fois " ont été 0 1 1 -1 -1 pour 1986 et 0 1 1 1 -1 -1 -1 pour 1987.

3) Les coéfficients du contraste " électrodyne contre ulv " ont été 0 1 0 -1 1 0 -1 pour 1987. L'appareil ULV n'a pas été testé en 1986.

4) Les coefficients du contraste " fontan contre les autres " ont été 0 1 -1 1 -1 pour 1986 et 0 1 -2 1 1 -2 1 pour 1987. Pour 1987 les contrastes sont effectivement le fontan contre l'électrodyne.

Compte tenu des problèmes liés aux essais en milieu paysan (variabilité de sols, difficulté de supervision, etc.) le fait que la moitié des essais montre un effet de traitement phytosanitaire significatif indique que ces traitements pourraient avoir un effet important et relativement consistant sur les rendements. Le choix des appareils et des produits testés semble avoir peu d'importance sur le rendement, donc ils peuvent être choisis sur la base du coût.

La Rentabilité Economique du Traitement. L'analyse de la rentabilité du traitement phytosanitaire se limite aux changements de coût et de revenu liés directement au traitement de la culture de niébé pur. Le calcul de revenu utilise les prix moyens du marché en Octobre, car c'est la période de l'année où le niébé est récolté et souvent vendu par les paysans. Les prix sont estimés à partir des données collectées dans les marchés locaux de la zone de Maradi et de la région de Filingué. Les coûts des produits phytosanitaires ont été calculés à partir des prix de la Centrale d'Approvisionnement pour l'année de l'essai.

La rentabilité est examinée selon trois perspectives : le revenu monétaire, le revenu net et le taux de rémunération. Le revenu monétaire est calculé comme le revenu brut moins les coûts monétaires, les produits phytosanitaires et les piles ou l'essence. Le revenu net est calculé comme le revenu monétaire moins le coût d'opportunité de la main d'oeuvre familiale (estimée à 700 FCFA/jour). Le taux de rémunération est calculé comme le revenu net divisé par la somme des coûts.

Tableau 4. Les traitements ayant le revenu monétaire maximum, le revenu net maximum, et le taux de rémunération maximum (1).

Village et année	Revenu monétaire	Revenu net	Taux de rémunération
Kouka, 1988	Elect. 1 fois	Elect. 1 fois	Elect. 1 fois
Kouka, 1989	ULV 1 fois	ULV 1 fois	ULV 1 fois
Kodarogo, 1986	Elect. 2 fois	Elect. 2 fois	Elect. 2 fois
Kodarogo, 1987	Fontan 2 fois	Fontan 2 fois	Elect. 1 fois
Lili, 1986	Fontan 2 fois	Fontan 2 fois	Fontan 1 fois
Lili, 1987	Elect. 1 fois	Elect. 1 fois	Elect. 1 fois
Maiguéro, 1986	Elect. 2 fois	Elect. 2 fois	Elect. 2 fois
Maiguéro, 1987	Elect. 2 fois	Elect. 2 fois	Elect. 2 fois
Maiguéro, 1988	ULV 2 fois	ULV 2 fois	ULV 1 fois
Maiguéro, 1989	Elect. 2 fois	Elect. 2 fois	Elect. 2 fois
Tchizon, 1986	Elect. 2 fois	Elect. 2 fois	Elect. 1 fois
Tchizon, 1987	Elect. 2 fois	Elect. 2 fois	Elect. 2 fois

1) Voir (Ibro *et al*, 1991) pour le calcul du revenu monétaire, du revenu net et du taux de rémunération.

A Kouka les essais suggèrent qu'un seul traitement phytosanitaire au début de la floraison est d'habitude l'approche la plus rentable parmi les alternatives testées (Tableau 4). Mais il faut noter que cette conclusion est tirée de deux années de données seulement et qu'il y a des approches qui n'ont pas été testées. Par exemple, au lieu de faire le même traitement chaque année, on peut penser à adapter ce traitement à la campagne. Si on peut identifier dans quelles conditions le deuxième traitement est rentable, on peut faire le deuxième traitement quand il est probable qu'il soit rentable. On peut envisager des règles qui recommandent ce deuxième traitement seulement si la pluviométrie et autres facteurs sont favorables aux développements des insectes nuisibles.

Dans la zone de Maradi (Kodarogo, Lili, Maiguéro, Tchizon), les résultats montrent que dans beaucoup de cas deux traitements sont rentables, mais la rentabilité du deuxième traitement est très variable (Tableau 4). Dans la moitié des cas, le taux de rémunération du deuxième traitement a été inférieur à 40 %, seuil de référence selon Perrin *et al.*, (1976). Le premier traitement est presque toujours rentable. Comme àKouka pour améliorer la rentabilité du deuxième traitement, on peut envisager des approches qui limitent ce traitement au cas où les conditions sont favorables aux insectes nuisibles.

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Identification of Cowpea Diseases and Evaluation of Selected Cowpea Varieties to Brown Blotch and Web-blight Diseases in the Forest Ecology of Ghana.

J.K. TWUMASI and M.A. HOSSAIN.

Crops Research Institute
and
IITA/GGDP Project, Kumasi, Ghana.

Abstract

Sixty-two exotic and local cowpea varieties were tested under natural field infection for their natural resistance to fungal diseases in 1989 at Fumesua in the Rain Forest and Ejura in the Forest-Savanna transitional ecologies of Ghana. Of these, 31.0, 48.0 and 21.0% were found to be resistant, moderately resistant, and very susceptible to more than one disease in the Rain Forest ecology while 36.0, 45.0 and 19.0% were resistant, moderately resistant and very susceptible to more than one disease in the Forest-Savanna transitional ecology, respectively. The most important diseases in both ecologies were brown blotch and web-blight, followed by Fusarium wilt/blight, target spot and anthracnose. Other diseases of lesser importance were lamb's tail pot rot, wilt, blight or basal stem rot caused by *Macrophomina phaseolina*, and leaf spots or other blights caused by various fungi.

Seedlings of 33 cowpea varieties which showed apparent multiple disease resistance at Fumesua in 1988 were artificially inoculated in the field in 1989 with *Colletotrichum truncatum* and *Rhizoctonia solani*, the causal agents of brown blotch and web-blight, respectively. It was observed that 73.0% were resistant, 21.0% moderately resistant, and 6.0% susceptible to brown blotch while 70.0% were resistant, 21.0% were moderately resistant, and 9.0% were susceptible to web-blight. It was evident from the study that these germplasm maintained high level of resistance for one or more diseases which might be of economic importance in developing resistant varieties and reducing cost of production in cowpea.

Introduction

Cowpea *(Vigna unguiculata* (L.) Walp) is one of the major sources of plant protein. It has a protein content of 20-25%. Although the bulk of its production comes from Africa, the West African grain yields are reportedly among the lowest (Dovlo *et. al.*, 1976). In Ghana, the average national yield of cowpea was also reported as low as 100 kg/ha (Hossain and Atuahene-Amankwa, 1987). These low yields in West African countries are partly due to diseases (Emechebe and Soyinka, 1985; Williams, 1975).

In Ghana, cowpea is traditionally grown as a mixed crop in the drier parts of the country where the incidence of diseases had been relatively low (Hughes, 1952 and 1953; Leather, 1959; Piening, 1962). But with the crop presently cultivated widely

and on large scale as a monocrop, it is hardly surprising that various diseases have become rampant in occurrence and intensity especially in the Rain Forest and Forest-Savanna transitional ecologies.

Earlier studies by Twumasi et al. (1987 and 1989) had established that economically important cowpea diseases which occur in other countries (Emechebe and Shoyinka, 1985; Singh and Allen, 1979; Williams, 1975) also occur in Ghana. The purpose of this study was to re-examine the level of field resistance of some selected cowpea varieties to fungal diseases both in the Rain Forest and Forest-Savanna transitional ecologies and to identify the level of resistance through artificial inoculation of some of these varieties to brown blotch (pod blight) and web-blight, two of the most important fungal diseases identified earlier (Twumasi *et al.*, 1987 and 1989).

Materials and Methods

Identification of Cowpea Diseases. Seeds of 62 IITA and local cowpea varieties (12 extra-early maturing, 60-69 days; 20 medium maturing, 75-80 days; 10 bruchid-resistant 75-80 days; 10 aphid resistant 50-70 days; and 10 dual purpose lines) were sown on 15 May and 11 October, 1989 at Fumesua in the Forest ecology of Ghana. The experiment was also conducted at Ejura in the Forest-Savanna transitional ecology where planting was done on 8 June and 26 October, 1989 in the major and minor seasons, respectively. A randomized complete block design was used with two replications. Seeds of each variety were planted in four rows on 4 m long plot. The plant-to-plant distance was 60 cm between rows and 20 cm within rows. Three seeds were planted in each of the hills and seedlings were later thinned to two stands per hill in order to maintain 160 plants/plot. Recommended cultural practices were followed.

No artificial inoculation was done in this experiment. After germination, the seedlings were regularly observed for disease incidence but disease assessment was done 4 weeks after germination on a weekly basis, using a 0-5 scale for each disease, where "0" was for disease-free and "5" severely diseased or dead plants. Final disease assessments were done on 5 July and 20 November at Fumesua and on 20 August and 18 December, 1989 at Ejura in the major and minor seasons, respectively.

The intensity of each disease was determined by the mean disease index, calculated by adding all the numerical ratings of a particular disease in individual plants in each plot and dividing the sum by the number of plants in that plot. The cumulative mean disease index thus represented the mean intensity of all the diseases that occurred on the plants in a particular plot. Scores of 0-1.5 were considered as resistant, 1.6-3.5 as moderately resistant, and 3.6-5.0 as susceptible.

Harvesting was done on 27 July and 22 December at Fumesua; 23 and 24 August for the major season, and 19 and 20 December, 1989 for the minor season at Ejura. The infected plants were sampled and used for identifying associated micro-organisms. The infected plant parts were either teased and examined under stereo and compound microscopes, or cultured on moist filter papers and on potato

dextrose agar in sterile petri dishes and incubated either under near-ultra-violet light or in darkness for 4-7 days before microscopic examinations and identification of fungal colonies.

Evaluation of Selected Varieties. The second set of experiment was conducted in 1989 only at Fumesua and involved the assessment of 33 cowpea varieties which had earlier shown apparent field resistance to fungal diseases. The varieties were screened against inocula of two pathogens, *Colletotrichum truncatum,* the causal organism of brown blotch, and *Rhizoctonia solani,* the causal agent of web-blight. The seeds of each variety were surface-sterilized for 5 minutes with chlorex (1: 1 v/v) which is a commercial disinfectant and antiseptic solution containing 5% active ingredients of sodium hypochlorite and sodium chloride. Planting and thinning were done as described for the first experiment.

For the development of adequate inocula, infected pods and leaves were collected from the field and pathogens were isolated from these diseased plant parts. The isolated pathogens were kept on potato dextrose agar in slants and kept at 4-5°C in a refrigerator for use when needed. They were transferred on to petri dishes containing 20 ml of the agar each and incubated. By means of a 5 mm cork borer, two plugs of fungal colonies were removed from advancing edges of growing colonies and placed upside down on petri dishes containing 20 ml of agar. These were incubated under near-UV light at room temperature (26-28°C) for 7 days. Sterile distilled water was added to the cultures and they were scraped with flamed needle and scarpel to suspend the fungi. In the case of *C. truncatum,* mycelial fragments were removed from the suspension by straining it through cotton wool into a beaker. Concentration of the conidial suspension was determined by the use of haemacytometer. The final suspension contained 1 x 105 conidial/ml and used as inoculum. With *R. solani,* mycelial fragments from each of 10 petri dishes were comminuted in a Waring blender containing 500 ml sterile distilled water for 1 _ minutes at low speed. The suspension was made up to one litre with sterile distilled water and used as inoculum.

Using atomizers, the conidial and mycelial suspensions of the two pathogens were sprayed on the aerial parts of 21-day old healthy cowpea seedlings. The controls were sprayed with sterile distille water. The plants were then enclosed in the humidity chambers overnight and observed daily for symptom development. Forty days after inoculations, disease assessments were made on a 0-5 scale as earlier described. Samples of leaves and stems from both healthy and diseased plants were cultured and fungal colonies were examined and identified under a stereo and compound microscopes.

Results and Discussion

Field screening scores showed that under natural infection, 31% of the cowpea varieties were resistant to multiple diseases at Fumesua compared with 36% at Ejura.

The most prevalent diseases in both ecologies were in the decreasing order: brown blotch or pot blight caused by *Colletotrichum truncatum,* web-blight caused by

Rhizoctonia solani, Fusarium wilt and/or blight caused by *F. solani*, *F. moniliforme*, target spot *(Corynespora cassiicola)* and anthracnose *(Colletotrichum lindemuthianum)*.

Table 1. Number of cowpea varieties showing various levels of resistance to major diseases in the rain forest ecology of Ghana, 1989.

Type of variety	Total n° of varieties	Resistant	Moderately resistant	Susceptible
Extra-early maturing	12	5	4	3
Medium maturing	20	4	1	5
Bruchid resistant	10	2	5	3
Aphid resistant	10	5	3	2
Dual purpose	10	3	7	-
Total	62	19	20	13
Percent (%)	100	31	31	21

17.0% moderately resistant and 57.0% resistant. With web-blight screening, the respective proportions were 13.0,29.0 and 58.0%, respectively and 13.0,29.0 and 58.0% for Lamb's tail pod rot. This later disease caused much floral abortion in infected plants.

Other diseases encountered were Lamb's tail pod rot caused by *Choanephora cucurbitarum* and other leaf spots caused by *Botryodiplodia theobromae*, *Ascochyta phaseolorum*, *Curvularia inequalis*, *C. pallescens*, *Alternaria alternata*, and *Phoma* sp. It was evident from the studies that all these diseases occurred both in the Forest and the Forest-Savanna transitional ecologies. However, the proportion of resistant varieties in the Rain Forest ecology (Table 1) was lower compared to the Forest-Savanna transitional ecology (Table 2) which might have resulted due to the presence of favourable environmental conditions for many pathogens to attack the crop more severely in the Forest ecology. It was also observed that the pathogen of Lamb's tail pod rot caused much floral abortion in plants.

In the minor season in the Rain Forest ecology, it was observed that more than 5% of the cowpea varieties were affected by wilt or charcoal rot caused by *Macrophomina phaseolina*. The extent of mortality ranged from 1.0% in VITA-7, IT83S-728-13, IT84S-2081, and IT82D-699 to 79.0% in IT84S-2137. The high temperatures might have favoured the activity of this fungus.

The incidence of individual diseases and the levels of resistance of cowpea varieties to various fungal diseases are given in Table 3. At Fumesua, field

screening showed that 26% of all the varieties tested were susceptible to brown blotch.

Table 2. Number of cowpea varieties showing various levels of resistance to major diseases in the forest-savanna transitional ecology of Ghana, 1989.

Type of variety	Total n° of varieties	Resistant	Moderately resistant	Susceptible
Extra-early maturing	12	3	6	3
Medium maturing	20	9	7	4
Bruchid resistant	10	4	3	3
Aphid resistant	10	2	6	2
Dual purpose	10	4	6	-
Total	62	22	28	12
Percent (%)	100	36	45	19

The results of field screening at Ejura followed a pattern similar to that observed at Fumesua. Generally, there was a greater disease incidence at Fumesua than at Ejura. The disease incidence at Fumesua was also greater in the previous years (Twumasi *et al.*, 1987 and 1989). The higher amount of disease incidence at Fumesua could be attributed to the prolonged moist and warm conditions exhibited due to more frequent rainfall.

The results of artificial inoculation studies of selected 33 resistant cowpea varieties, using *R. solani* and *C. truncatum* as inocula, are presented in Tables 4 and 5, respectively. At the inoculum densities used, 70.0% of the varieties showed resistance to *R. solani,* 21.0% moderately resistant and 9.0% susceptible. With regard to *C. truncatum* infection, 73.0% of the varieties showed resistance, 21.0% moderately resistant and 6.0% susceptible. Although equal proportions of the selected varieties were moderately resistant to both pathogens, only IT83S-871 was moderately resistant to both. Out of the varieties tested, 52.0% were resistant to both pathogens, including TVx 3236-OIG, TVx 1948-OIF, TVx 4659-03E, IT81D-699, IT81D-895, IT81D-1228-10, IT84S-2163, IT82D-716, IT84D-513, IT84S-2208-7, IT84D-371, IT83S-728-14, IT83D-326-3, IT84D-2231-15, IT83S-728-5 and Amantin. Varieties which were susceptible to *R. solani* were not susceptible to *C. truncatum.* For example, IT83S-742-13 and IT83S-728-13 were both resistant to *R. solani* but susceptible to *C. truncatum.*

Some varieties consistently showed lesions only on the leaves or stems, while others had such symptoms on both stems and leaves. In varieties susceptible to

either pathogen, there was either defoliations or large lesions on the stems or both. Hypersensitive reactions were exhibited in some of the resistant varieties which had tiny pinhead lesions on the stems, indicating possible production of phytoalexin(s). Re-isolations of pathogens from such varieties were not possible, suggesting that the pathogens could not survive in the inoculated plants.

Table 3. Percent (%) incidence of fungal diseases on individual plants of some of selected cowpea varieties at two locations, 1989.
* R = Resistant ; MR = Moderately resistant ; S = Susceptible

Location	Brown Blotch			Web-blight			Lamb' tail prod rot			Anthracnose			Fusarium wilt/blight			Target spot			Leaf blights/ others		
	R	MR	S*	R	MR	S	R	MR	S	R	MR	S	R	MR	S	R	MR	S	R	MR	S
Fmesua	57.0	17.0	26.0	59.0	28.0	13.0	58.0	29.0	13.0	77.0	13.0	10.0	73.0	16.0	11.0	78.0	12.0	10.0	78.	12.0	10.0
Ejura	76.0	14.0	10.0	74.0	16.0	10.0	90.0	5.0	5.0	81.0	14.0	5.0	78.0	12.0	10.0	80.0	12.0	8.0	84.0	10.0	6.0

Table : 4. Disease reaction levels of 33 resistant cowpea varieties artificially inoculated in the field with *Rhizoctonia solani* (web-blight) at Fumesua, 1989.

Table 5. Disease reaction levels of 33 resistant cowpea varieties artificially

Resistant	Moderately resistant	Susceptible
TVX 3236-OIG	IT 81D-1228	IT 84E-16
IT 82D-699	IT 83S-871	IT 84S-2049
IT 81D-994	IT 84D-449	IT 84S-2127
TVX 1948-OIF	IT 84S-2081	
IT 81D-1228-10	IT 83D-356-1	
IT 83D-326-3	IT 83S-725-18	
IT 81D-985	VITA - 7	
IT 84D-368	IT 83S-818	
IT 81D-1137		
IT 84S-2163		
IT 83S-320-10		
IT 82D-716		
TVX 4659-03E		
IT 84S-2208-7		
IT 84D-448		
IT 83S-728-5		
IT 84D-2231-15		
IT 83S-742-15		
IT 83S-728-13		
Amantin		

inoculated in the field with *Colletotrichum truncatum* (brown blotch) at Fumesua, 1989.

Leaf spot disease caused by *Cercospora canescens* and *C*.

Resistant	Moderately resistant	Susceptible
TVX 3236-OIG	IT 81D-994	IT 83S-742-13
IT 84S-2081	IT 84D-368	
IT 82D-699	IT 81D-1137	IT 83S-728-13
TVX 1948-OIF	IT 84D-448	
IT 81D-1228-10	IT 83S-871	
IT 81D-985	IT 84S-2127	
IT 84S-2163	IT 84S-2049	
IT 82D-716	IT 83S-818	
TVX 4659-03E		
Amantin		
IT 84D-513		
IT 83D-356-1		
IT 84S-2208-7		
IT 83S-728-5		
IT 84D-371		
IT 84D-2231-15		
VITA-7		
IT 81D-1228		
IT 84D-449		
IT 83S-725-18		
IT 84E-16		
IT 83D-326-3		
IT 82D-927		

cruenta which was reported earlier in Ghana on cowpea (Leather, 1959; Piening, 1962) was not recorded in the present studies, perhaps due to a measure of resistance to the pathogen in the varieties tested.

Conclusion

Several important cowpea diseases capable of reducing crop yields exist in the Forest and Forest-Savanna transitional ecologies of Ghana. Some of the resistant varieties identified in these studies could be used for varietal improvement programmes. Studies on yield performance with the resistant varieties need to be carried out in order to qualify their yield potential.

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Field Evaluation of Seed Treatment Fungicides for the Control of

Cowpea Scab,Brown Blotch and Septoria Leaf Spot in Nigeria's Northern Guinea Savanna.

A.M. EMECHEBE., O. ALABI and M. TARFA.

Department of Crop Protection, Institute for Agricultural Research/Faculty of Agriculture, Ahmadu Bello University, Zaria, Nigeria.

Abstract

During the 1988 growing season several seed treatment fungicides were evaluated in the field for the control of seed-borne transmissions of cowpea scab (*Elsinoe phaseoli* with *Sphaceloma* anamorphic state), brown blotch (*Colletctrichum capsici*) and Septoria leaf spot (*Septoria vignae*). Since the results of 1988 trial corroborated those of previous years with respect to brown blotch and *Septoria* leaf spot, the focal point of the 1989 and 1990 trials was on control of scab. Fernasan-D (thiram) and Dithane M45 (manxozeb) were applied at the rate of 3.3 g of commercial product per kg of seed while Benlate (benomyl), Delsene M (carbendazim + maneb) and Apron plus (metalaxyl + carboxin) were applied at 0.6 g of product per kg of seed. Rovral TS (carbendazim + iprodione) was evaluated at three rates (0.3, 0.6 and 1.2 g of product per kg of seed) in 1988, at two rates (0.6 and 1.2 g of commercial product per kg of seed) in 1989 and at one level (0.6 g of product per kg of seed) in 1990. All fungicides were applied as dry seed dressings. Untreated seeds served as the check. For each year, seeds from plants that were severely affected by the diseases in the field during the preceding year were used. Final disease scores were taken within 5 weeks of sowing to reduce confounding effects caused by secondary spread of disease.

The results showed that Fernasan-D was inferior to the other fungicides for the control of brown blotch and Septoria leaf spot; it was, however, relatively effective against scab. Rovral TS was effective against all three diseases; with respect to scab, its effectiveness increased with increase in the dosage. Thus, at the rate of 0.6 g or 1.2 g of commercial product per kg of seed, Rovral TS compared favourably with Benlate and Delsene M. In general, Benlate gave the best control of seed-borne transmission of the three fungal diseases of cowpea. The practical implications of these results in the control of these diseases are discussed.

Introduction

The cowpea (*Vigna unguiculata* (L.) Walp.) is important as a food crop throughout West Africa and especially in the Sudan savanna, being second only to groundnuts as a cultivated legume (Purseglove, 1974). In Nigeria, cowpea grains form an important source of cheap vegetable, containing approximately 25% protein (Oyenuga, 1959).

The annual production of cowpea in Nigeria has been estimated to be between 700,000 and 800,000 tons (Raheja and Apeji, 1979). As much as 80% of this is produced in the northern parts of the country (Raheja and Apeji, 1979; Emechebe

and McDonald, 1979; Emechebe, 1981).

Cowpea suffers from various diseases wherever it is grown. For example, Williams (1975) and Singh and Allen (1979) listed over 35 diseases of cowpea in Nigeria, mostly caused by fungi, viruses and bacteria.

There are three major fungal diseases of cowpea in the Northern Guinea savanna, namely: scab (*Elsinoe phaseoli* with *Sphaceloma* anarmorphic state), brown blotch (mostly *Colletotrichum capsici* but occasionally *C. truncatum*) and *Septoria* leaf spot (*Septoria vignae*) (Allen *et al.*, 1981; Emechebe and Shoyinka, 1985). These diseases cause up to 75% crop loss on susceptible varieties under favourable environmental conditions.

Earlier workers have established seed-borne nature and seed transmission for both brown blotch and Septoria leaf spot (Emechebe and McDonald, 1979; Emechebe 1981). Recently, Emechebe (1988) reported that scab is also seed transmitted.

Seed treatment has been found to be effective against several cowpea diseases. For example, brown blotch can be controlled by dressing the seed with either benomyl or carbendazim and maneb (Alafiatayo, 1982). In addition, *Septoria* leaf spot can be controlled effectively by seed treatment with benomyl (Tarfa, 1986). Seed treatment has been found to be the most economical use of fungicides in controlling seed-borne pathogens (Edgindton, *et al.*, 1980).

No attempt has been made to control the seed-borne transmission of scab by fungicidal seed treatment which should preferably control the other two fungal diseases. This paper presents the results of our work in this direction.

Materials and Methods.

The composition and chemical nature of the six fungicides tested are given in Table 1. Benlate (benomyl) Delsene M (carbendazim + maneb), Rovral TS, (Carbendazim + ipriodione), Fernasan-D. (thiram), Apron plus (metalaxyl + carboxin) and Dithane M-45 (mancozeb) were evaluated in the field for three years.

In 1988, five seed treatment fungicides were evaluated for the control of scab, brown blotch and *Septoria* leaf spot. Fernasan-D was applied at the rate of 3.3 g of commercial product per kg of seed while Benlate, Delsene M and Apron plus were applied at 0.6 g of commercial product per kg of seed. Rovral TS was evaluated at three rates, namely 0.3, 0.6 and 1.2 g of (commercial product) per kg of seed. All fungicides were applied as dry seed dressings. Each plot consisted of three 75 cm ridges, 5 m long, the trial being a randomized complete block design with four replicates. Ife Brown seeds (obtained from a field that was moderately to severely affected by scab, brown blotch and *Septoria* leaf spot in 1987 crop season) were used, two seeds being sown per hole at an inter stand distance of 20 cm. Germination count was taken 2 weeks after sowing (WAS) and the number of infected plants were recorded 4 WAS. Percentage incidences of the three diseases were determined and recorded.

Table 1. Chemical nature, trade and common names of fungicides evaluated in

the field for efficacy against the three pathogens.

Since the 1988 results confirmed those obtained in previous trials about the

Trade name of fungicides	Common name of fungicidal active ingredient	Chemical nature of fungicidal active ingredient
Benate	Benomyl	methyl 1-(butyl-carbamoyl benzimidazol-2-ylcarbamate
Delsene M.	Carbendazim + maneb	methyl benzimidazol-2-yloarbamate + manganese ethylene bis (dithiocarbamate).
Dithane M-45	Mancozeb	2.5 % Zn ion + 20 % Mn as in maneb.
Fernasan D	Thiram	tetramethylthiuram disulphide
Apron plus	Metalaxyl + carboxin furathiocarp	(±) = methyl-N-(2-methoxy acetyl)-M- (2.6-xylyl) alaminate + 2.3-dihydro-6-methyl-5-phemylcarbamoyl--1. 4 Oxathin + furanthicarb.
Rovra TS	Iprodione + carbendazim	3-(3.5-dichlorophenyl)-N-isopropyl-carbomyl-2.4 dioxoimidazolidine-1-carboxamine+methyl benzimidazol-2-ylcarbamate.

superiority of benomyl and carbendazim as seed treatment fungicides for the control of brown blotch and Septoria leaf spot, these two diseases were not the subject of investigations in 1989 and 1990. In both years, benomyl and carbendazim as well as other fungicides were further evaluated for the control of seed-borne transmission of scab.

Table 2. Effect of fungicidal seed treatment on incidence of cowpea brown blotch in the field*

Treatment	Disease incidence (%)	
	3 weeks after sowing	4 weeks after sowing
Benlate	7.05c	10.83c
Delsene M	6.84c	17.08c
Aldrex T	18.94b	32.9b
Verdasan	20.13b	35.93b
Control	28.34a	46.03a

Means in the same column followed by the same superscript are not significantly different (P=0.05).

* Based on Alafiatayo (1982).

In 1989, seeds from a crop of Sampea-7 cowpea that was severely affected by scab

in the 1988 crop season were used in two experiments. In one experiment, four fungicides (Benlate, Apron plus, Rovral TS and Fernasan D) were evaluated at the rates used in 1988. A randomized complete block design was used and untreated seeds served as the check. Of the four fungicides used in the first experiment, three (namely Benlate, Apron plus and Rovral TS) were each evaluated at three rates, namely: 0.3, 0.6 and 1.2 g of commercial product per kg of seed. The remaining fungicide, Fernasan-D, served as the check treatment but was evaluated only at 3.3 g of commercial product per kg of seed.

In 1990, all the fungicides evaluated in 1989 were again evaluated. Also studied in 1990 were Delsene M, Dithane M-45 and a bench mixture of Dithane M-45 and Benlate. The trial was laid out as a randomized complete block design with four replicates.

Results

Results of the earlier work are presented in Tables 2 and 3 to demonstrate the effectiveness of benomyl and carbendazim as seed treatment fungicides for the control of cowpea brown blotch (Table 2) and *Septoria* leaf spot (Table 3). The results obtained in 1988 (Table 4) show that Fernasan-D was inferior to all other fungicides and was only slightly better than the untreated check. Rovral TS performed very well and its effectiveness increased with increase in dosage. At the rate of 0.6 or 1.2 g of commercial product per kg of seed, Rovral TS compared favourably with Benlate and Delsene M.

The results presented in Table 5 show the high efficacy of benomyl against seed-borne transmission of scab; the incidence of scab at 3 WAS in plots grown from seeds treated with benomyl was 1.3% which was significantly lower than 57% in plots sown with untreated seeds. As expected, Rovral TS was also effective against scab. Fernasan-D (thiram) surprisingly gave some control of scab, though it was not as effective as benomyl. Apron plus was ineffective.

The data presented in Table 6 corroborate those in Table 5. The data also suggests that it may be necessary to use a higher rate of benomyl than has been tried in previous trials.

Table 3. The effect of seed-dressing chemicals on the incidence of *Septoria* leaf

spot in the field in 1985*

Seed treatment chemical	Disease incidence (%)	
	22 days after sowing	28 days after sowing
Benlate	0.0 (0.0)**	1.01 (5.74)
Dithane M-45	1.03 (5.74)	5.03 (12.92)
Aldrex T	0.98 (5.68)	7.56 (16.0)
Macuprax	0.76 (5.00)	4.58 (12.25)
Bavistin	0.0 (0.0)	1.33 (6.55)
Cupravit	0.86 (5.32)	6.06 (14.30)
Delsene M	0.32 (3.24)	4.17 (11.83)
Calixin M	0.33 (3.29)	7.71 (16.11)
Control	1.17 (6.29)	8.82 (17.26)
L.S.D. (0.05)	4.209	4.470

* Based on Tarfa (1986)
** Number in parenthesis = Angular transformed values.

The results of the 1990 season (Table 7) showed that even at 4 WAS, the superior efficacy of benomyl and carbendazim, as seed treatment fungicides for the control of cowpea scab, compared to that of any of the other fungicides. As in 1989, the popular seed treatment fungicide, Fernasan-D, gave some control of seed-borne scab but it was not as effective as carbendazim or benomyl. Again, Apron plus was the least effective of all the fungicides or fungicidal mixture evaluated.

Discussion

The results of the present study have demonstrated that seed treatment with benomyl and carbendazim give effective control of seed-borne infections by the pathogens of cowpea scab, brown blotch, and *Septoria* leaf spot. These results corroborate those of Alafiatayo (1982) and Tarfa (1986) who used carbendazim against seed-borne transmissions of brown blotch and *Septoria* leaf spot, respectively.

Table 4. Mean effect of seed treatment chemicals on the incidence of cowpea

scab, brown blotch and *Septoria* leaf spot in 1988.

However, this is the first report of the high efficacy of benomyl and carbendazim

Seed treatment fungicide	Application rate of commercial product (g/kg of seed)	Disease incidence (%) at 5 weeks after sowing		
		Scab	Brown blotch	*Septoria* leaf spot
Benlate	0.6	1.11	2.65	2.87
Delsene M	0.6	0.62	1.23	6.55
Apron plus	0.6	1.96	1.96	6.08
Rovral TS_1	0.3	0.45	4.93	6.50
Rovral TS_2	0.6	1.16	1.87	4.89
Rovral TS_3	1.2	1.05	0.42	3.38
Fernasan D	3.3	1.46	11.02	7.25
Control	-	1.35	9.18	9.44

as seed treatment fungicides against seed transmission of scab. Both benomyl and carbendazim have protective, eradicative and systemic properties (Edgington *et al.*, 1980) and so were able to eradicate most of the seed-borne infections by the three pathogens. Benomyl has been found to be an effective seed treatment for the control of French bean anthracnose (Maude and Kyle, 1971) and sorghum anthracnose (Mishra and Siradhana, 1979). Also Sinha and Khare (1977) reported that benomyl gave the most effective control of seed-borne *Macrophomina phaseolina* and *Fusarium equiseti* in cowpea.

Table 5. Mean effect of fungicidal seed treatment chemicals on incidence of scab at 3 and 4 weeks after sowing at Samaru in 1989.

Table 6. Effect of type and rate of fungicidal seed treatment on the incidence of

Seed treatment (%) fungicide	Application rate of commercial product (g/kg of seed)	Disease incidence	
		3 WAS	4 WAS
Benlate	0.6	1.3	22.4
Rovral TS	1.2	4.9	26.9
Rovral TS	0.6	8.1	41.6
Apron plus	0.6	44.9	76.8
Fernasan D	3.3	7.3	29.4
Control	-	57.8	88.8

scab at 4 weeks after sowing at Samaru in 1989.

Table 7. Effect of seed treatment chemicals on the incidence of cowpea scab,

Seed treatment (%) fungicide	Application rate of commercial product (g/kg of seed)	Disease incidence (%) at 4 weeks after sowing
Benlate	1.2	1.0
Benlate	0.6	4.9
Benlate	0.3	11.8
Rovral TS	1.2	16.7
Rovral TS	0.6	11.5
Rovral TS	0.3	13.1
Fernasan D	3.3	8.9
Apron plus	1.2	28.9
Apron plus	0.6	21.5
Apron plus	0.3	24.4

brown blotch and *Septoria* leaf spot in 1990.

Although Fernasan-D (thiram) was somewhat effective against scab, it was much

Seed treatment (%) fungicide	Application rate of commercial product (g/kg of seed)	Scab incidence (%) at 4 weeks after sowing
Benlate	0.6	2.4
Dithane M-45	3.3	6.8
Benlate + Dithane M-45	2.2	3.4
Apron plus	1.2	10.6
Delsene M	1.2	1.3
Fernasan D	3.3	5.3
Rovral TS	1.2	2.1
Control	-	26.6

more inferior than either benomyl or carbendazim. The low efficacy of thiram against brown blotch was reported earlier by Alafiatayo (1982).

The much higher incidence of scab at 4 WAS indicates the secondary spread of disease from primary lesions and emphasizes the need to score seed treatment experiments early.

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Economic Importance of the Bean Flower Thrips Megalurothrips

Siostedti (Trybom) (Trhysanoptera: Thripidae) on Cowpeas With Reference to Economic Injury Levels.

A.B. SALIFU,

Nyankpala Agricultural Experiment Station, P.O. Box 483, Tamale, Ghana.

Abstract

Field and screenhouse studies were conducted to quantify the effect of feeding injury of the bean flower thrips (BFT) *Megalurothrips sjostedti* on cowpea (*Vigna unguiculata* (L.) Walp.) and to establish economic injury levels on two cultivars. The relationship between BFT-induced flower bud abscission and pod setting was best described by a quadratic function and the extent of pod setting depression due to feeding injury ranged between 14-60% on resistant and susceptible cowpea cultivars, respectively. Economic injury levels were developed on racemes of cultivars TVx 3236 (resistant to BFT) and VITA-7 (susceptible to BFT) by infesting individual caged racemes with varying populations of field-collected adult BFT. Grain yield from caged racemes were combined with data on prevailing market price of cowpeas and the cost of insecticidal protection of sole cowpeas to determine economic injury levels on the basis of simple cost: benefit analysis. Economic injury levels were found to be 5 thrips/raceme on the resistant cultivar and 3 thrips/raceme on the susceptible cultivar.

Introduction

The bean flower thrips (BFT), *Megalurothrips sjostedti* (Trybom) is a major pest of cowpeas throughout tropical Africa. Cowpeas are particularly vulnerable to BFT feeding during the plant's reproductive phase, causing infested racemes to become necrotic and the open flowers variously malformed, leading to abscission. Yield losses due to BFT and the other major cowpea pests is almost 100% in unsprayed farmers' fields (Singh & Allen, 1980).

The development of a viable integrated control strategy for BFT depends on a clear understanding of the insect-plant interactions. Very few quantitative assessments of the effect of BFT feeding on cowpeas exist in the literature. Earlier reports have qualitatively estimated that BFT often causes up to 60% damage to the crop (Singh & Taylor, 1978). In what appears to be the first attempt at quantitative assessment of the effect of BFT on cowpeas, Koehler & Mehta (1972) ended by reiterating the need for further investigation of the relationship between the thrips and cowpea yields. The economic injury level of a pest population, defined as the lowest population density that will cause economic damage, continues to function as the primary mechanism for making pest management decisions with short range objectives (Pedigo *et al.*, 1986). The only attempt at establishing an economic threshold for BFT was reported from IITA (1983). Insecticides were used to vary thrip populations and to study their relationship with yield reduction. These studies were, however, inconclusive.

The study presented in this paper was undertaken to further our understanding of

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the effect of thrip injury and cowpea performance, including attempts at establishing economic injury levels.

Materials and Methods

Relationship Between Thrip Damage and Pod Production. The aim of this investigation was to quantify the extent of thrip damage in terms of flower bud abscission on different cowpea cultivars and also to determine the level to which pod setting could be depressed as a result of the damage. Seed yield was not considered in this investigation because it is the result of too many factors to be of use as a direct measure of thrip effect. The experiments were conducted at the International Institute of Tropical Agriculture, Ibadan, Nigeria during the first (April-May) and second (September-November) growing seasons of 1982 and repeated during the second and first seasons of 1983 and 84, respectively.

In order to distinguish between abscission due to thrips and that due to physiological and other factors, the experiment was designed to include a control plot in which thrips were controlled with insecticide. The entire experimental area (ca. 0.2 ha) was divided into two quadrats designated as sprayed (Quadrat 1) and unsprayed (Quadrat 2), respectively. These quadrats were separated by a maize border. In each quadrat, four cowpea cultivars, TVu 1509, TVx 3236, Ife Brown (TVu 3629) and VITA 7, were replicated four times in a randomised complete block design. The cultivars were planted in plots of 5 rows, 4 m long, at a spacing of 0.75 m between rows and 0.30 m between plants in a row. Plants were thinned to one stand per hill at 10 days after planting (DAP).

At 20 DAP, insecticide (Deltamethrin EC at 15 g a.i./ha) was applied on all replications in Quadrat 1; this being repeated at anthesis (ca. 38 DAP). At 25 DAP, fine nylon mesh cloths measuring 75 x 75 cm, were fitted under each of 10 plants per replication per cultivar in both Quadrats 1 and 2 to facilitate the counting of abscissed flower buds. The mesh cloth under each plant was held off the ground by pinning its corners onto styrofoam cubes (painted green) carried about 18 cm high on thin aluminium rods.

Abscissed bud counts were started at 30 DAP and continued on alternate days, ending at full bloom. At each counting, all flower buds (and later some flowers) that had abscissed and retained by the nylon mesh were counted and recorded. This was done for all 10 plants in all replications in both quadrats. At the end of data collection, counts from different days were pooled for each plant in each replication to determine the average number of abscissed buds per plant. Abscission due to thrips on each cultivar was computed by subtracting Quadrat 1 (i.e. sprayed replications) counts from corresponding replications in Quadrat 2 (i.e. unsprayed replications). Furthermore, pod setting depression was calculated for each cultivar by subtracting pod counts in Quadrat 2 from those of corresponding replications in Quadrat 1, and expressed as a percentage of counts from Quadrat 1 in the function:

$$PSD\% = (1-Q2/Q1)100 \text{ (i.e. } (Q1-Q2/Q1)100),$$

Where PSD	=	extent of pod setting depression, and
Q1 and Q2	=	pod counts from corresponding sprayed and unsprayed replications.

Economic Injury Levels were determined on racemes of uninfested pot-cultured plants of cultivars TVx 3236 and VITA 7 in the screenhouse. Individual racemes (peduncle length 1.5-2.0 cm) were caged in transparent polystyrene diet cups ventilated by fine nylon mesh glued to their sawn-off bottoms with Bostik clear adhesive. The bonds formed between the nylon and the plastic cup were not very strong and although sufficient to retain thrips inside the cup, the light bonding enabled elongating pods to push the mesh out of place and grow out of the cup to develop normally. Caged racemes were infested with 10 different thrip population levels, viz: 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 per raceme. Uninfested controls (i.e. 0 thrips per raceme) were included for each cultivar. Each infestation level was replicated twice per plant. Pods developing from infested racemes were monitored daily until pod maturity when they were harvested and hand-threshed to obtain grain yield corresponding to the different population levels. With data gathered on the prevailing market price of cowpeas and the cost of insecticidal protection of a hectare of sole cowpea, simple cost-benefit analysis was followed to determine the economic injury level for each cultivar.

Results and Discussion

Relationship Between Thrip-induced Abscission and Performance of Cowpeas. A quadratic function best described the relationship between BFT-induced abscission and pod setting (Fig. 1) and the predictive significance of this relationship was indicated by the high R_ values. Comparison of the trends between resistant and susceptible cultivars indicated that the susceptible cultivars were probably less able to set pods with abscission greater than about 20 buds per plant. There were significant differences in the extent of pod setting depression between resistant and susceptible cultivars (Table 1). The results showed that pod setting depression attributable to BFT ranges from 14-60% per plant (4-season average); reflecting resistance-susceptibility. This range includes those recorded for other thrips on a number of legumes, e.g. a mean reduction in yield (pod-set) due to *Frankliniella insularis* (Franklin) on pigeon peas was 47% (Pollard & Guiseppi-Eli, 1981) whereas in *Pisum sativum* maximum losses were 67.1% due to *Caliothrips indicus* Bagnall (Vaishampayam & Singh, 1969).

Economic Injury Levels. Before computing the economic injury levels, damage functions relating yield loss to thrip density were determined by regressing yield loss (g/raceme) on thrip density. Thrip density was used as proxy for host injury. The regressions were not forced through the origin (zero thrips or injury should produce zero yield).

Table 1. Extent of pod-setting depression (PSD) due to BFT feeding on resistant

and susceptible cowpeas over four seasons.

Cultivar	PSD ± S.E. (%)*			
	1	2	3	4
TVu 1509	11.1 ± 3.8	22.0 ± 5.1	6.5 ± 2.7	18.1 ± 4.4
TVx 3236	7.5 ± 2.1	34.9 ± 6.3	17.9 ± 4.3	27.6 ± 7.1
Ife Brown	33.5 ± 5.6	54.9 ± 5.4	57.9 ± 3.9	43.0 ± 5.6
VITA 7	48.0 ± 6.8	70.5 ± 6.1	64.1 ± 5.0	59.0 ± 4.8

* PSD% = (1 - Q2/Q1)100; Where Q1 = pod counts from sprayed plots; Q2 = pod counts from unsprayed plots. 1 = First season 1982; 2 = second season 1982; 3 = second season 1983 and 4 = first season 1984.

Thrip populations were negatively correlated with yield per raceme for both TVx 3236 and VITA 7. Both correlations were highly significant. With VITA 7 (r = -0.90), the regression equation was y = 3.24-0.35x (R^2 = 0.80) where y = yield (g) per raceme and x = number of thrips per raceme. Each unit increase in the number of thrips per raceme was associated with a decrease of 0.35 g of VITA 7. The correlation coefficient, r, was -0.84 for TVx 3236 where the regression equation was y = 3.02-0.26x ($R_{_}$ = 0.70). Each unit increase in thrip infestation resulted in a decrease of 0.26 g per raceme of TVx 3236, suggesting that TVx 3236 was better able to tolerate thrips than VITA 7. A smaller amount of variance was accounted for when the data were fitted to a second degree polynomial, hence a linear relationship appeared to describe the association adequately. Some extrapolations (inherent hazards notwithstanding) were made before final computation of economic injury levels.

Firstly, the yield per raceme of each of the test cultivars was converted into yield per plant by multiplying the mean yield per raceme by the mean number of pod-bearing peduncles, estimated on 30 non-infested potted plants of both cultivars cultured under similar environmental conditions. The yield loss due to different infestation levels was calculated as the reduction in the different infestation levels over the control. These yields were then converted into yield in kilograms per hectare by multiplying the yield per plant by a plant population of 50,000 per hectare.

Table 2. Cost-Benefit analysis and economic injury levels for resistant and

susceptible cowpea cultivars.

* 1 kg cowpea cost N1.20; # Assuming insecticides gives 90% kill;

Thrip density per raceme	Yield loss (kg/ha)	Value of yield loss (N)	Value of loss saved (Benefiit B)*	Profit accrued (B - C) + (N)
		TVx 3236 (Resistant)		
1	19.9	23.8	21.4	-63.5
2	22.8	27.4	24.6	-60.3
3	44.3	53.2	47.9	-37.1
4	66.9	80.3	72.3	-12.7
5	90.9	109.0	98.1	13.2 EIL
6	486.3	583.6	525.2	440.3
7	561.6	781.9	703.7	618.7
8	688.5	826.1	743.5	658.6
9	671.2	805.4	724.8	639.9
10	1357.1	1628.5	1465.7	1380.7
		VITA 7 (Susceptible)		
1	24.9	29.9	29.9	-58.1
2	43.5	43.5	52.2	-38.0
3	80.0	95.9	86.4	1.4 EIL
4	122.3	146.7	132.0	47.1
5	270.8	324.9	292.4	207.5
6	372.5	446.9	402.3	317.3
7	546.1	655.3	589.8	504.8
8	649.0	778.7	700.9	615.9
9	649.0	778.7	700.9	615.9
10	649.0	778.7	700.0	615.9

\+ cost of pest control (C) calculated @ N84.95;
EIL - Economic Injury Levels (B - C > 0).

The prevailing market price of cowpea at the time of the investigation was pegged at N1.20 (N1 = $1.40) per kilogram. Cost of pest control was estimated on the basis of input costs accrueing in the provision of insecticide application. Using a manual knapsack sprayer and applying the synthetic pyrethroid Deltamethrin EC 0.5 l/ha, the cost of protecting a hectare of sole cowpea was calculated at N84.95. The value of yield saved by pest control (potential benefit, B) was calculated as 90% kill of the pest population. Finally, net profit accrueing was calculated at the various

infestation levels by subtracting the cost of pest control (C = N84.95) from potential benefit, B.

Cost-benefit analyses for the two cultivars are summarised in Table 2. According to cost-benefit analysis, the economic injury levels would be reached any time B-C is more than zero. Consequently, the economic injury level for VITA 7 was found to be 3 thrips/raceme whereas that of TVx 3236 was 5 thrips/raceme. Thus, if farmers are able to keep thrip populations at these levels they should be in a position to optimise their pest control investments. The advantage of TVx 3236 of a higher economic injury level may bear important implications for integrated control tactics. Although not particularly investigated in this study, it is possible that lower insecticide dosage on this cultivar may achieve similar levels of thrip control compared to such cultivars as VITA 7. Already, it has been established that TVx 3236 requires fewer sprays in comparison with local checks in a variety of multi-locational tests (IITA, 1982).

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Critères d'Evaluation au Champ de la Résistance du Niébé au

Striga gesnerioides.

T.J. OUEDRAOGO, J.B. TIGNEGRE et N. MULEBA.

INERA et IITA/SAFGRAD, Ouagadougou, Burkina Faso.

Résumé

Afin de comparer différents critères d'évaluation au champ de la résistance du niébé au *Striga*, 16 cultivars de niveaux de résistance variables ont été utilisés sur des parcelles infestées de *Striga* à Kamboinsé en 1988 et en 1989 respectivement sur deux et un sites.

L'analyse des résultats montre des corrélations hautement significatives entre les critères d'évaluation pour la résistance au *Striga*. Cependant, la date d'émergence du premier plant de *Striga* et le nombre de plants de *Striga* par unité de surface paraissent les critères les plus fiables pour l'évaluation au champ.

Introduction

Le *Striga gesnerioides* Wild (Vatke), à l'instar de *S. hermonthica* sur les céréales, cause des pertes considérables de rendements sur le niébé (*Vigna unguiculata*) dans les zones semi-arides d'Afrique, et même dans les zones côtières. Cette baisse de rendement peut atteindre 30 % (Aggarwal et Ouédraogo, 1986). Dans les différentes études de résistance du niébé au *Striga*, plusieurs critères sont utilisés pour évaluer ou identifier les variétés résistantes (Ouédraogo et Muleba, 1988). L'utilisation d'un seul critère d'évaluation pouvant s'avérer insuffisant et celle de plusieurs, complexe, il nous a semblé opportun d'étudier les corrélations entre certains de ces critères.

Matériel et Méthode

Seize (16) variétés de niveau de résistance au *Striga* variable ont été utilisées, dont 4 témoins-sensibles (KVx 396-18-10, KN-1, TN88-63 et IT82E-32) et 4 témoins-résistants (Gorom Local, B301, IT82D-849 et KVx 61-1). La parcelle a été préalablement infestée artificiellement, avant le semis, avec des semences de *Striga* vieilles d'une année. Le dispositif expérimental était en Blocs complets randomisés (Blocs de Fisher) à 6 répétitions. Les parcelles expérimentales étaient de 4 lignes de 4 m de long, les écartements de 0,75 m entre les lignes et 0,20 m entre les poquets. Les observations ont été effectuées sur les 2 lignes centrales.

L'étude a été menée à Kamboinsé sur 2 sites en 1988 et sur un en 1989. Les principales opérations culturales ont consisté en un sarclage 2 semaines après semis (SAS) et en un désherbage manuel 3 SAS afin de ne pas endomager les plantules de *Striga*.

Les critères d'évaluation retenus sont les dates d'émergence du premier plant, le nombre de plants/m2, le poids sec de *Striga* et le pourcentage d'infestation (nombre

de plants de niébé attaqués/nombre total de plants de niébé), les rendements grains du niébé. Les coéfficients de correlation ont été calculés selon la formule proposée par Little et Hills (1975).

Résultats et Discussion

Les variétés sensibles ont connu une émergence très précoce du *Striga*, 31 jours environ après semis alors que les variétés résistantes n'ont pas connu d'infestation ou ne l'ont subie que très tard, après leur mâturité (Tableau 1). Les variétés sensibles ont ainsi connu des taux d'infestation et des densités de parasitisme beaucoup plus élevés que les variétés résistantes. De même, le poids sec de *Striga* récolté sur les parcelles de variétés sensibles était plus élevé que celui du *Striga* provenant des parcelles de variétés résistantes (Tableau 1), une différence attribuable au nombre de plants de *Striga* mais aussi au fait que ces plants présentent plus de ramifications que ceux présents chez les variétés résistantes.

La réinfestation artificielle des parcelles de criblage avec des semences de *Striga* assure sa bonne répartition dans le sol et une identification facile des variétés résistantes. Toutefois, nous avons observé que l'utilisation répétée sur 4 ans au moins de la même parcelle, même sous infestation artificielle, entraîne la baisse de la vigueur du parasite et de sa densité dans le champ. Des hyper-parasites seraient à la base de cet affaiblissement et de la réduction de la densité du *Striga*.

L'association statistique entre les différents critères d'évaluation est consignée dans le Tableau 2. Les corrélations sont hautement significatives, ce qui révèle qu'on peut utiliser l'un ou l'autre de ces critères - et non pas leur totalité - pour l'évaluation de la résistance au champ.

Tableau 1. Résultats des variétés selon les 4 critères d'évaluation de la résistance au *Striga* et les rendements en grains (kg/ha).

Nota : K_1, K_2 et K_3 sont des numéros de sites. Pour les variétés qui n'ont pas connu

Critères	Emerg. 1e *Striga*			% Infestation		Nbr *Striga* m/2			Poids sec *Striga*(g)		Rendements (kg/ha)		
Variétés						K_1	K_2	K_3	K_1	K_2	K_1	K_2	K_3
Kvx 396-4-2	31	38	33	70.15	76.40	15.3	16.1	8.5	50.45	28.67	963	1166	1144
KVx 396-4-4-2	33	32	33	67.27	90.25	12.1	20.7	8.75	50.45	28.67	1115	1121	1233
KVx 396-4-4-4	32	31	32	85.03	82.74	26.8	21.1	11.5	116.5	53.3	935	1031	1064
KVx 396-6-1G	63	68	72	0.47	0.00	0.1	0.01	0.0	0.12	0.00	1077	1171	959
KVx 396-8-5G	70	72	82	0.42	0.00	0.1	0.00	0.0	0.17	0.00	842	1116	960
KVx 396-11-6G	51	65	67	15.40	10.48	4.2	1.70	0.5	5.53	2.32	1241	1139	1055
KVx 396-16-10-2	51	49	49	13.87	12.20	1.1	1.20	0.75	0.58	0.72	924	1050	1008
KVx 396-18-10	31	31	35	70.07	84.80	20.2	24.6	7.25	84.10	98.07	911	890	950
KVx 61-1	72	72	73	0.00	0.00	0.0	0.00	0.01	0.00	0.00	956	1267	1215
KVx 65-114	50	53	82	3.52	3.03	0.4	0.60	0.0	1.70	2.18	1009	1090	1226
IT82E-32	31	33	32	85.50	77.83	32.2	18.80	6.25	124.9	52.88	1092	884	993
IT82D-849	72	72	82	3.52	0.00	0.00	0.00	0.0	0.00	0.00	1043	1272	923
B301	72	72	82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1109	1167	953
KN-1	33	36	37	84.93	77.38	11.5	27.9	9.75	89.97	30.13	803	1005	917
TN88-63	31	34	36	60.82	75.35	11.5	15.7	5.50	22.50	31.63	686	804	715
Gorom local	65	72	82	0.001	0.00	0.01	0.00	0.00	0.00	0.00	719	766	773

d'infestation de *Striga*, nous avons considéré la date de récolte comme date d'émergence du premier plant de *Striga*, soit 72 et 82 jours après semis respectivement pour 1988 et 1989.

Tableau 2. Coefficients de corrélation entre 4 critères d'évaluation de la résistance au *Striga* de cultivars de niébé à Kamboinsé, Burkina Faso.

** : Hautement significatif

Site	% infest.	N° *Striga* M/2	Poids *Striga*	Rendement
1. Date emergence1e *Striga*				
K88-1	-0.891**	-0.813**	-0.789**	0.260
K88-2	-0.950**	-0.912**	-0.821**	0.459
K89-1	-	-0.903**	-	0.168
2. Pourcentage d'infestation				
K88-1		0.820**	0.757**	-0.233
K88-2		0.968**	0.858**	-0.421
3. Nbre *Striga*/m2				
K88-1			0.935**	-0.358
K88-2			0.864**	-0.418
K88-1			-	-0.176
4. Poids *Striga*				
K88-1				-0.143
K88-2				-0.471

Cependant, le choix d'un seul critère d'évaluation de la résistance est rendu difficile par l'existence de plusieurs mécanismes de cette résistance du niébé. C'est ainsi que le jaunissement des feuilles suivi de flétrissement du plant de niébé sont le signe d'attaque de *Striga* après sa germination et avant son émergence chez certaines variétés très sensibles de niébé (cas de TVx 3236). En outre chez certaines variétés le *Striga* émerge mais meurt avant la floraison ou la fructification et chez d'autres il atteint la fructification et la maturité. On pourrait appeler ces 2 types de variétés respectivement *Striga* " sensible stériles " qui contribueraient à diminuer le stock de semences du parasite dans le sol et les *Striga* " sensible fertiles " (Ouedraogo et Muleba 1988). Les études en pots permettent d'effectuer le dénombrement des Striga qui germent sans que leurs haustoria ne s'attachent aux racines de l'hôte, ce qui permet de contourner les difficultés sus-mentionnées.

Si en serre, au laboratoire et en poticulture des critères plus fins peuvent être utilisés, pour un criblage en plein champ les critères date d'emergence du premier plant de *Striga* et surtout la densité du parasite sont fiables et peuvent être renforcés par le pourcentage d'infestation et le poids sec de *Striga*.

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Identification et Recherche de Variétés Résistantes aux Principaux Virus du Niébé au Togo.

M.Y. GUMEDZOE.

Université du Benin, Lomé , Togo.

Résumé

Plusieurs virus importants du niébé ont été identifiés par sérologie au Togo; ce sont le "Cowpea aphid borne mosaic virus" (CAbMV), le virus de la marbrure (CMeV) le virus de la marbrure légère (CMMV), le virus de la mosaïque du niébé (CPMV), le "southern bean mosaïc virus" (SBMV) et le virus de la mosaïque du tabac-souche légumineuse (TMV-CS). Des infections mixtes ont été souvent observées impliquant un ou plusieurs de ces virus. Différentes plantes sauvages ont été trouvées infectées par cinq des six virus : ex. *Cassia hirsuta* par SBMV; *Centrosema pubescens* par CMMV; *Nauclea latifolia* par CMMV et CABMV et Mucuna sp. par TMV-CS. Plusieurs cultivars du niébé (TVx1850-01E, IT82E-16, etc...) criblés en utilisant un isolat cloné de chacun des virus CMeV, CPMV et SBMV se sont révélés résistants à ces isolats.

Introduction

Le niébé (*Vigna unguiculata* (L.) Walp.) est une légumineuse à graine très sensible à un grand nombre de maladies et d'insectes. Parmi les maladies graves du niébé figurent de nombreuses viroses. Plus d'une vingtaine de virus ont été identifiés sur le niébé dans différentes régions productrices de cette légumineuse en Afrique et ailleurs dans le monde (Bozarth et Shoyinka, 1979 ; Gliem, 1984 ; Gumedzoe *et al.*, 1990a,b ; Rossel et Thottappilly, 1985 ; Shoyinka *et al.*, 1978 ; Singh et Allen, 1979; Thottappilly et Rossel, 1985).

Bien que des travaux antérieurs signalent la présence au Togo de plusieurs viroses des légumineuses dont le niébé (Gliem, 1984 ; Rossel et Thottappilly, 1985), aucune étude de caractérisation des isolats viraux ni d'identification de variétés résistantes à l'égard de ces virus n'a été effectuée. Nous avons donc entrepris de 1987 à 1990, des prospections phytosanitaires en vue d'inventorier les principaux virus du niébé dans les diverses régions productrices de cette légumineuse au Togo. Le présent article rapporte les résultats de ces et de recherche de variétés résistantes à certains des isolats clonés de trois de ces virus (CMeV, CPMV et SBMV).

Matériel et Méthodes

Les anticorps utilisés lors du test sérologique ont été fournis par le laboratoire de Virologie de l'Institut International d'Agriculture Tropicale (IITA, Ibadan, Nigéria). Les conditions de semis et de production des plantes utilisées ont été décrites dans des publications antérieures (Gumedzoe *et al.*, 1990a, b).

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La collecte des échantillons de feuilles virosées a été réalisée de 1987 à 1990 dans les champs des paysans et dans les parcelles de certains organismes et institutions de recherche ou de production de semences du niébé dans le pays. Des feuilles avec symptômes (marbrure ou mosaïque) ou sans symptôme sont récoltées aussi bien dans les cultures pures que dans les cultures associées. Certains échantillons ont été prélevés sur des plantes sauvages ou fourragères et sur des espèces végétales cultivées en dehors du genre *Vigna*. Deux tests sérologiques précédemment décrits (immunodiffusion dans un gel d'agarose et immunoenzymatique ; Elisa : Enzyme Linked Immunosorbant Assay) ont été utilisés pour l'identification des isolats viraux (Clark et Adams, 1977 ; Gumedzoe *et al.*, 1990a,b ; Thottapilly et Rossel, 1980).

Nous avons procédé à l'inoculation de 38 cultivars de niébé avec des isolats clonés 7-17 et 21-50 du CPMV; pour le CMeV l'isolat cloné 1-43 a été utilisé pour inoculer 23 cultivars de niébé. Cinquante-huit cultivars de niébé ont été inoculés avec les isolats clonés 18-10 et/ou 10-19 du SBMV. La procédure d'inoculation est la même que celle décrite précédemment (Gumedzoe *et al.*, 1990b). Les plantules de niébé ont été généralement inoculées au stade de feuilles cotylédonnaires. Les plants inoculés et les témoins sont gardés séparément dans différentes cages pendant 4 à 6 semaines. Les critères d'évaluation ont porté sur la présence ou l'absence de symptôme, le nombre de plants infectés de même que l'effet de l'infection sur la croissance des plants, suivant une échelle de 1 à 5 (Gumedzoe *et al.*, 1990a,b). Les plants ne présentant pas de symptômes (note 1) et vérifiés par le test d'immunodiffusion dans l'agarose, sont déclarés résistants si le test est négatif.

Résultats

Après avoir analysé 705 échantillons recueillis dans les différentes régions productrices du niébé, les virus suivants ont été identifiés (Tableau 1) : le virus de la mosaïque du niébé transmis par puceron (CAbMV),le virus de la marbrure (CMcV), le virus de la mosaïque du niébé (CPMV), le "southern bean mosaïc virus" (SBMV), le virus de la mosaïque du concombre (CMV) et le virus de la mosaïque du tabac-souche légumineuse (TMV-CS).

Le CPMV est le plus fréquent des virus identifiés avec un taux de prévalence de 64 % dans certains cas, puis suivent le CMeV, le CAbMV, le SBMV et le CMMV. Le CMV et le TMV-CS sont identifiés de façon sporadique dans certains échantillons. Plus de la moitié des échantillons (63,05 %) ont réagi positivement lors des tests sérologiques aux antisera de l'un au moins des six virus du niébé identifiés au Togo, dans les infections mixtes.

Différentes plantes sauvages ont été trouvées infectées par cinq des six virus identifiés (notamment Cassia hirsuta par SBMV, *Centrosema pubescens* par CMMV, *Nauclea latifolia* par CMMV et CAbMV et *Mucuna* sp. par TMV-CS.

Les résultats d'évaluation de la résistance indiquent que 44,74 % des cultivars de niébé sont très sensibles au CPMV et que 34,21 % sont résistants soit à l'un soit aux deux isolats testés.

Tableau 1. Répartition des virus identifiés sur le niébé (*Vigna unguiculata* (L.) Walp) au Togo en fonction des préfectures (prospections phytosanitaires de 1987 à 1990).

PREFECTURE	VIRUS				
	CABMV	CMEV	CMMV	CPMV	SBMV
AMOU			+	+	
GOLFE	+	++	+	+++	+
HAHO	+	+	+	+++	+
KLOTO	+	+		+++	+
KOZAH				++	
OGOU	++			+++	+
SOTOUBOU \	+			++	+
TONE		+	+		
VO		+		+++	+
YOTO				+++	
ZIO	+	+		+++	+

Légende : +++ Très fréquent
++ Assez fréquent
+ Peu fréquent

La résistance de ces cultivars aux deux isolats viraux du CPMV a été ensuite vérifiée par inoculation à des niébé sensibles et par le test d'immunodiffusion dans l'agarose.

Ainsi, les cultivars IT81D-1007, IT82E-16 ; IT83S-818 et TVx 1850-01E sont résistants aux deux isolats étudiés et deux accessions de niébé de l'IITA ; (TVu 410 et TVu 645) sont résistantes à l'isolat 21-50 du CPMV.

Les résultats indiquent de même, que seul le cultivar 58-146 est résistant au CMeV (isolat 1-43) tandis que le cultivar TVx 1850-01E est tolérant à ce virus.

En ce qui concerne le SBMV, l'étude révèle que seize cultivars (soit 27,58 %) se sont montrés résistants à l'isolat 18-10. Ce sont : IT82D-789 ; IT82D-786, IT82D-703, IT82E-16 ; IT82E-60, IT83S-818, IT82E-885, TVx1850-01E, TVx1193-9FTVu645, TVu19, TVu410, 58-146, Locale Blanche, Locale Afagnanga et Diapaga. De même, six cultivars se sont révélés résistants àl'isolat 10-19 de ce virus; il s'agit de IT82D-786, IT82D-703, TVx1193-9F, TVx1850-01E, 58-146 et IT83S-818.

Discussion

Parmi les trois virus isométriques CMeV, CPMV et SBMV identifiés, le CPMV est le plus fréquent. Nos résultats confirment ainsi ceux obtenus par d'autres auteurs (Gliem, 1984 ; Singh et Allen, 1979). D'autres virus du niébé, non moins importants, regulièrement identifiés dans différentes régions (Thottappilly et Rossel, 1985) ont été retrouvés au Togo : ce sont : le CAbMV, le CMMV, le TMV-CS et le virus de la mosaïque du concombre (CMV).

En vue de recenser d'autres virus du niébé parfois en concentration plus faible dans les plantes il est important d'améliorer les techniques actuelles d'identification pour les rendre plus sensibles, ou de développer de nouveaux tests plus fiables (ex dot-blot, hybridation moléculaire etc...) (Miller et Martin, 1988). Dans le même ordre d'idée, l'usage d'anticorps monoclonaux (spécifiques ou non) devra être privilégié lors de l'inventaire des principaux virus du niébé.

Diverses sources de résistance au CPMV et à d'autres virus du niébé ont été identifiés dans le germplasme de plusieurs accessions de niébé de l'IITA : ce sont TVu393, TVu493 ; TVu1185, TVu 410 et TVu616 (Singh et Ntare, 1985 ; Singh et al., 1984). Ces sources de résistance ont permis la mise au point de variétés résistantes de niébé au CPMV et à d'autres virus de cette légumineuse. Ainsi plusieurs cultivars du niébé, avaient été identifiés comme résistants à l'égard du CPMV (IT82E-16, IT83S-818, TVx1850-01E etc.. (Singh et Ntare, 1985). Certains de ceux-ci se sont également révélés résistants aux deux isolats du CPMV étudiés (7-17 et 21-50) et à l'un des deux virus CMeV et SBMV.

La variété de niébé 58-146 largement diffusée dans les régions productrices de cette légumineuse est résistante au CMeV, mais très sensible à l'égard du CPMV. D'autres cultivars de niébé couramment cultivés (Vita 5, IT81D-985 etc..) sont très sensibles aux trois virus isométriques (CMeV, CPMV et SBMV) étudiés. Seul le cultivar TVx1850-01E est résistant à la fois aux trois virus ci-dessus mentionnés. Compte tenu de ce niveau de résistance multiple affichée par ce cultivar et aussi de son bon niveau de rendement (plus d'une tonne à l'hectare) ce cultivar peut-être largement diffusé au niveau des paysans si la contrainte couleur des grains est levée dans certains milieux.

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PART III

Maize

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Regional Approach to Maize Research for the Semi-Arid Zone of West and Central Africa.

J.M. FAJEMISIN.

Coordinator, Maize Network IITA/SAFGRAD Ouagadougou, Burkina Faso.

Abstract

Maize *(Zea mays* L.) is an important food crop and major component of the cropping systems in West and Central Africa with about 3.8% per year increase in production over the past 20 years. The sub-region has, however, stagnated in yield over the period at 1.0 t/ha whereas world average has virtually doubled from 2.2 to 3.5 t/ha. The SAFGRAD Maize Network is a research strategy to: (i) address the prevailing climatic, biotic, physical and socio-economic constraints, most of which are common to the countries in the sub-region, by pooling the limited resources of the national programmes to promote the generation of appropriate technologies, through collaborative priority research projects by Lead Centres, and (ii) enhance the interaction and exchange of information, germplasm and manpower. Managed under a concerted leadership of a Steering Committee of elected active national maize scientists, the Maize Network has recorded significant progress over the past four years. Among the indicators of achievements towards the attainment of set objectives are: (i) increasing number of varieties composing regional trials comes from the national programmes, (ii) several national programmes are using varieties selected from the regional trials for release or as sources of germplasm for breeding, (iii) influence on the research agenda of international centres, (iv) increase in the number of scientific papers presented by national scientists in SAFGRAD organized workshops, and (v) improved precision in field experimentation and the handling of trial data.

Introduction

The semi-arid ecology of the West African savanna belt is shared by 15 of the 24 countries in the sub-region of West and Central Africa (Table 1). This ecology of about 211 million hectares gross land area repre-sents approximately 22% of the total land area in the sub-region.

Maize (*Zea mays* L.) is an important food crop in the sub-region, with over 70% of the production being used as food (CIMMYT, 1981). It is a principal component of the cropping systems. Maize production has increased at about 3.8% per year in the sub-region within the past 20 years compared to 1.4% for Eastern and Southern Africa (Table 2). However, yields in West and Central Africa have, virtually stagnated at about 1.0 t/ha compared to 2.2-3.5 t/ha world average (CIMMYT, 1981 and 1990).

The poor maize yields in West and Central Africa is due to low and unstable yield potential of the available production technologies; increasingly unfavourable

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climatic and soil conditions, and a complex of disincentive agricultural policies. The Semi-Arid Food Grain Research and Development (SAFGRAD) Project is an attempt to address these problems through regionally-oriented research. During SAFGRAD Phase I (1979-86), IITA-SAFGRAD scientists, in collaboration with scientists from the National Agricultural Research System (NARS) in Africa, developed or introduced new improved varieties of maize, higlighted the crop management problems of the semi-arid zone, and proposed improved crop management options.

Table 1. Classification of West and Central African countries according to percentage of total land area under semi-arid ecology (600-1100 mm rainfall).

Area Under Semi-arid Ecology %	Countries
0 (Too Wet)	Congo, Equatorial Guinea, Gabon, Liberia, Sao Tome & Principe, Sierra Leone, Zaïre.
0 (Too Dry)	Cape Verde, Mauritania.
1 - 10	Guinea-Bissau, Niger, Chad
11 - 25	Côte d'Ivoire, Ghana, Togo, Guinea.
26 - 50	Benin, Cameroon, Central Africain Republic, Mali, Nigeria, Senegal.
Over 50	Burkina Faso, Gambia.

SAFGRAD Phase II (1987-91) was developed to identify and bring leaders and scientists of NARS to the forefront through the implementation of regional and commodity-based research Networks, including the West and Central Africa Maize Research Network. The major emphasis of each of the five Networks is to strengthen linkages within and among NARS in order to promote the development and diffusion of technologies.

Constraints to Maize Production

The constraints to adequate and efficient maize production in semi-arid West and Central Africa as assembled by scientists from 16 countries in the sub-region include the following (SAFGRAD, 1987a):

Table 2. Maize statistics for West and Central Africa and some other socio-geographical groupings of the world*.

Maize Statistics	West and Central Africa	Eastern and Southern Africa	Developing countries	Developed countries	World
Estimated population (million)	250.8	228.1	3,948.3	813.8	5,190.1
Estimated growth of population 1987-2000 (%)	3.0	3.2	1.9	0.5	1.6
Maize area harvested 1986-88 (000 ha)	5,295	9,871	81,813	34,258	127,771
Maize production, 1986-88 (000t)	5,080	13,662	182,732	213,712	450,91
Maize yield, 1986-88 (t/ha)	1.0	1.4	2.2	6.2	3.5
Maize yield, 1961-65 (t/ha)	0.8	1.0	1.4	3.5	2.2
Growth rate of maize production 1962-66 to 1973-77 (%/yr)	1.3	4.2	4.1	4.1	3.9
Growth rate of maize production 1973-77 to 1984-88 (%/yr)	3.8	1.4	3.5	2.3	2.8
Growth rate of yield of all cereals, 1962-66 to 1973-77 (%/yr)	0.9	1.3	2.5	1.9	2.5
Growth rate of yield of all cereals, 1973-77 to 1984-88 (%/yr)	1.3	0.1	2.8	2.0	2.3

* Source: 1. CIMMYT, 1981.
2. CIMMYT, 1990

a) Need for maize varieties of different maturity cycles, for adaptation to traditional cropping systems and with good husk cover.

b) Susceptibility to major foliar diseases, *Striga*, stem borers, termites and to drought stress.

c) Problems of soil fertility, soil water conservation, production systems and weeds.

d) Inadequate on-farm testing, seeds and other farm inputs, pricing and marketing policies as well as trained manpower.

The Maize Network Approach

a) **Collaborative Research.** Guided by the facts that: (i) virtually all the constraints highlighted are common to most of the countries, (ii) the different national maize programmes are at various levels of research development regarding manpower, infrastructure and programme structure, and (iii) that no one country has the requisite resources to combat all the problems, the approach employed allowed a pooling together of available resources across the sub-region towards developing technologies that are regionally exploitable.

Even then, the pool of resources is not enough to take care of the major constraints identified. Consequently, six of the NARS institutions considered reasonably well endowed with an effective research set up were designated Lead Centres and assigned specific responsibilities for the generation of technologies in addition to the backstopping provided to the Network by IITA. Thus, the various Lead Centres were assigned research responsibilities by the Steering Committee as follows:

The other Network member countries were designated technology-adapting NARS.

Comprising of six elected active NARS maize scientists, the Maize Network Steering Committee is charged with the examination of the work plans, monitors the activities and reviews progress on these assigned projects. The Steering Committee meets biannually and provides concerted leadership for the management of the Network. The IITA provides technical backstopping to the Network by responding to needs from the national programmes for germplasm, experimental techniques and consultation.

b) ***Regional Trials.*** In view of the commonality of production problems, maize trials are composed according to target ecologies or identical production requirements. The approach serves the dual purpose of providing a mechanism for the wide testing of the technologies emanating from IITA and/or the Lead NARS Centres and also avails the technology adapting NARS the opportunity to evaluate elite varieties and other improved packages from which each country can select the most promising for its further testing and eventual release to farmers.

Lead NARS Centre	Breeding	Agronomy
Burkina Faso	Maturity groups and drought tolerance	-
Cameroon	Maturity groups, drought tolerance, and *Striga* control	Production systems for maturity for maturity groups
Côte d'Ivoire	Maturity groups and stem borer resistance	-
Ghana	Maturity groups and streak resistance	-
Nigeria	-	Production systems for maturity groups
Togo	Maturity groups and streak resistance	-

c) ***Training***. Inadequacy of trained manpower is a major constraint in the conception, design and implementation of research projects appropriate to the promotion of increased maize production in most countries. The scarcity of trained manpower is more serious in the technology adapting NARS. Consequently, the Network organizes an annual 5-month practical training for serving maize research technicians, with emphasis on trial management, varietal maintenance, seed production as well as data analysis and interpretation. Such a training programme results in the effective participation of NARS in regional trials.

d) ***Monitoring Tour***. Effective interaction among maize scientists is crucial to a successful Network. In this regard, monitoring tours represent one of the various approaches employed by the SAFGRAD Network system towards enhancing interaction among national programmes and between individual scientists. Organized biennially and involving national maize scientists from different countries together with backstopping from IITA, the monitoring tours enable participants to visit maize research and development activities in the sub-region and to relate experiences to happenings in their respective countries.

e) ***Workshops/Seminars***. The Network organizes biennial workshops/seminars in alternate years with monitoring tours. At such workshops, the status of collaborative research projects is reviewed and scientific papers are presented on findings. The approach permits exchange of methodologies and technologies, thus helping to avoid unnecessary repetition of less viable research options in other countries.

Programme Implementation

a) ***Steering Committee.*** Since its establishment in March 1987, the Maize Steering Committee has guided the Network towards the attainment of set objectives. The participation of IITA, SAFGRAD Coordination Office (SCO) as well as USAID in meetings of the Steering Committee ensures technical and administrative backstopping and effective linkages. The holding of eight meetings thus far in four different countries provides further credibility for the regional approach of the Network system.

b) ***Collaborative Research Projects.*** The collaborative research projects of the Maize Network are at various stages of implementation at Lead NARS Centres. Among notable achievements recorded thus far has been the establishment of streak screening facilities by the Togolese Lead Centre where many breeding populations are at different stages of improvement for streak resistance.

Maize varieties of different maturity cycles have been developed by the Ghana, Togo and Cameroon Lead Centres. These programmes have ensured that the varieties possess resistance to maize streak virus and other important foliar diseases.

Control measures for the parasitic weed, *Striga*, are being sought by the Cameroon Lead Centre within an integrated approach embracing utilization of *Striga* tolerance/resistance source from IITA as well as agronomic options such as the use of trap crops, selective herbicides and fertility management.

Agronomists in Nigeria and Cameroon have commenced research into the determination of appropriate plant populations and fertilizer management for early and extra-early varieties rather than applying the current technologies recommended originally for late-maturing maize.

c) ***Regional Trials.*** From 1987 to 89, the Maize Network organized three types of regional trials, namely: early maturing, drought tolerant varieties; intermediate/late maturing varieties; and extra-early maturing varieties. In order to avoid duplication of efforts in the germplasm offered to NARS, an arrangement has been reached whereby trials relating to early-maturing varieties are, with effect from 1990, to be organized by the SAFGRAD Maize Network while the intermediate/late-maturing trial are to be coordinated by IITA as the Institute charged with maize improvement in the West and Central African region.

There has been a progressive increase in the number of trials requested by NARS, particularly the early and extra-early variety trials (Fig. 1). Similarly, there has been an overall increase in the proportion of the varieties contributed into the regional trials by Lead NARS Centres and other Network-related activities. It is also encouraging that the number of collaborators returning data had increased over the years (Fig. 2), so also has been an increase in the precision level of the trials as reflected by the number of trials with acceptable CV values. Data from the various trials and countries are promptly compiled and distributed to all the member-countries.

d) ***Training.*** Fifteen technicians from 12 countries have so far been trained in the 5-month annual residential practical course at Kamboinse. The technicians are now reportedly capable and effective in the management of regional and other trials, in seed production, varietal maintenance as well as in data analysis and interpretation.

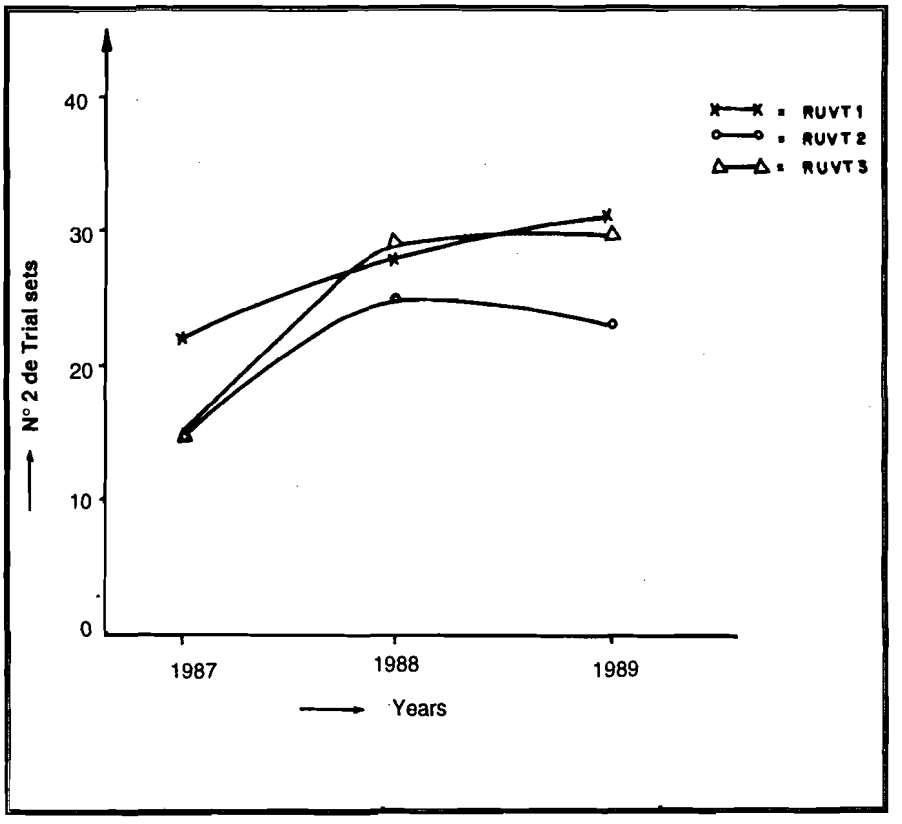

Fig. 1 Regional maize trials, 1987 : n° of sets dispatched

e) ***Workshops and Seminars.*** The Network has so far organized two workshops/seminars for the exchange of research results and methodologies among scientists in the sub-region. A total of 42 maize scientists from NARS and IITA participated in the first workshop in Lomé, Togo, from 20-24 March, 1989. Apart from discussing progress report on collaborative projects, 15 scientific papers were also presented covering maize breeding, agronomy, protection and utilization (Fajemisin *et al.*, 1990). In the second workshop held from 8-14 March, 1991 in Niamey, Niger, 24 scientific papers on maize were presented.

In joint efforts with the Sorghum and Cowpea Networks, a Seminar was organized in January 1991 at Ibadan, Nigeria, for research agronomists in the sub-region and attracted an unprecedented close interaction.

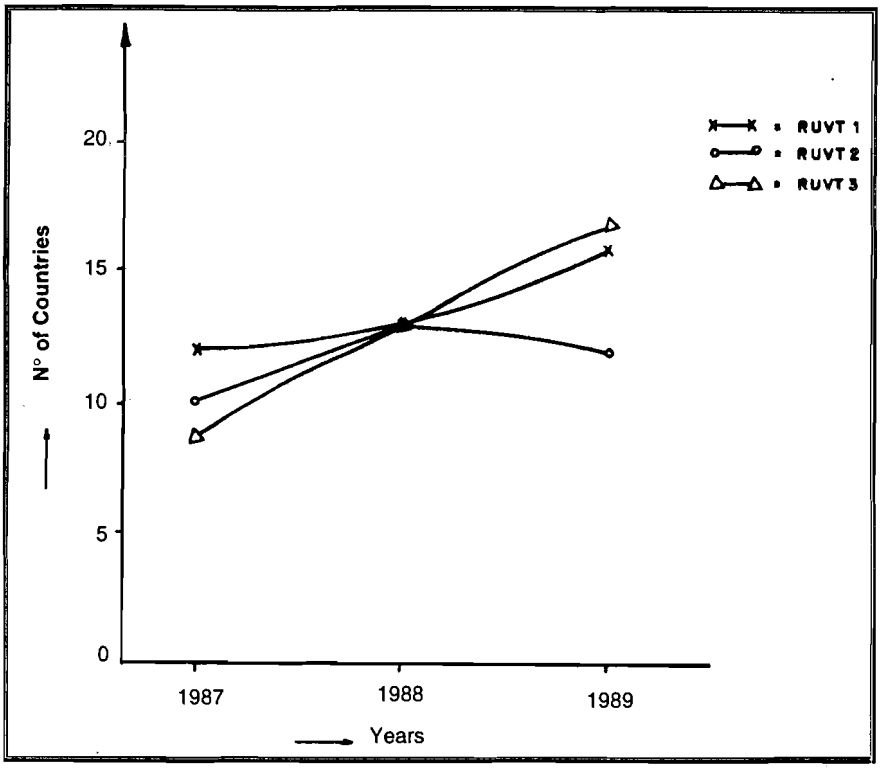

Fig. 2. Regional maize trials, 1987-1989 : data recovery

f) ***Consultation Visits***. The Maize Network Coordinator as well as members of the Steering Committee carried out periodic visits, mostly individually, to member countries. Such visits afforded the on-the-spot generation of feedbacks on the activities of the network in the various countries. The visits by Steering Committee members, in particular, constituted an invaluable exchange of researchers among member countries and a sustainable method of strengthening NARS.

Progress and Achievements

The major objective of SAFGRAD II is to strengthen NARS commodity research programmes and to improve linkages within and among NARS scientists for the ultimate goal of increased and sustained food grain production. To this end, the Maize Network can cite several examples of indicators of commendable progress which are of positive contribution towards the attainment of project objectives and goal. Among achievements recorded and progress made are the following:

a) Regional variety trials are no longer composed exclusively of varieties from the International Agricultural Research Centres; there has been an increasing number of varieties from the national programmes such as Kawanzie, Aburotia, Okomasa and Abeleehi from Ghana; AB22 from Togo; and Ndock 8701 and CMS 8710 from Cameroon.

b) Not only has interest in receiving and attending to regional trials been increased, their execution, data recovery and precision of observations have also steadily improved.

c) Several NARS are using varieties selected from SAFGRAD regional trials as sources of improved germplasm for further breeding and/or release to their farmers (Tables 3 and 4).

d) The re-structuring of research programmes suggested by the Network during consultation visits have mostly resulted in the institutionalization of national variety trials, prudent varietal and germplasm maintenance as well as seed production.

e) Feedbacks on the technicians trained by the Maize Network as obtained during consultation visits, evaluation panels and written commendations received from their supervisors have revealed that the trainees are making outstanding contribution within their respective national programmes.

f) The increase in the number of scientific papers presented at SAFGRAD-organized workshops/seminars is a strong indicator of increased research activities within NARS.

g) The various avenues of scientist-to-scientist contact resulting from the Network activities have created lasting ties for routine exchanges of germplasm and scientific information.

h) Research problems that were once reserved for international agricultural research centres are now gradually and enthusiastically being addressed by NARS.

i) The seriousness of purpose of the Steering Committee as reflected in the reports of its regular and fully attended meetings has influenced the research agenda and/or modified concepts and approaches of international agricultural research centres.

Table 3. National breeding programmes using specific germplasm identified from SAFGRAD Regional Maize Trials.

National Programme	Maize Germplasm
Benin	Across 86 Pool 16 DR, TZE-F, DMR-ESRW
Burkina Faso	TZEE-W
Cameroon	Across 86 Pool 16 DR, TZEF-Y, CSP, TZESR-W Gua 314 BC1 F4, CSP x Local Raytiri
Côte d'Ivoire	Across 86 Pool 16 DR, TZEF-Y, Maka
Gambia	Pool 16 DR
Guinea	DMR-ESRY
Mali	Pool 16 DR
Senegal	Maka
Togo	TZESR-W x Gua 314 BC1 F4, Pool 16 DR

Table 4. Maize varieties released/in the process of release to farmers in some countries in West and Central Africa.

Country	Maize Varieties
Benin	Pirsaback 7930-SR, Sekou 81 TZSR-W-1, EV 8443-SR, TZB-SR
Burkina Faso	22-SR (=EV 8422-SR), KPB (=EV 8430-SR), KPJ (= EV 8431-SR)
Cameroon	Mexican 17E, SAFITA-2, CMS 8806 (= DMR-ESRY), Pool 16 DR, TZEF-Y, TZPB K81
Ghana	Kawanzie, Aburotia, Mexican 17E, SAFITA-2, Abeleehi, Okomasa, Golden Crystal
Mali	SAFITA-2, DMR-ESRW, DMR-ESRY, Golden Crystal
Chad	TZESR-W, CMS 8602 (= EV 8431-SR)
Togo	Ikenne 8149-SR, Pirsaback 30-SR, Poza Rica 43-SR, AB22.

j) Consultation visits by Steering Committee members to other countries portray the increasing leadership role being played by NARS scientists in the sub-region.

k) The production and circulation of several documents originating from the Network, including workshop/seminar proceedings, variety characterization and compilations of regional trial data are vivid examples of information exchange towards strengthening NARS research capabilities.

l) In response to internal and external evaluation reports, the Maize Network has diversified its activities to include agronomic research and agronomic seminars/workshops.

The Tasks Ahead.

In addition to the need to forge ahead with on-going research projects and other activities of the Network, there are other important areas which would need to be resolved in the coming years. For instance, the larger grain borer, *Prostephanus truncatus*, poses real threats to maize production in the sub-region. This extemely voracious insect pest has been reported from Togo, Benin and Ghana and its spread to other countries is only a question of time. There is, therefore, the need to look into its control alternatives, including biological control. The other areas of future concern relate to termites which are widespread in the sub-region; stored-grain pests continue to deplete even the inadequate maize production; and research for better and diversified utilization of maize will go a long way to encourage production and catalyze research efforts. Needless to add the fact that all these challenges can only be done in an environment of improved funding, increased/improved research infrastructure and substantial incentives to NARS scientists.

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Overview of Maize Research at IITA

MARK D. WINSLOW.

Director, Maize Research Programme, International Institute for Tropical Agriculture, Ibadan, Nigeria.

Introduction

Maize is a popular crop in Africa because it is easy to grow, store, transport, mill and cook. With the availability of nitrogen fertilizers, it enjoys a "boom" as a cash crop in the savanna zone, because it is more nitrogen-responsive than the traditional African cereals, millet and sorghum.

IITA conducts research on maize genetic improvement and "pathosystem analysis" within its Maize Research Programme, which activities will be outlined in this presentation. However, it also conducts equally important research on improving maize farming systems in the context of the Resource and Crop Management Programme. The latter work is reaching NARS through a new network of Collaborative Group on Maize-Based System Research, COMBS, which is associated with the West African Farming Systems Research Network.

Focus and Strategy

The Maize Programme at IITA currently focuses on the moist savanna ecology with *Striga* as the highest priority issue. The overall goal of the Programme is to develop varieties that will help West and Central African farmers to reduce the risks associated with intensified maize production. Our strategy for doing this involves breeding for resistance to African-specific pests, diseases and stresses. The IITA extensively utilizes CIMMYT (and other) germplasm as a starting point and incorporate resistances into this base.

How are these resistances found? How can they be screened for effiently? Will they be stable? These are all questions addressed by "pathosystems research". Entomologists, pathologists and *Striga* biologists seek to increase our understanding of the life cycles and ecology of the pests and diseases. This information is used to develop efficient, reliable artificial rearing and infestation techniques which the breeders can use. It also gives us clues as to how genetically variable the pest/pathogen may be and, therefore, how stable a resistance is likely to be. Breeders use this knowledge to develop appropriate genetic resistances.

The IITA Approach

A well-known case study is the development of maize streak virus resistance methodology, which won for IITA the 1986 King Baudouin award, CGIAR's highest accolade. Entomologists and virologists studied the life cycle and ecology of the leafhopper vector and virus and developed mass rearing techniques. Together with breeders, they applied these methods to select not for a single-gene unstable

immunity, but rather for a polygenic, stable resistance. This resistance still holds wherever it has been tested.

This tried-and-true approach, linking pathosystem research to breeding, is being applied to other constraints such as stem borers, storage insects, downy mildew, grain quality and *Striga*.

Striga has become our focus constraint at present and 1990 was a banner year for it. We markedly improved the infestation technique and identified more promising inbred, hybrid and open-pollinated germplasm. A "*Striga* thrust" got underway, which links us with colleagues in other Programmes specializing in agronomy, economics, modelling and biocontrol. Agronomists verified our tolerance/resistance on-farm; economists and modellers started developing a systems model towards helping to see which groups of farmers will find the *Striga* tolerant/resistant varieties most useful; and nematodes have been implicated as a new biocontrol agent. One of the most fascinating things about *Striga* research is that there are so many angles from which to approach the problem.

At present, the level of IITA's *Striga* tolerant/resistant varieties is only moderate; these varieties still suffer considerable yield loss under severe infestation. Nevertheless, progress is continuing; response to selection in our populations has still not reached a plateau. Furthermore, in combination with practices like "ridging up" weed control, the present *striga* tolerant/resistant varieties show a synergistic benefit greater than either component technology alone.

Linkages to NARS

The IITA considers NARS institutions as partners in research and will continue to share any new technologies and germplasm it develops and to benefit from similar advances made by national systems. The NARS must refine and adapt IITA technologies for their own local conditions and consumer preferences if they are to have any impact.

International trials continue as our main modality of germplasm dissemination. The IITA is presently helping several NARS to establish streak resistance screening facilities and uniformly-infested *Striga* screening fields. We are also writing, in collaboration with several NARS scientists, a *Striga* methodology handbook to help transfer the full range of current *Striga* techniques to NARS.

The NARS scientists often mention training as one of IITA's most valuable contributions. Computer and hybrid seed production short courses are being organized for 1991. We continue with internship attatchments and degree training, helping build the human capital that will solve the maize problems of the not-too-distant future.

In every ite mentioned above, IITA has benefitted immensely from the role played by SA GRAD. Without the SAFGRAD Network system, we would simply not h ve the n npower to keep even half of our collaborative links going.

Looking to the Future

For the future, IITA looks forward to the establishment of a Savanna research station in collaboration with Côte d'Ivoire. We are awaiting signing of the agreement with the Government. This facility will particularly improve our ability to work collaboratively with West African Francophone NARS.

We also look forward to rapid progress on *Striga*. We have assembled a critical mass of outstanding scientists who, given a little time, will give us cause to apply for another King Baudouin award. IITA feels that biotechnology may play a greater role in our future work. We are using RFLP now to measure genetic variability in the downy mildew fungus. We are studying what biotechnology might contribute against stem borers and *Striga*.

We also see for the future the looming problem of over- production of maize in the region, which could drive prices (and farmer profits) down. We are wondering about alternative uses of maize that might provide new markets. What quality factors should we need to breed for ?

In conclusion, it is our belief that close collaboration between IITA and NARS maize scientists will be essential if research findings are to have practical impact.

Analysis of Daily Rainfall Data and Its Application to Maize Production in the Transitional Zone of Ghana.

S. OHEMENG-DAPAAH.

Ghana Grains Development Project, Kumasi, Ghana.

Abstract

Data for daily rainfall for 40 years at Wenchi, a transition zone in Ghana, were analysed by the simple direct method. The analysis revealed that in 40% of the years the suitable planting date for maize in the major season occurred between 12-18 March. The risk of a false start was calculated as 0.1. The importance of the use of daily data for the analysis was stressed. The simple or direct approach method was used to answer such questions as dry spells and the start of the growing season for maize crop.

Introduction

It is universally true that many areas which experience seasonal rainfall pattern also experience high year-to-year variability in the pattern of rainfall. Although the mean rainfall may seem adequate for crop growth, there is high probability that in any one year there may be marked extended drought resulting in insufficient moisture at critical stages of crop growth.

Rainfall variability constitutes the dominant characteristic of the climate of Ghana. Adequate precipitation may not always coincide with critical crop growth stages due to the high year-to-year variability in the onset of rainfall. The date of planting is, therefore, critical and by correctly deciding on when to plant, the risk of crop failure may be minimised. Considerable difficulty has been experienced in establishing the most appropriate planting date and it has often been necessary to plant twice or even thrice in order to get a crop established. This irregular onset on rains has also made the interpretation of agronomic experiments quite difficult.

The usual practice of determining the optimum planting time has been to plant a crop at various potential planting times and record the yields. The planting time resulting in the highest yield is then noted. This is usually done for a maximum period of five years and the mean of the optimum dates found each year is taken as the best planting time for the crop. The limitations of this approach arise from the high year-to-year variation in rainfall. Furthermore, a five-year period of data is extremely inadequate to arrive at any meaningful conclusions and, consequently, planting dates based on such data usually prove unreliable. Also there is a high probability that all five years will have extreme high or low rainfall and the mean optimum planting date will be correspondingly misleading.

Maize is known to be particularly sensitive to water shortage immediately after germination and flowering. Glover (1959) emphasized that maize stomata do not

recover after a severe drought of 7 or more days, although leaves may recover their turgidity. Knowledge of the relationship between the number of dry days in the growth cycle of maize could be of great economic and agronomic value.

The objective of this study was, therefore, to estimate the optimum planting time, with emphasis on dry spells, by analysis of climatic data alone. This alternative approach makes the obvious assumption about the relationships between crop growth and water. Data from Wenchi, a large maize growing area in the transition zone of Ghana, was used in the study.

Materials and Methods

a) ***Data Availability and Accuracy***. The data for the study were made available by the Ghana Meteological Department in Accra. Data from 40 years (1950-89) were used. To ensure that any analysis performed draw valid conclusions, the quality of the data was investigated at the initial stage of the analysis. Monthly totals were calculated and compared to monthly totals supplied by the Meteological Department and where there was any discrepancy, the necessary corrections were made.

b) ***Start of Growing Season***. In defining an event to mark the start of the growing season, Stern et al. (1982) emphasized that daily rainfall values should be used. Most authors have in their studies of the start of rains used rainfall amounts summarized over years which makes it difficult to interpret the resulting average dates. The start of the growing season for this analysis was computed based on the simple assumption that the earliest date (D) is when rainfall is sufficient to provide water equivalent to or greater than one half of reference crop evapo-transpiration (ETo) and remain greater than ETo for the remainder of the growing season. The potential start was considered a false start if a dry period of 7 days or more occurred in the week after this date. The earliest date, D, as defined here, was chosen to be 14 February before which farmers would normally not do any planting. Studies that have used this definition (rainfall - 1/2 ETo) include Benoit (1977) in the determination of the start of the growing season in Northern Nigeria. There are different methods used for calculating ETo values, but in the present study the Priesttly Taylor method was used. The minimum requirements for the Priesttly Taylor equation are the daily net radiation and the mean daily temperatures. Using these assumptions and procedures, a suitable planting date was determined for each year for the major rainy season.

c) ***Dry Spells.*** A dry day was defined as a day when rainfall was zero or less than a threshold value of 0.85 mm. This threshold value was used to overcome the problems of data recording which sometimes vary from station to station and possibly between periods at the same station. Days on which less than 0.85 mm of rainfall occurred were considered dry. Daily rainfall data was used in this analysis to allow the risks of dry spells and probability of heavy erosive rainfall to be estimated (Stern *et al.*, 1982). The daily observations were used to calculate the probabilities of dry spells of length 5, 7, 10 and 15 days in overlapping 30-day periods from 1st January to 31st December.

Results and Discussions

The results indicated that for a sample of 40 years, late plantings occurred on 2nd April, 1983 and 4th April, 1988 (Table 1). A considerable variability in the distribution of the planting dates was found (Fig. 1). No simple explanation could be put forward for the large variation in the onset of the growing season in individual years. In a number of years, the early rainfall had been sufficient and exceeded half of ETo, but were usually followed by dry periods of one week duration or more. Thus, the term 'false start' of the growing season may be applied to such dates which had early rainfalls and yet were followed by long dry periods (Table 1). For the 40 years data, the risk of false start was calculated as 0.1 or 4 out of 40 years.

A cumulative percentage distribution of the start of the growing season indicated that the median date for the start of the growing season was week 11 (12th-18th March) in 16 out of the 40 years (Fig. 2). The median date was used instead of the mean because it (median) is not affected by extreme dates. The results also showed that in 75% of the years, the start of rains occurred by week 12 (19-25 March) while in 52.5% of the years the start occurred by week 11. The results, therefore, indicated that the commencement of the growing season in order of highest probability were: week 11 (40%), week 12 (22.5%), week 13 (17.5%), week 14 and 10 (7.5%) and week 9 (5%). It was, thus, obvious that the best time for the 40 year period to start planting was week 11 (12-18 March) in the Wenchi area.

Dry Spells. Results of the probabilities of dry spells are depicted in Fig. 3. The high probabilities (=90%) of dry spells of 5 days or more occurred between January to the middle of March and from July to August. The probabilities were lowest during the rainy seasons in June and September. The probabilities of dry spells of at least 7 days was similar to that of 5 days, but the values were lower. The probabilities of dry spells of at least 10 days were very low in June and in the middle of September. Rainfall at these periods is, therefore, reliable for maize growth. The problem of death of young crops especially soon after emergence is mainly due to false start of rains. This normally occurs when crops are sown during substantial rainfall but followed by long dry periods. In the Wenchi area, it is recommended that planting should not be done before March, since there is a high probability that a long dry spell of 10 days or more would occur.

Table 1. Predicted optimum start of the growing season in specific years in Wenchi, Ghana, 1950-89.

Year	Optimum Date	Year	Optimum Date
1950	March 28th	1970	March 10th
1951	March 22nd	1971	March 31st
1952	March 16th	1972	March 13th
1953	March 13th	1973	March 26th
1954	March 14th	1974	March 4th
1955	March 20th	1975	March 15th
1956	March 15th	1976	March 11th
1957	March 17th	1977	March 28th
1958	March 19th	1978	March 13th
1959	March 4th	1979	March 17th
1960	March 14th	1980	March 16th
1961	March 24th	1981	March 26th
1962	March 21st	1982	March 13th
1963	March 22nd*	1983	April 2nd
1964	April 3rd	1984	March 10th
1965	March 15th	1985	April 1st
1966	March 14th*	1986	March 31st*
1967	March 20th	1987	March 14th
1968	March 22nd	1988	April 4th
1969	March 20th	1989	March 12th

* In the dates indicated with asterisk, there were possibilities of planting earlier than the indicated dates but dry spell of seven days or more occurred between earlier ("false") date and given date for start of growing season.

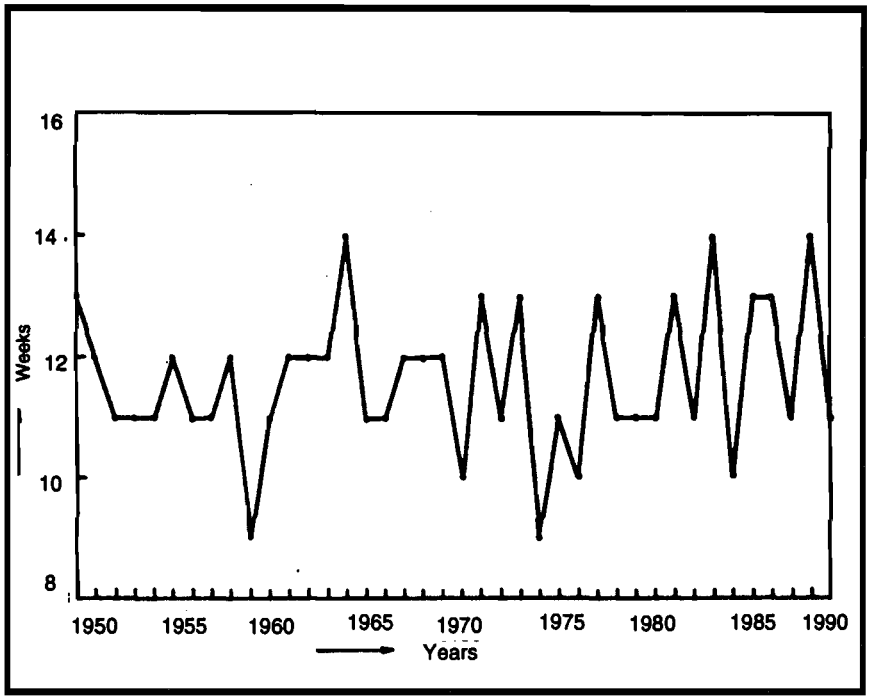

Fig. 1 - Predicted Optimum Start of the Major Cropping Season, Wenchi, Ghana.

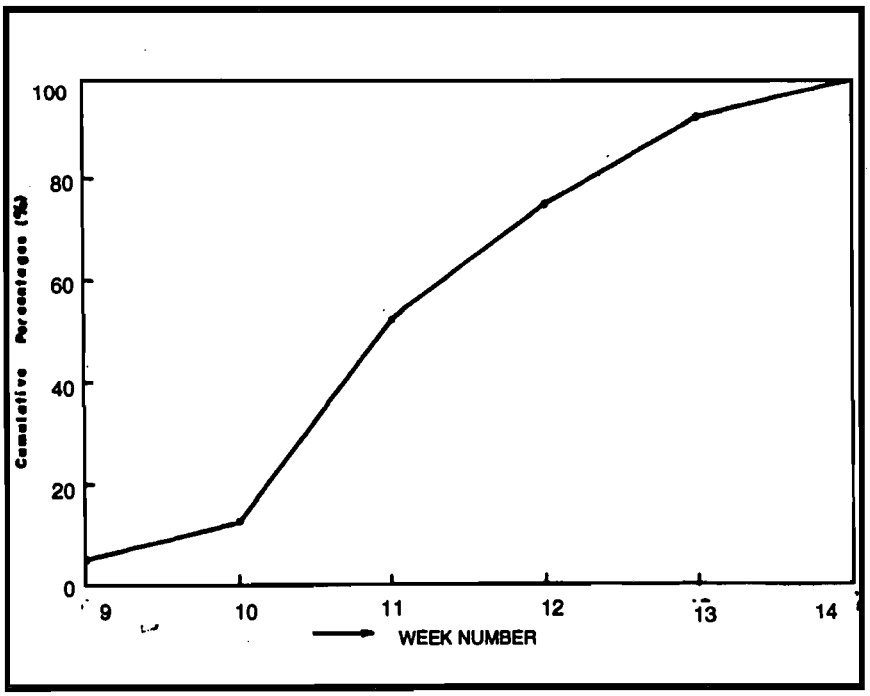

Fig. 2 - Cumulative Percentages : Start of the Major Cropping Season, Wenchi, Ghana.

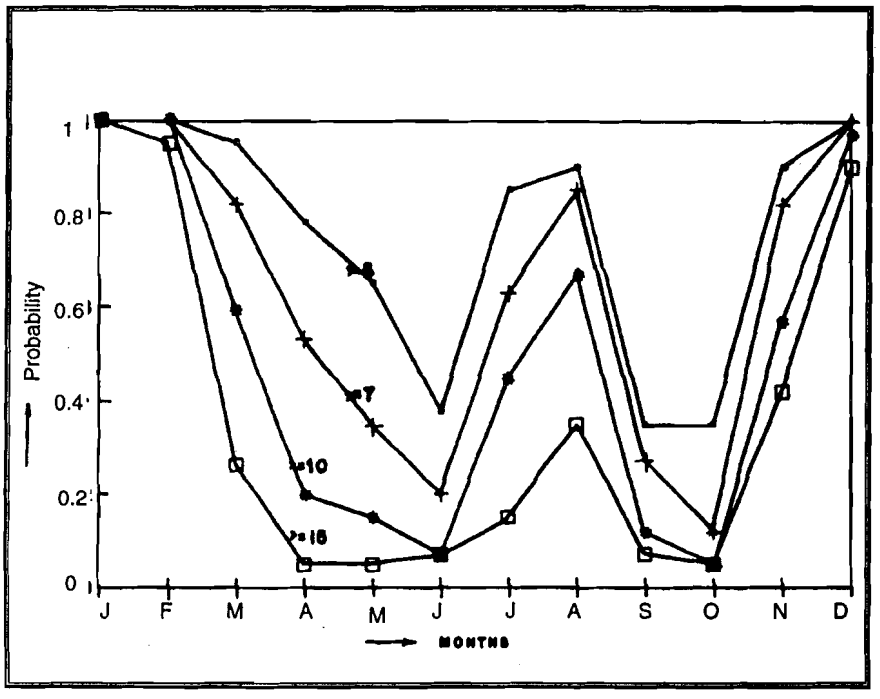

Fig. 3 - Probability of dry Spells at Wenchi, Ghana (dry Spell Length > = 5, 7, 10. 15 days in 30 days).

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Diallel Analysis of Maize Inbred Lines Evaluated in the Forest-Savanna Transition and Guinea Savanna Zones of Ghana.

TWUMASI-AFRIYIE, S., B. BADU-APRAKU and P.Y.K. SALLAH.

Ghana Grains Development Project, Kumasi, Ghana.

Abstracts

One of the most important problem facing maize breeders is the identification of specific inbred lines that will produce high agronomic performance in hybrid combinations. A diallel cross (excluding parents and reciprocals) of 12 maize (*Zea mays* L.) inbred lines were evaluated in three different environments in Ghana in 1989. The objective of the trial was to identify the inbred lines with the best specific combining ability for hybrid production. The inbred lines included three S6 lines derived from S3 lines received from CIMMYT and selected following topcross evaluation in Ghana; inbred lines 1393 and 1368 from IITA, and seven S6 Ghana inbred lines derived form Ejura (1) 7843. The evaluations were conducted at Ejura in the forest-savanna transition zone and at Nyankpala and Damongo in the Guinea Savanna zone. The diallel analysis was done using Griffin's Method 4 for the characters grain yield, plant height and number of days to mid-siling.

The results revealed that both general combining ability and specific combining ability effects were significant for all three characters studied but the latter was more important than the former. General combining ability effect for grain yield was highest for GH24 derived from Ejura (1) 7843, for GH2 and GH3 derived from CIMMYT materials and for 1368 and 1393 from IITA. High specific combining ability effects were manifested by several single crosses. The highest specific combining ability effects based on grain yield were obtained for the crosses GH24 x GH3 and GH2 x 1368. The results showed that specific combinations existed that could be considered for further testing for possible commercial hybrid production. Also, the high general combining ability effects for particular lines indicated their possible use in forming synthetic varieties.

Introduction

Until 1986, the main focus of the national maize programme in Ghana was on the development of open-pollinated maize varieties. In 1986, a review team recommended that a modest effort should be devoted to the development of hybrid maize (Badu-Apraku and Arias, 1987). This was in the recognition of the fact that advances made in maize research and extension especially through the efforts of the Ghana Grains Development Project, has produced elite farmers who will be able to take advantage of the increased yield potential expected from hybrid maize. The initial approach to hybrid maize development was to select the Tuxpeno-based Population 43 from CIMMYT, Mexico, as the female population in the hybrid programme, since materials from this population had proved to have the highest yield potential in Ghana (Twumasi-Afriyie, 1983). Inbred line development was,

therefore, initiated in Ejura (1) 7843. It was of interest to determine which materials from the programme and elsewhere will combine well with inbred lines derived in the Tuxpeno material. Combining ability study was, therefore, initiated for these materials. The term combining ability is used to denote the performance of lines in hybrid combination (Sprague and Tatum, 1942). These workers also defined general combining ability (GCA) as the average performance of a line in hybrid combination. They also used the term specific combining ability (SCA) to refer to cases where particular hybrid combinations do relatively better or worse than would be expected on the basis of the average performance of the lines involved. Thess concepts were developed qualitatively mainly by Griffing (1956) and have been widely applied both in crop and animal breeding. The objective of this study was, therefore, to identify inbred lines with the best specific combining ability for hybrid maize production.

Materials and Methods

A total of 12 inbred lines were used in the study: GH22, GH23, GH24, GH26, GH27, GH29, GH32, GH1, GH2 and GH3 developed in Ghana's national maize programme; 1368 and 1393 developed by IITA, Ibadan, Nigeria. The first six of the Ghanaian inbred lines were S6 lines derived from Ejura (1) 7843 through continuous selfing and selection. GH1, GH2 and GH3 were among 10 inbred lines received as S3 lines from CIMMYT in Mexico in 1987. The S3 lines were topcrossed to Ejura (1) 7843 and also advanced to S5 by selfing. The three lines were selected as a result of the topcross evaluation and advanced to S6. Diallel crosses were made among the 12 inbred lines in 1988 by crossing them in all possible combinations. For the evaluations, parents and reciprocals were not included. Thus, the 12 inbred lines gave 66 entries.

The experimental design was a randomized complete block, with two replications. The experiments were grown at Ejura in the forest-savanna transitional zone and at Nyankpala and Damongo in the Guinea savanna zone of Ghana. The land was ploughed and harrowed. At planting time, Primagram was applied at 2.5 kg a.i./ha. In Cyperus-infested areas, a combination of Sutan and Primagram at 1.8-2.5 kg a.i./ha was substituted for Primagram alone.

Gross plots measured 5 m long, with 0.8 m row spacing and 0.5 m between plants. A plot consisted of two rows of plants. At planting, three seeds were sown and later thinned to one seedling per hill. A fertilizer analysis of 90:60:0 kg N.P.K./ha was applied in split-application at planting and at 4 weekds after planting. Plots were kept free of weeds by hand weeding whenever it was found necessary.

Field data collected included number of days to silking, plant and ear height, lodging, grain moisture and grain yield. Specific to lodging, all plants broken below the upper eat (stalk-lodged) and those that had follen down at root level (root-lodged) constituted total lodging. Lodging data were transformed using the arcsin transformation. Streak infection was rated on a 1-5 scale, with 1 = resistance reaction and 5 = susceptible reaction.

The MSTAT Microcomputer statistical Programme, version 4.0 (Michigan State University, 1986) was used for all the statistical analyses. All the analyses of variance were based on individual plot means, except for plant and ear height which were on the mean for five competitive plants per plot. Environments were treated as random in the analyses. While varieties were considered fixed variables. A partial diallel analysis for general combining ability was done using the combined means and based on griffing Method 4 for p (p-1)/2 F1's without parents nor reciprocals (Griffing, 1956). A spreadsheet programme based on formulae by Griffing (1956) was written on a microcomputer and used for the partial diallel analyses. For the purpose of this paper, three variables, namely: grain yield, plant height and number of days to 50% silking, were used.

Results and Discussions

Mean squares obtained for all three characters used in the study were highly significant. Subsequently, the genotypic variation was partitioned into variation due to GCA and SCA in a combining ability analyses. Both GCA and SCA effects for all three characters were highly significant (Table 1). It may be noted, however, that in this study, SCA effect was more important than GCA effect as indicated by the relative magnitude of the respective mean squares.

Table 1. Mean squares from combining ability analyses of 12 maize inbred lines crossed in diallel and tested at three locations in Ghana, 1989.

Source of variation	df	Grain yield (kg/ha)	Plant height (cm)	50 % silking (days)
GCA	11	1,033,049**	747**	5**
SCA	54	316,613,029**	25,633,671**	2,757,081**
Error	195	442,426	79	0.9

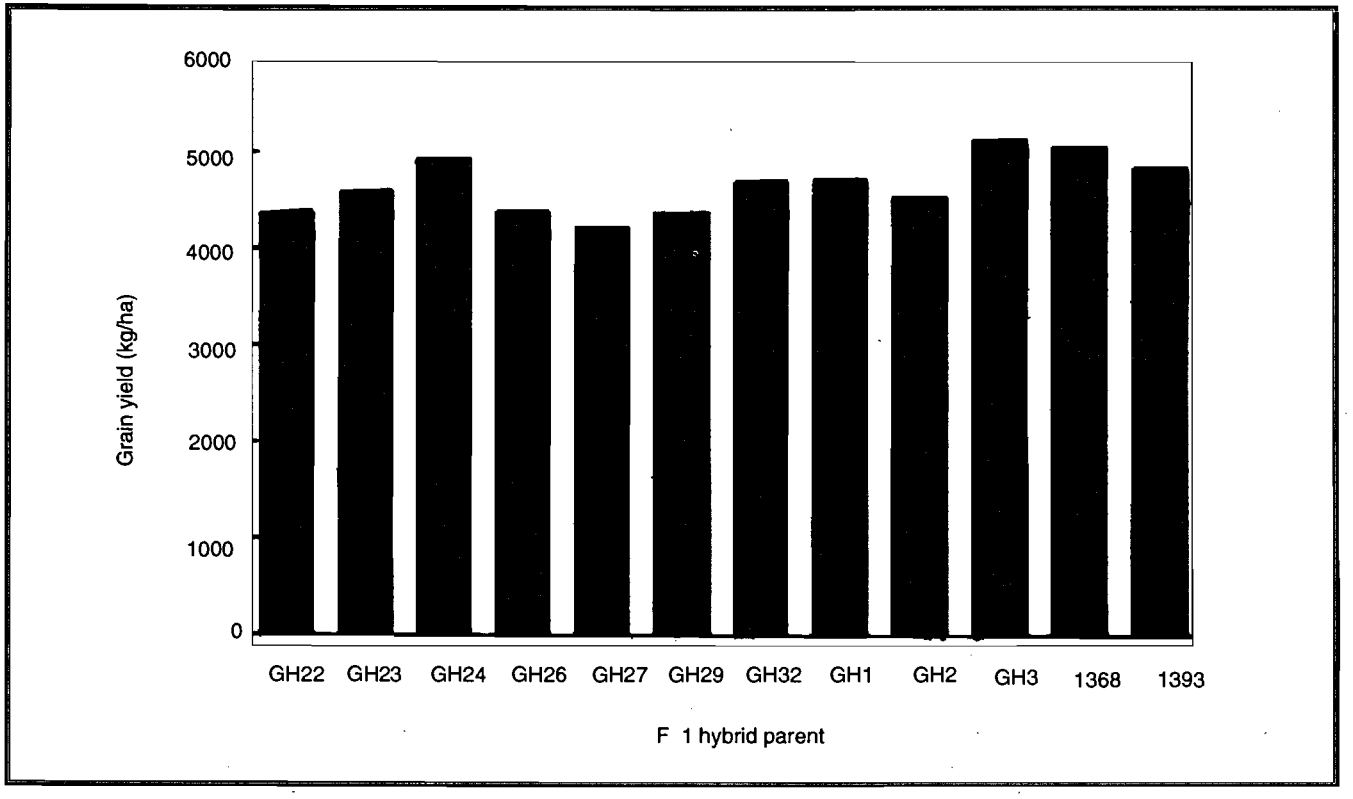

Fig. 1 Hybrid array means of grain yield of 12 maize inbred lines, Ghana, 1989.

Table 2. Estimates of general combining ability effects for maize grain yield, plant height and days to 50% silking of 12 inbred lines tested at three locations in Ghana, 1989.

Parent	Grain yield (kg/ha)	Plant height (cm)	50% silking (day)
GH22	-324.8	-7.8	0. 22
GH23	- 63.7	-2.2	-1.27
GH24	284.7	12.1	0.88
GH26	-296.2	-1.0	-0.85
GH27	-478.2	-3.0	0. 02
GH29	-291.4	-3.0	-0.52
GH32	37.2	7.6	0.11
GH1	66.6	6.4	0.88
GH2	116.8	1.7	-0.27
GH3	538.9	1.7	0.96
1368	439.0	8.1	-0.47
1393	204.6	-20.5	0.32
S. E. (gi-gi)	171.7	4.0	0.40

Table 3. Estimate of specific combining ability constants (sij) for maize grain yield of 12 inbred lines tested in diallel combinations in Ghana, 1989.

1368	GH22	GH23	GH24	GH26	GH27	GH29	GH32	GH1	GH2	GH3	1368	1393
GH22												
GH23	187											
GH24	-631	242										
GH26	493	63	534									
GH27	722	-82	9	277								
GH29	266	-38	-23	-306	-138							
GH32	98	-24	-145	-302	87	70						
GH1	367	-139	218	17	-520	665	171					
GH2	-1163	-240	335	279	287	-291	-37	29				
GH3	333	-238	917	-64	-629	-106	-262	-108	-195			
1368	-689	464	-97	82	-87	-248	43	-561	929	245		
1393	16	-196	-293	-7	72	149	302	-140	67	108	-81	

S.E. (sij-sik) 515 i = j, k; j = k
S.E. (sij-skl) 485 i = j, k, l; j = k, l; k = l

Hybrid array mean values for grain yield for F1's when each inbred line served as a parent in a series of single crosses indicated that GH24, GH3, 1368 and 1393 gave the top yields (Fig. 1). Depending on the character of interest, both positive and negative effects are of importance in combining ability analyses. Estimates of the GCA effects for grain yield indicated that the four inbred lines, GH24, GH3, 1368 and 1393 also gave the highest positive GCA effects (Table 2). Of these four inbred lines, GH3 and 1368 tended to increase plant height in hybrid combination as indicated by the high positive GCA effects for plant height. On the contrary, 1393 had the tendency to decrease plant height. Also, there was the tendency of F1's involving GH24 to flower later than expected.

Estimates of SCA effects indicated that for grain yield, high positive values were obtained for several crosses, prominent among them were: 1368 x GH2, GH3 x GH24, GH27 x GH22 and GH32 x GH29 (Table 3). The significant SCA effects indicated that these crosses yielded more than would be expected on the basis of average performance. Estimates of the SCA effects of the four inbred lines with the highest positive GCA effects for grain yield were compared to determine particular combinations that gave increased performance. From the results presented, it is evident that GH24 combined well with GH23, GH1, GH2 and GH3 while GH3 combined well with GH22, GH24 and 1368. In addition, 1368 combined well with GH23, GH2 and GH3 while the inbred line 1393 combined well with GH32.

Table 4. Estimates of general combining ability variances associated with each maize inbred parent on plot basis for three characters, Ghana, 1989.

Parent	Grain yield (kg/ha)		Plant height (cm)	50% Silking (days)
GH22	-29	715.0	-7.87	1. 27
GH23	1131	129.9	-2.23	2. 83
GH24	-54	133.8	12.07	2. 00
GH26	-47	488.4	-0.95	1. 94
GH27	93	473.1	-2.99	1. 22
GH29	-50	271.5	-2.99	1. 49
GH32	-133	800.4	7.64	1. 23
GH1	-130	749.6	6.42	1. 99
GH2	-121	544.9	1.65	1. 29
GH3	155	264.5	1.69	2. 15
1368	57	529.0	8.07	1. 44
1393	- 93	324.5	-20.50	1. 32

Table 5. Estimates of specific combining ability variances on plot basis associated with each maize inbred parent for three characters in a combining ability study.

Parent	Grain yield (kg/ha)		Plant height (cm)	50% Silking (days)
GH22	202	694.4	-28.56	-0. 16
GH23	-83	330.2	-11.47	-0. 50
GH24	53	101.9	-27.93	-0. 56
GH26	-44	385.6	-21.82	ä-0. 62
GH27	6	619.9	-17.99	ä-0. 38
GH29	-51	342.2	-6.59	ä-0. 58
GH32	-99	959.3	54.66	ä-0. 45
GH1	-3	735.2	33.44	ä 0. 05
GH2	134	893.5	28.58	ä-0. 25
GH3	28	260.8	34.44	ä-0. 40
1368	694	438.5	-36.97	ä-0. 11
1393	-104	157.5	285.60	ä-0. 77

Generally, GCA variances for grain yield associated with the inbred lines were low, except for GH23 and GH3 (Table 4). The four lines with the highest GCA differed in their effects. The inbred lines GH24 and GH3 had low SCA variances (Table 5) hence, they transmit their high yielding ability uniformly to all their F1's. On the other hand, 1368 had a high SCA variance associated with it, thus indicating that certain specific combinations involving this line yielded considerably more while others yieldless than expected. Overall, GH24 and GH3 appeared superior to 1368 especially where the interest is in the formation of synthetic varieties. But where the interest is for the formation of specific high yielding F1's, then inbred line 1368 would be preferred.

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Inheritance of Soft and Floury Endorsperm in Some Local Maize Varieties of West and Central Africa.

B. BADU-APRAKU[1], J.H. MARECK[2] and J. KLING[2].

[1] *Ghana-CIDA Grains Development Project, Kumasi, Ghana*
[2] *IITA, Ibadan, Nigeria.*

Abstract

The inheritance of the soft and floury endosperm of some local maize varieties of Ghana, Togo and Cameroon was studied in each of five generations derived from a cross between each local variety and the normal endosperm variety, TZESRW or 8321-18. The generations consisted of the F2, F1, reciprocal F1 crosses, backcrosses and reciprocal backcrosses. In addition, F1 crosses were made among the local varie-ties and the progenies selfed to obtain the F2 generation for tests for allelism. Chi-square analysis of the data indicated that the Ghana and Togo Locals possess the same single recessive gene for the floury endosperm. The Cameroon Local, however, was found to possess a different single recessive gene for the floury endosperm. Gene designations would be assigned to the two different single recessive genes conditioning the expression of the floury endosperm in the three local varieties after tests for allelism with other named genes are completed.

Introduction

Maize (*Zea mays* L.) is the dominant food crop in most of West and Central Africa. Maize forms the basis of the a wide range of local dishes and it is often consumed fresh on the cob. In the high maize-consuming countries, the local varieties with soft, floury endosperm are generally preferred because they can make better corn meal or dough. Even though a number of improved varieties which are higher-yielding have been released by the national maize programmes in collaboration with the international research centres (IITA, CIMMYT and SAFGRAD), their adoption are not very high. The result is that the improved varieties have not had the expected impact on production. In Ghana, for example, during harvesting time when maize is abundant, a premium price is usually paid for the local maize. A major reason for the reluctance of some farmers to adopt the available improved varie-ties is that they do not possess the desirable grain type of the local varieties. For a long time, the national maize breeders and the scientists of the international research centres did not take into serious consideration consumer preference for the soft, floury grain texture in the development of improved varieties. However, there is now an increasing awareness of the need for the incorporation of the desirable grain characteristics of local varieties into improved cultivars. As a result, attempts are currently being made to incorporate the soft and floury characteristics of the local varieties into improved varieties by maize breeders in Ghana, Togo, Cameroon and Nigeria.

Coe *et al.* (1988) have reviewed the inheritance of the floury grain texture in the maize endosperm and reported that the expression of this character is conditioned by

several genetic factors, these including cf12, f11, f12, f13, h, Mc, 01, 02, 05, 07, 09, 010, 011, 012, 013, pro, sen 1 through sen 6 eb.. and sup 1. The h, 01, 02, 05, 07, 09, 011, 012, 013 and pro assort as simple mendelian the other hand, the expression of f11, f12, and f13 are dosage - dependent. The segregation of these genes is clearly displayed through the female side in accordance with the two-dose (2n) contribution from the female parent to the endosperm. Kermicle (&çèè) has indicated that a group of genes acting in maize endosperm function in a manner that reflects their prior mode of sexual transmission. He used the term imprinting to denote the persistent influence of parentage and pointed out that the imprinting effects consist of parental influence that result in phenotypic inequality following reciprocal crosses. Variation imposed by the genotype of the maternal sporophyte and also instances of differential transmission by the two sexes involving either nuclear or extranuclear factors are not considered as effects of imprinting. Two characteristics useful for distinguishing imprinting from other gene action control systems are: (a) observed ratios that reflect the gametic contribution of only one sex (i.e. phenotype in the immediate generation is not influenced by one parent) and, (b) the presence of two distinct phenotypes corresponding to the same heterozygous geneotype.

Several cases of preferential maternal expression have been reported for which the usual criteria of cytoplasmic inheritance and maternal sporophyte effects seemed inapplicable. These include the floury versus flinty composition of maize endosperm, morphology of F2 kernels borne by mize-teosinte hybrids, the esterase - 2 protein (Schwartz, 1965) and R - mottling of maize kernels (kermicle, 1977).

Published information on the inheritance of the soft floury endosperm of local maize varieties in West and Central Africa is completely lacking. A knowledge of the mode of inheritance of the trait governing the floury endosperm of the local varieties would be useful in designing breeding strategies for incorporating the gene (s) into improved varieties. The objectives of this study were, therefore, to:

a) Examine the mode of inheritance of the soft, floury endosperm of some local maize varieties from Ghana, Togo and Cameroon, and

b) Determine whether the same gene conditions the expression of the soft, floury endosperm of these local varieties.

Materials and Methods

Three floury endosperm local varieties designated as Volta Region Local, Togo Local and Cameroon local were obtained from Ghana, Togo and Cameroon, respectively, for this study. Reciprocal F1 crosses were made between the early, white, normal endosperm variety, TZESR - (w) and each of the local varieties, except Togo Local which was reciprocally crossed onto the white, normal endosperm single cross hybrid, 8321-18. A few F1 kernels from each cross were bulked, planted in the field at Ibadan, Nigeria, and selfed to obtain the F2 generation. Also reciprocal backcrosses of the F1 progeny to the respective local variety were produced. In addition, F1 crosses were made among the local varieties and the progenies were selfed to obtain the F2 generation.

In 1990, the kernels from the reciprocal F1 crosses (Local x normal o and normal o x (Local), backcross (local/normal o x local and local o x local/normal) and the F2 generations were screened to determine the distribution of normal (translucent) and floury (opaque and semi-opaque) kernels from individual ears. The screening was done with the aid of flourescent light arranged in a box so that transmission of light through the endosperm could be observed.

The number of ears screened for each generation was 6-10, 10-15 and 20 for the F1, backcross and F2, respectively. The opaque and semi-opaque kernels were combined into one category to facilitate chi-square tests and genetic interpretation. Chi-square analyses were utilized to test the goodness of fit of the individual segregation ratios to various models.

Results and Discussion

a) **Volta Region and Togo Locals.** The results showed that only a few of the kernels of the F1 ears from the crosses, 8321-18 o x Togo Local o and TZESRW o x Volta Region Local o were floury (Tables 1 and 2), indicating recessiveness of the trait conditioning the floury endosperm of the local varieties. However, in the reciprocal matings, about 30% (223 of 738 kernels) and 37% (309 of 830 kernels) of the F1 progrny of the crosses involving Volta Region local and Togo local, respectively, were floury, whereas only normal kernels were expected. The F2 kernels segretated in a ratio of 3 normal to 1 floury, suggesting that the floury endosperm of each of the local varieties is conditioned by a single recessive gene. The progeny o of the backcross to the floury endosperm parents, Togo Local x (Togo Local x 8321-18) o and Volta Region local o x (Volta Region Local x TZESRW) o segregated in a normal floury ratio of 1:1, again providing a good fit for a single recessive gene model of inheritance. In the reciprocal backcrosses, the kernels segregated in a ratio of 3 normal to 1 floury, instead of the expected ratio of one normal to one floury.

Contrary to expectation, a small percentage of the kernels were rated as floury in the F1 crosses in which the normal endosperm parents served as female. This was probably due to misclassification of some kernels fue to their thickness which made it difficult for light to pass through, even though they might have possessed normal endosperm. The presence of floury endosperm kernels instead of only normal kernels in the F1 crosses in which the floury parents served as females and the deviation of the reciprocal backrosses (floury parent as male) from the expected normal to floury ratio of 1:1 suggests that the inheritance of the floury endosperm in Togo and Volta Region locals are not dosage-dependent. Mendelian inheritance assumes equivalent gene expression following passage through male and female gametophytes. In this study, there was phenotypic inequality in the segregation of the kernels in F1 whenever the floury endosperm parent was used as the female, indicating that parental influences were involved in the inheritance of the floury endosperm in the Togo and Volta Region locals. This finding is in support of kermicle (1977) who reported that the class of genes acting in the maize endosperm function in a way that reflects their prior mode of sexual transmission and denoted the persistent influence of parentage as imprinting. According to this worker, two distinguishing features of imprinting are that the observed ratios should reflect the

gametic contribution of only one parent and two distinct phenotypes corresponding to the same heterozygous genotype should be present. The occurrence of both floury and normal kernels phenotypes on individual F1 ears rules against determination of this variation by the genotype of the maternal sporophyte, either nuclear or cytoplasmic.

Table 1. Distributions of floury (opaque) and translucent kernels of generations derived from a cross between a soft, floury endosperm maize variety, Volta Region local and normal endosperm maize variety, TZESRW.

Generations	Observed kernel (n°)		Expected kernel (n°)		P value
	Translucent	Opaque	Translucente	Opaque	
(Volta region local x TZESRW) ♀ x Volta region local♂	3543	1186	2364.5	23645	1173.7*
Volta regional local ♀ x (Volta region local x TZESRW) ♂	1522	1457	1849.9	14895	1.38
Volta region local ♀ x TZESRW ♂	515	223			
TZESRW ♀ x Volta region local♂	2241	19			
(TZESRW x Volta region local F2	4618	1484	4576.5	15255	1.49

* Significant at P = 0.05

Table 2. Distribution of floury (opaque) and translucent kernels of generations derived from a cross between a soft, floury endosperm maize variety, Togo local, and a normal endosperm maize variety, 8321-18.

Generations	Expected kernel (n°)		Observed kernel (n°)		P value
	Translucent	Opaque	Translucent	Opaque	
(Togo local x 8321-18) ♀ x Togo local ♂	3766	1455	2610.5	2610.5	1022.04*
(Togo local ♀ x (Togo local x 8321-18) ♂	1388	1296	1342	1342	3.08
Togo local ♀ x 8321-18 ♂	521	309			
8321-18 x Togo local ♂	3247	311			
(Togo locl x 8321-18) F2	4516	1532	4536	1512	0.35

* Significant at P = 0.05.

b) **Cameroon Local.** The F1 kernels from the cross TZESRW x Cameroon Local were mostly normal (Table 3), indicating that the gene for the floury endosperm was recessive. In the reciprocal cross, Cameroon Local x TZESRW, 58% of the kernels were classified as normal while 42% were floury. The F2 kernels segregated in a normal floury ratio of 3:1, thus providing a good fit to a single-gene model of inheritance. The backcrosses to TZESRW segregated in a ratio of 1 floury to 1 normal, thus supporting the hypothesis that a single recessive gene controls the floury endosperm in the local variety. In the reciprocal backcross in which the floury parent served as the female, there was a significant deviation from the expected 1:1 ratio of floury to normal kernels. For example, in the recirpocal backcross to Cameroon local, the percentage of floury kernels was 60.1% (2334 of 3834 kernels) as compared to 39.9% normal kernels. The results suggest that the Came-roon local carries a single, recessive gene for the floury endosperm. The F1 kernels in which the TZESRW served as female parent, the F2 and backcross with the floury parent as female followed the ratios expected for a single, recessive gene model of inheritance.

Table 3. Distributions of floury (opaque) and translucent kernels of generations derived from a cross between a soft, floury, endosperm maize variety, Cameroon Local, and normal endosperm maize variety, TZESRW.

Generations	Observed kernel (n°)		Expected kernel (n°)		P value
	Translucent	Opaque	Translucent	Opaque	
(Cameroon local x TZESRW) ♀ x Cameroon Local ♂	2256	2336	2296	2296	1.36
Cameroon local ♀ x (Cameroon local x TZESRW) ♂	1500	3234	1917	1917	180.98*
Cameroon local ♀ x TZESRW ♂	1116	783			
TZESRW ♀ x Cameroon local♂	2551	123			
(TZESRW x Cameroon local) F2	4924	1709	4974.75	1658.75	2.03

* Significant at P0.05

The presence of a few floury kernels in the F1 in which the normal parent served as a females may have resulted from mis-classification of some kernels due to their abnormal shape and/or thickness. The unexpected segregation of the kernels in the F1 and the deviation from the expected 1 normal to 1 floury in the backcross progenies in the matings in which the Cameroon local served as the female, may be explained in terms of epigenetic variation which presumes that the genetic material has the potential to reflect some prior influence of parental sex in its subsequent expression (Kermicle, 1977). In otherwords, the observed deviations could be due to differences in the expression of the gene for floury endosperm following meternal

and paternal transmission to the endosperm, i.e. to imprinting (Kermicle, 1977). At any rate, the overall data support a single, recessive gene model of inheritance of the floury endosperm in the Cameroon local.

c) ***Genetic Allelism of Floury Endosperm.*** The results of the test for allelism conducted to ascertain whether the genes for the floury endosperm in the three local varieties were the same or different are presented in Table 4. The F2 kernels derived from the cross between Togo local and Volta Region local were uniformly floury, except for some few kernels. The low frequency of floury kernels unexpectedly observed in the F2 generation could be attributed to misclassification of some few kernels. It is, therefore, assumed that the Togo and VOlta Region locals have the same single recessive gene conditioning the expression of the floury endosperm.

Apart from the cross between Volta Region Local and Togo Local, the F2 kernels of the other crosses involving the local varieties segregated in a normal to floury ratio of 9:7, which is consistent with a two-gene model of inheritance. Therefore, it is assumed that only the Volta Region local and Togo local have the same gene for the floury endosperm, and that BSR81 has a different single recessive gene for the floury endosperm.

Gene symbols would be assigned to the two different genes for the floury endosperm in the five local varieties when the allelism tests with the other named genes for floury endosperm (f11, f12, f13) and when the additional studies currently going on are completed.

Table 4. Segregation of floury (opaque) and translucent kernels of F2 generation derived from crosses involving soft, floury endosperm local variety.

Crosses	Observed kernel (n°)		Expected kernel (n°)		P value
	Translucent	Opaque	Translucente	Opaque	
(Volta region x Togo local) F2	697	6474	0	7171	
(Volta region local x Cameroon local) F2	2349	1726	2292.21	1782.83	3.16
(Cameroon local x Togo local) F2	1882	1382	1836	1428	2.58

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Effects of Six Cycles of Recurrent Selection on the Nitrogen Response of a Lowland Tropical Maize Population.

PETER Y.K. SALLAH.

Ghana Grains Development Project, Tamale, Ghana

Abstract

Nitrogen is an important nutrient which directly influences the yield of maize (*Zea mays,* L.) and other non-leguminous crop plants. This study was conducted to determine whether the pattern of nitrogen response in a lowland tropical maize population was altered by six cycles of recurrent selection for improved agronomic performance. In 1986, cycle 0, 2, 4 and 6 of CIMMYT Population 43, improved using full-sib family selection for high grain yield and other important agronomic traits, were evaluated in replicated field experiments at 0, 80 and 160 kg N/ha and under 50,000 plants/ha density at six locations in Ghana.

Individual cycle responses showed that grain yield, plant height, lodging, and ear acceptability increased; days to mid-silk decreased, and grain moisture and number of ears per plant did not change as fertilizer N was increased. However, most of these changes occurred at 80 kg N/ha. Identical N response patterns were observed in cycles 0 through 4. The pattern observed in cycle 6 for grain yield was different from the other cycles. Progress per cycle of selection for grain yield, days to mid-silk, plant height, and lodging were all highly significant. Full-sib selection was effective for improving grain yield, days to mid-silk, plant height, and lodging in the population at 80 or 160 kg N/ha. Also, recurrent selection seemed to have indirectly altered the N fertilizer response of the population.

Introduction

Nitrogen (N) is an essential plant nutrient which influences the growth, development and productivity of maize (*Zea mays* L.) and other non-leguminous crop plants. Because the available N is limited in most soils, inorganic N fertilizers are usually applied to maize. Increase in the N supply may influence the grain yield of maize through increase in the harvest index (Viets, 1965), average ear weight, weight of the second ear in two-eared varieties as well as the number of ears per plant in multiple ear hybrids (Krantz and Chandler, 1954).

Nitrogen utilization in maize is under polygenic control (Harvey, 1939); Pollmer *et al.*, 1979) and variations exists among maize genotypes for N utilization (Harvey 1939; Chevalier and Schrader, 1977; Pollmer *et al.*, 1979). Genotypic variation for N utilization has permitted selection for this trait in maize (Muruli and Paulsen, 1981; Moll *et al.*, 1987).

Maize breeding programmes traditionally develop varieties under high levels of N fertilization. Since genotypic variation for N-utilization exist in maize, the N response of the original population is probably altered in successive cycles through recurrent selection for improved agronomic performance. Preliminary work in the U.S.A. (Muruli and Paulsen, 1981; Kamprath *et al.*, 1982) and in Kenya (Allan and Darrah, 1978) appear to support this hypothesis. However, little information is available for maize adapted to the lowland tropics.

Tropical maize plants are profusely vegetative and have low harvest index (Yamaguchi, 1974; Fischer and Palmer, 1980). Grain yields of tropical maize are relatively unresponsive to increased fertilization and high plant populations, probably because the increase in productivity associated with increase in these factors goes to increase non-yield plant components (Goldsworthy *et al.*, 1974). To what extent recurrent selection for improved agronomic performance also affects the N response of tropical maize is not known.

The objectives of the present study were, therefore, to: (a) determine if changes have occurred in terms of response to N fertilizer in a lowland tropical maize population following six cycles of recurrent selection, and (b) estimate genetic gains from full-sib family selection for grain yield and other important agronomic traits in the population under different rates of applied N fertilizer.

Materials and Methods

Nitrogen response of cycles 0, 2, 4 and 6 of CIMMYT maize Population 43 (La Posta) was studied in Ghana, West Africa. CIMMYT Population 43 is a white dent, late maturing Tuxpeno-related synthetic maize which produces tall and vigourous-growing plants, well adapted to lowland tropics (Pandey *et al.*, 1986; CIMMYT, 1987). Cycles 1 and 2 were developed using full-sib selection in which only among family selection was done. Cycles 3 through 6 were developed using a modified full-sib selection in which both among and within family selection was practiced. Both selection schemes were based on an international progeny testing programme with one test located in CIMMYT, Mexico, and in five other countries in the lowland tropics. Some 250 full-sib families were evaluated in each country and, based on the international yield trial and stress nursery (CIMMYT only) data, approximately 40% superior families were selected using an independent culling procedure. Grain yield, days to mid-silk, plant and ear heights, lodging, and disease reaction were the major traits considered for improvement. Details of the selection schemes have been well described (Pandey *et al.*, 1986).

The experimental design employed in evaluating the cycles was a randomized complete block in split-plot arrangement, with four replications each at Nyankpala, Damongo, Pokuase, Ejura, Kpeve and Kwadaso, Ghana, in 1986. Nitrogen rates were assigned to main plots and selection cycles were the sub-plots. Sub-plots consisted of two 5m rows spaced 0.8m apart. Hills were spaced 0.5m, over-planted and thinned to two plants per hill at the 6-8 leaf stage to give a uniform population density of 50,000 plants/ha. All trials were rainfed, except at Kwadaso where irrigation was applied. Nitrogen rates of 0, 80 and 160 kg N/ha were applied as ammonium sulfate in a split dose, with half applied at 2 weeks and the remainder at

4 weeks after emergence. Phosphorus was applied at 60 kg P205/ha to all plots as triple superphosphate prior to planting. No potassium (K) was applied because of consistent lack of response of maize to this nutrient element in Ghana (Ahn, 1970; Dennis, 1983).

Bordered 2-plant hills were hand-harvested, ears of each sub-plot weighed and the equivalent weight of the shelled grain determined by multiplying total ear weight per sub-plot by an assumed 0.8 shelling factor. A 250-g grain sample from each sub-plot was analysed using an electronic moisture meter to estimate grain moisture at harvest (fresh weight basis). Grain yield was expressed as Mg/ha adjusted to 150g/kg moisture. Lodging was visually scored on a 1-5 scale, where 1 = all plants erect and 5 = all plants broken below the ear or leaning at an angle greater than 45_. Ears were visually scored for acceptability also on a 1-5 scale, where 1 = good and 5 = poor ears based on uniformity of size, kernel rows, kernel texture, and damage from ear rots and insects. Plant height was measured as the distance between the base of the plant and the point where tassel branching began. Number of ears per plant, and days to mid-silk were computed.

Cycles of selection and N levels were considered fixed effects and environments were considered random effects. Analyses of variance were computed in each environment (location) and combined over locations for all traits (Steel and Torrie, 1980). Response to selection was estimated as the regression coefficient of the linear regression of the mean value of trait on number of selection cycles (Hallauer and Miranda, 1981).

Results and Discussion

The combined analyses of variance for all traits measured are presented in Table 1. Environments (locations), N, and cycles were significant sources of variation in all traits. The N x environment interaction effects were significant for days to mid-silk, lodging and ear acceptability, while the cycle x environment interaction effects were significant for grain yield, mid-silk and plant height. These significant interactions were due to differences in magnitude rather than the rank order of values of the traits in the different environments. No significant N x cycle interaction effects were detected for any trait, indicating that the relative performance of the cycles did not change under the diffferent N regimes. In other words, the nature of the N and cycle responses can be explained entirely by their main effects (Table 2).

Table 1. Combined analyses of variance for the agronomic traits measured, 1986.

Source of Variation		Grain yield (mg/ha)	Mid-silk (days)	Plant height (cm)	Lodging + (score)	Ear acceptability + (score)
Environnments (E)	5	76.1*	278.1*	23526*	35.9	9.8*
Replications/E	18	5.0	16.4*	1390	2.0	0.9
Nitrogen (N)	2	132.9*	80.8*	4044*	4.1*	11.1*
E x N	10	3.8	13.5	1166	1.8*	5.2*
Error (a)	36	3.1	5.5	1019	0.8	0.4
Cycles (c)	3	3.6*	74.7*	4432*	1.9*	0.8*
C x N	6	0.4	1.5	149	0.3	0.1
C x E	15	0.6*	3.1*	291*	0.3	0.3
C x N x E	30	0.4	0.8	147	0.3	0.3
Error	162	0.3	1.6	127	0.3	0.3
C.V. %	-	13.7	2.1	6	25.2	17.8

* Significant at P = 0.05.

\+ Data from 5 environments, 1 = n° lodging or good ear ; 5 = all plants logdged or poor ear.

Table 2. Mean response of six cycles of selection in CIMMYT Population 43 to N fertilization.

Nitrogen applied	Population cycle	Grain yield mg/ha	Mid-silk (days)	Grain moisture (g/kg)	Plant height (cm)	Ears per plant (N°)	Lodging score	Ear acceptability score
kg/ha								
	C0	2.89	58.1	248	192	0.90	1.9	3.5
	C2	2.93	57.3	242	181	0.90	1.9	3.6
0	C4	2.86	56.6	239	178	0.93	1.9	3.5
	C6	3.15	56.0	247	174	0.91	1.8	3.3
	X	2.96	57.0	244	181	0.91	1.9	3.4
	C0	4.56	56.7	151	203	0.92	2.3	2.9
	C2	4.42	56.1	247	198	0.95	2.3	2.9
	C4	4.75	54.7	243	186	0.95	2.0	2.8
80	C6	5.06	54.3	242	187	0.95	1.9	2.6
	X	4.70	55.4	246	193	0.94	2.1	2.8
	C0	5.00	56.6	250	201	0.92	2.5	2.9
	C2	5.07	55.8	244	196	0.94	2.6	2.8
160	C4	5.09	55.3	249	182	0.96	2.2	2.9
	C6	5.63	54.0	244	187	0.93	2.2	2.7
	X	5.20	54.8	247	192	0.93	2.3	2.8
	C0	4.15	57.1	250	198	0.91	2.2	3.1
	C2	4.14	56.4	244	198	0.93	2.3	3.1
Overall	C4	4.23	55.5	244	182	0.93	2.0	3.1
	C6	4.62	54.8	245	183	0.93	1.9	2.8
	X	4.29	56.0	246	189	0.93	2.1	3.0
SE :		0.25	0.3	NS	5	NS	0.1	0.1
Nitrogen means		0.10	0.2	NS	2	NS	0.1	0.1
Cycle means		0.17	0.2	NS	3	NS	0.2	0.2
Cycle means at same N level		0.29	0.4	NS	5	NS	0.2	0.2
N means at same/different cycles								

Mean grain yield at zero fertilizer N was about 37 and 43% lower than grain yield at 80 and 160 kg N/ha, respectively. Grain yield at 160 kg N/ha was 10% higher than at 80 kg N/ha, but the difference was not significant. The relatively high yield under unfertilized conditions indicated a high soil residual N at the experimental sites.

Treatment means for the other agronomic traits showed their response to N fertilization was similar at 80 and 160 kg N/ha. There was a significant delay in silk emergence and a significant reduction in plant height and lodging in the absence of N. Maize ears from plants grown without N fertilizer were rated less acceptable than ears from plants which received fertilizer N. Though silking was delayed by two days when fertilizer N was not applied, no significant differences were observed among N treatments for grain moisture content at harvest, indicating that the grains dried at a faster rate in N-deprived plants.

The grain yield of individual cycles as affected by N fertilization is illustrated in Fig. 1. Grain yield of all cycles increased as fertilizer N supply was increased, but a much greater yield response was obtained when 80 kg N/ha was applied than with 160 kg N/ha. The yield response was similar for cycles 0 through 4 and slightly, but significantly higher for cycle 6.

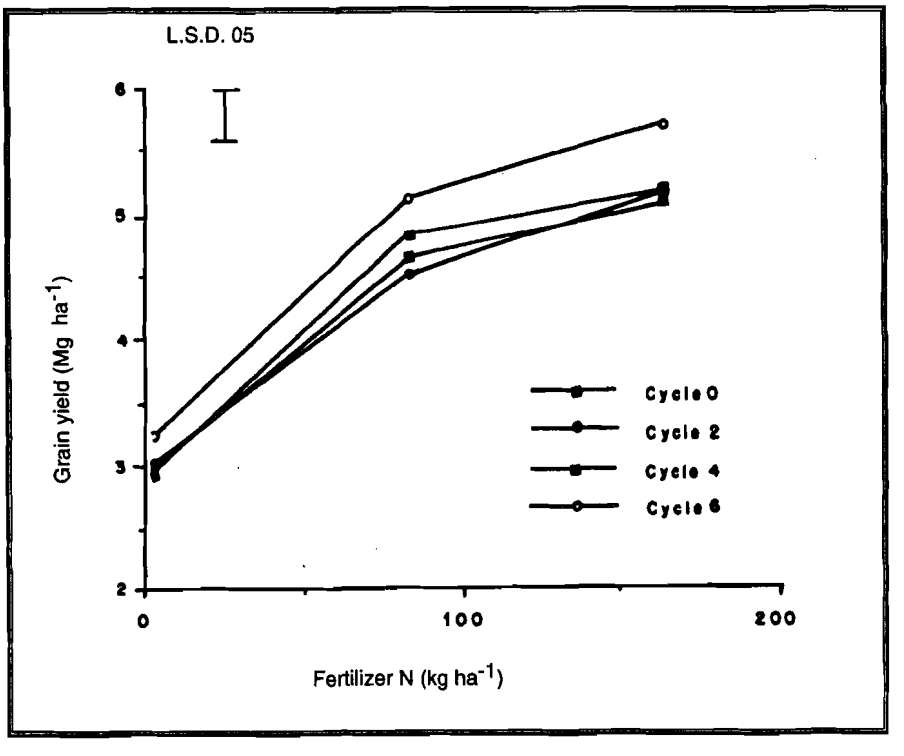

Fig. 1. Relationship between fertilizer N applied and grain yield of selection cycles O to 6.

The effects of N fertilization on days to mid-silk, plant height, lodging and ear acceptability followed the same trend as observed for grain yield. Days to mid-silk decreased and plant height, lodging and ear acceptability increased as N supply was increased. Grain moisture and number of ears per plant were not significantly influenced by fertilizer N application. Nitrogen response of the original population did alter significantly through selection for increased agronomic performance.

Least square estimates of linear response per cycle of full-sib family selection are shown in Table 3. Linear gains per selection cycle were highly significant for grain yield, mid-silk, plant height, and lodging at 80 and 160 kg/n ha. Grains were highly significant also for mid-silk and plant height under the unfertilized condition and when estimated over the three N levels.

Linear increase in grain yield per cycle was 2.1% at 80 kg N/ha and 1.8% at 160 kg N/ha. These rates of linear increase were low compared with the 2.5% reported by Pandey *et. al.*, (1986) and 5.4% reported elsewhere in the literature. The relatively low selection intensity (40%) used by be the reason for the low linear increase in grain yield per cycle. Comparable progress per cycle of selection were made in reducing plant height and mid-silk at 80 and 160 kg N/ha, but the gains were less than those reported by Pandy *et al.*, (1986). The greatest gain was made in reducing lodging at 80 kg N/ha (by 3.5%) and at 160 kg N/ha (by 2.8%). No significant response from selection was observed for grain moisture, ear acceptability, and number of ears per plant at both N levels. Pandy *et al.*, (1986) did not report on grain moisture, but they also did not observe any significant progress in the selection for ear acceptability and ears per plant.

Table 3. Progress per cycle of full-sib selection for four traits under three N rates and across N rates.

N treatment (kg N/ha)	Grain yield	Mid-silk	Plant height	Lodging
0	1.56	- 0.60**	- 1.46**	- 1.05
80	2.08**	- 0.76**	- 1.48**	- 3.48**
160	1.80**	- 0.74**	- 1.39**	- 2.80**
Mean	1.57	-0.68**	- 1.39**	- 2.78

*, ** Significant at P = 0.05 and 0.01 levels of probability, respectively.

Much less progress from selection was observed for mid-silk and plant height than reported by Pandy *et al.*, (1986), probably due to differences in environments and in the method used in estimating the progress.

In conclusion, it is evident that Nitrogen fertilizer effects on the number of days to mid-silk, grain moisture, plant height, lodging, ears per plant, and maize ear acceptability were similar in all the cycles evaluated. Identical N effects were observed for these traits at 80 and 160 kg/N. The N response pattern observed in cycle 6 for grain yield was different from the other cycles. Significant progress was made in increasing grain yield and reducing the number of days to mid-silk, plant height, and lodging under 80 and 160 kg N/ha. Results from the 6 cycles studied suggest that: (i) full-sib selection was effective in improving grain yield, mid-silk, plant height, and lodging in the population under 80 or 160 kg N ha-1 and, (ii) recurrent selection for improved agronomic performance seemed to have indirectly altered the N response of the population.

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Comparaison de Méthodes d'Appréciation de la Stabilité de la Productivité de Variétés de Maïs en Zone Semi-Aride.

ABDOU NDIAYE

Institut Sénégalais de Recherche Agricole (ISRA).

Résumé

L'adaptabilité de 13 variétés de maïs résistantes et/ou tolérantes à la sécheresse est étudiée sur la base de leurs rendements moyens dans 14 localités réparties dans 9 pays. La stabilité du rendement a été discutée afin de proposer une stratégie d'action qui maximisera les chances de mettre à la disposition de l'agriculteur moyen de la sous-région une gamme de variétés stables et performantes lui permettant d'ajuster ses plans de culture en fonction des aléas climatiques, de la pression parasitaire et des besoins du marché.

Introduction

Obtenir des rendements élevés et réguliers a toujours été une préoccupation majeure des sélectionneurs et des agriculteurs. Dans la zone semi-aride d'Afrique Occidentale et Centrale, l'adaptabilité et/ou la stabilité générale des variétés a été toujours d'une importance particulière suite aux grandes variations édaphiques et saisonnières entre les différentes localités.

Dire, cependant, que tous les milieux n'ont pas la même aptitude à révéler les potentialités variétales c'est conclure, en somme, à l'existence d'interaction génotype x environnement constituant en elle-même une information riche. De ce fait, la régularité du rendement correspondrait à un des aspects nombreux et divers des relations génotype x environnement, lesquelles ont donné lieu à une terminologie abondante. Différentes méthodes d'étude de la stabilité du rendement, ont été mises au point pour obtenir des variétés stables à partir des résultats de réseaux d'essais variétaux (Freeman et Perkin, 1973; Jacquot, 1974; Weil et Ngoc Quoi, 1974; Sanou et Sauvaire, 1988).

Dans ces travaux, les interactions génotype x environnement ou génotype x saison ont été les principales sources de mesure de l'adaptabilité variétale. La stabilité du rendement étant ainsi à l'ordre du jour, dans les préoccupations des sélectionneurs, il nous a paru utile de faire le point de ce que l'on connaît comme méthodes sur la question.

Pour ce faire, nous avons profité du large réseau d'expérimentation multilocale du SAFGRAD pour ainsi étudier la stabilité de la productivité de variétés de maïs en zone semi-aride par le biais des principales méthodes de mesure jusqu'alors proposées. Ceci nous permettra de faire, d'une part la comparaison desdites méthodes et de faire, d'autre part, des propositions allant dans le sens de l'adoption d'une stratégie bonne à maximiser les chances de choisir des variétés stables et performantes.

Matériels et Méthodes

Les variétés étudiées sont essentiellement des composites provenant de l'essai RUVT 1 ; variétés tolérantes et/ou résistantes à la sécheresse. Bien que d'autres caractères morphologiques, agronomiques et de régularité du rendement aient été observés, seul le rendement en grain a été pris en compte.

Le dispositif expérimental utilisé pour l'évaluation est du type essai en blocs complets randomisés avec 4 répétitions. La parcelle élémentaire comporte 4 lignes de 5,0 m de long ; les écartements étant de 0,75 m entre les lignes et de 0,40 m entre les poquets. Différentes techniques statistiques ont été développées pour comparer la performance du lot de variétés. Parmi celles-ci on peut citer :

- l'identification de l'adaptabilité des variétés à partir de la mise en évidence et de la partition de l'interaction variété x environnement. Deux différentes approches sont possibles : (i) l'approche des sites homogènes relative à la classification des sites en groupes homogènes de façon que l'interaction génotype x environnement ne soit pas significative. (ii) l'approche des traitements homogènes qui consiste àidentifier la ou les variété(s) dont la contribution àl'interaction génotype x environnement est importante ou mieux, les variétés dont la performance varie largement à travers les sites et qui seront considérées comme ayant une adaptabilité trop étroite.

- l'utilisation de la technique de régression, idée de Yates et Cochran (1938) que reprirent Finlay et Wilkinson (1963) qui caractérise chaque environnement par le rendement moyen de tous les génotypes testés dans cet environnement et calcule pour chaque génotype la régression du rendement individuel sur le rendement moyen de tous les génotypes dans chaque environnement.

- deux autres auteurs, Eberhart et Russel (1966), ont fourni une importante contribution à la définition de la stabilité du rendement. Etant donné qu'une même droite de régression peut être en effet tracée à partir d'un nuage plus ou moins large de points, ils ont ajouté au coefficient de régression b la somme des carrés des écarts par rapport à la droite de régression, Sd2, pour caractériser une variété ; b et Sd2 sont, pour ces deux auteurs, les deux paramètres de la stabilité d'une variété.

D'autre part, les mêmes auteurs caractérisent l'environnement Ej par un index Ij déduit de la moyenne Mj de toutes les variétés testées dans l'environnement Ej et de la moyenne générale M par la formule Ij = Mj - M. Il s'agit donc en fait d'un changement d'origine par rapport à la mesure de l'environnement chez Finlay et Wilkinson (1963).

- Letourmy (1989), faisant la synthèse des différentes approches, propose une méthodologie d'étude de la stabilité du rendement dans les regroupements d'essais variétaux. Une telle méthode d'étude et d'analyse des résultats s'effectue en trois étapes : (i) analyse des essais individuels ; (ii) sélection des essais de même variance résiduelle par les tests d'égalité des variances (Test de Bartlett par ex) ; (iii) analyse dans chaque groupe d'essais de variance homogènes.

- enfin, l'utilisation des tests non-paramétriques.

Dans les calculs de moyennes et de régression qui vont suivre, la transformation logarithmique a été utilisée pour la variable rendement car elle permet d'obtenir, d'une part, un haut degré de linéarité dans la régression des rendements individuels sur les moyennes de rendement par site et, d'autre part d'induire un degré raisonnable d'homogénéité de l'erreur expérimentale (Finlay et Wilkinson 1963).

Résultats et Discussions

I Analyses Statistiques : Regroupement des essais

L'analyse de la variance faite séparément pour chacune des 14 localités, est consignée dans le Tableau 1.

Des regroupements d'essais variétaux ont été testés en tenant compte de l'homogénéité des variances résiduelles des expériences grâce à la méthode de Bartlett. Le Tableau 2 montre les différents groupes ainsi obtenus. L'analyse de variance réalisée pour les groupes I et II (Tableau 3) montre un effet "localité" significatif. L'interaction génotype x localité étant non significative pour le groupe II, on en déduit que la réponse variétale est identique sur l'ensemble des essais et des lieux concernés. Quant au groupe I, l'interaction génotype x localité est significative, alors sa structuration a été effectuée (Tableau 3).

Tableau 1. Analyse de variance individuelle localité par localité.

		CARRE MOYEN													
Sce var.	Ddl.	Bagou	Ina.	F. Ba	Ngklo.	Sang.	Cedou.	Sombé	Dang.	Nygpla.	B. Khan.	Sotba.	Gassi.	Ttgou.	Brouk.
Répétition	3	0.737	0.007	0.075	0.118	0.008	0.099	0.021	0.014	0.002	0.079	0.001	0.073	0.024	0.033
Génotype	12	0.323	0.007**	0.035	0.018**	0.004	0.025	0.009	0.025	0.005*	0.004	0.004	0.031	0.091	0.011
Résiduelle	36	0.199	0.002	0.034	0.004	0.003	0.017	0.015	0.022	0.002	0.004	0.003	0.029	0.092	0.006
C.V. (%)		14.43 %	1.21 %	5.46 %	1.73 %	1.39 %	3.79 %	3.45 %	4.25 %	1.32 %	1.79 %	1.52 %	5.32 %	8.62 %	2.12 %
Pays		Bénin	Bénin	B. Faso	B. Faso	B. Faso	CAMRN	R.C.A.	GHANA	GHANA	GUINEE	MALI	TCHAD	TOGO	TOGO

** = Test F significatif à 1%
* = Test F significatif à 5%

Tableau 2. Résultats de regroupement des essais/Test de Bartlett.

Groupe	Localités (Pays)	X^2 obs	X^2 5,5 %
I	Ina (Bénin), Niangoloko (Burkina Faso), Sanguéré (Cameroun), Nyankpala (Ghana), Bordo Kankan (Guinée), Sotuba (Mali).	6,83	11,07
II	Farako-Bâ (B. Faso), Soucoundou (Cameroun), Soumbré (R.C.A.), Damongo (Ghana), Ferme de Gassi (Tchad), Broukou (Togo).	9,57	11,07
III	Bagou (Bénin), Tantiégou (Togo).	2,26	3,83

Tableau 3. Analyse de variance intragroupe des 13 variétés testées.

Source de variation	ddl	Groupe I	Groupe II
Localité	5	0,347***	0,891***
Rép. (localités)	18	0,036	0,053
Génotype	12	0,008***	0,023 ns
Génotype x local	60	0,005**	0,022 ns
Régressions	12	0,4594**	-
Déviation	48	0,0121**	-
Résiduelle	216	0,003	0,020
CV (%)		1,51	4,16

*** : F significatif à 0.1%,
** : F significatif à 1%,
* : F significatif à 5%,
ns : F non significatif.

Ainsi on peut noter que 83% de la composante de la variance génotype x environnement est attribuable aux régressions linéaires. La variance résiduelle génotype x environnement (0.0121) est très largement supérieure à la variance expérimentale.

II Stabilité du Rendement

La stabilité correspond en général au terme régularité ou adaptabilité. Elle peut se définir ici comme la capacité d'une population de s'accommoder de changements d'environnements, c'est-à-dire de demeurer fonctionnelle dans une série d'environnements différents.

L'analyse de la stabilité a porté sur six (6) localités. Deux principales méthodes sont utilisées et comparées dans ce document : la méthode de Finlay et Wilkinson (1963) et celle de Eberhart et Russel (1966). Auparavant, la méthode d'approche graphique pour la mise en évidence de l'interaction génotype x localité a été effectuée. La Figure 1 montre que Across 86 Pool 16DR et Early 86 Pool 16 DR ont des comportements différents par rapport aux autres.

La décomposition de l'interaction génotype x localité pour chacune des variétés permet de retenir quatre variétés stables au sens de Eberhart et Russel (1966) : Pool 16 DR C1 Pool 16 DR C2 DMR-ESRY et Safita-2 (RE) (Tableau 4). Les valeurs du coefficient de régression (b) sont comprises dans l'intervalle 0,94 et 0,98. Les droites de régression de quelques variétés sont représentées à la Figure 2.

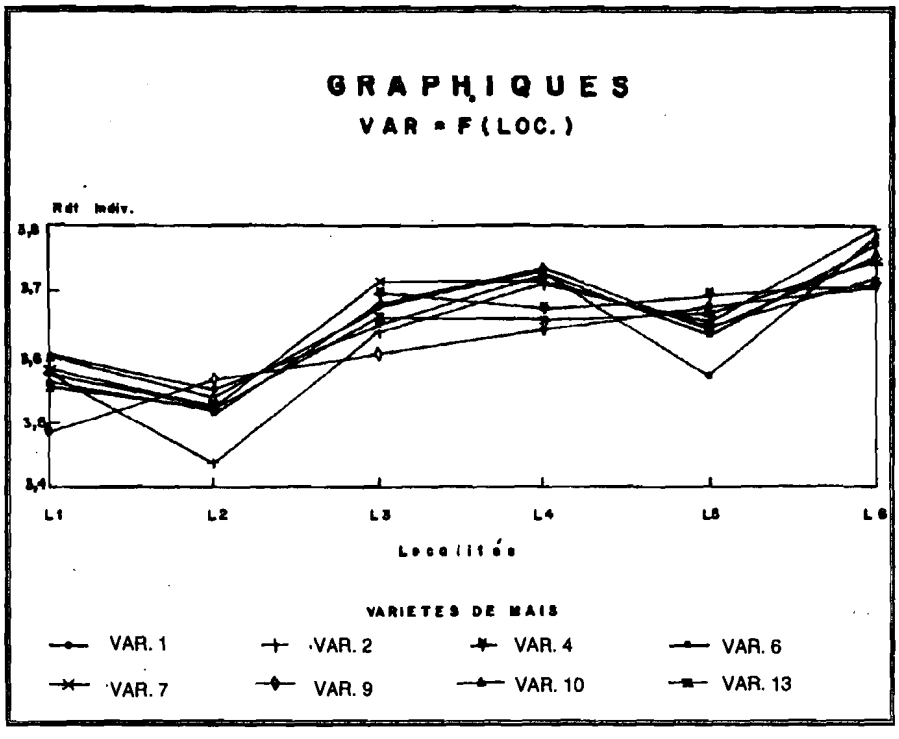

Fig. 1. Mise en évidence de l'interaction variétés x localité (moy. var./moy. loc.) dans le groupe I

Tableau 4. Analyse de la stabilité du rendement. Composantes de la variance due à l'environnement. Méthode de EBERHART et RUSSEL (1966).

N°	Variétés	Edt. moy. kg/ha	Paramètres de stabilité			
			b	Sd^2	Test dév/err.	Conclusion
1	Ac.86.P16 DR	4504	1,20	0,241	S	
2	Early 86P16 DR	4485	1,46	0,137	S	
3	F.Bâ P16 DRHD	4586	0,83	0,048	S	
4	K.86 P16 DR	4491	0,87	0,192	S	
5	P16 DR Co	4440	0,70	0,174	S	
6	P16 DR C1	4644	0,95	0,133	NS	Variété stable
7	P16 DR C2	4541	0,94	0,185	NS	Variété stable
8	K(1) 84 TZESRW	4530	1,20	0,079	S	
9	Kawanzie	4210	0,8	0,284	S	
10	DMR-ESRY	4626	0,95	0,114	NS	Variété stable
11	TZE-C3x F4	5024	0,70	0,118	S	
12	TZE-C. Early	4452	1,40	0,199	S	
13	Safita-2 (RE)	4427	0,98	0,113	NS	Variété stable

S = significatif, NS = non significatif.

Selon Finlay et Wilkinson (1963), les variétés dont le coefficient de régression sont proches de 1.0 auront une stabilité moyenne ; tel est le cas des variétés identifiées ainsi : Pool 16 DRC1, Pool 16 DRC2, DMR-ESRY et Safita-2.

Les variétés Across Pool 16 DR et Early 86 Pool 16 DR dont les coefficients de régression sont supérieurs à 1.0 ont une stabilité inférieure à la moyenne et sont spécifiquement adaptées aux environnements favorables. A l'opposé, les variétés Pool 16 DRCo, Kawanzie et TZE Comp. 3x4 F4 ayant des coefficients de régression inférieurs à 1.0, ont une stabilité supérieure à la moyenne et sont relativement adaptées aux environnements défavorables.

En somme, Finlay et Wilkinson (1963) caractérisent donc une variété par son rendement moyen et son coefficient de régression alors que Eberhart et Russel (1966) considèrent plutôt que le coefficient b doit tendre vers 1.0 et les déviations à

la régression Sd2 tendre vers 0; alors, les variétés stables sont celles ayant une Sd2 faible et qui sont représentées dans la partie hachurée (Fig. 3). Celle-ci correspond à la pointe du triangle dans la représentation donnée par Finlay et Wilkinson (1963) avec les mêmes coordonnées (Fig. 4).

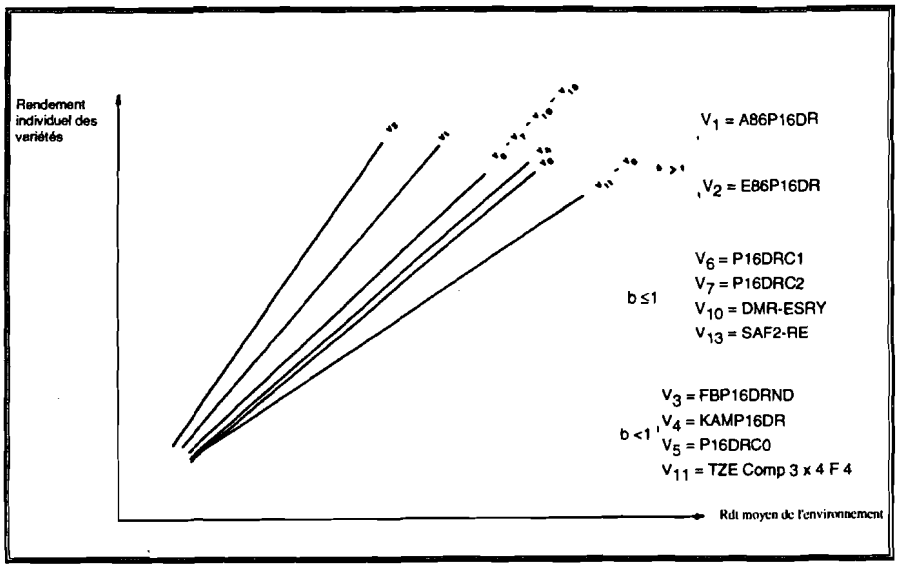

Fig. 2. Finlay et Wilkinson : Exemples de droites de régression traduisant la relation entre les rendements individuels de diverses variétés et le rendement moyen de l'ensemble des variétés dans les tests.

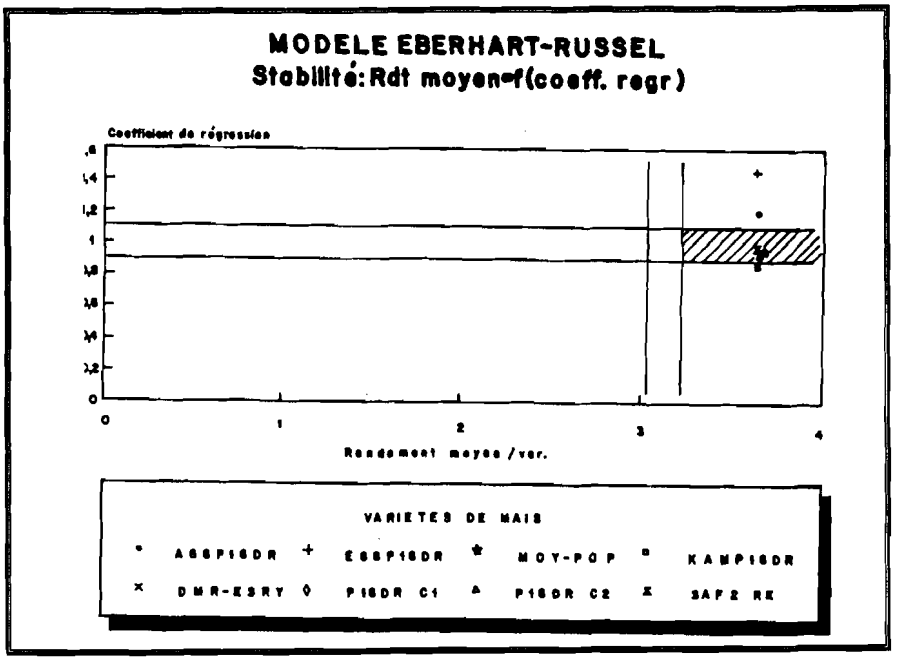

Fig. 3. Eberhart et Russel : Les variétés stables sont celles qui à la fois présentent une Sd^2 faible et sont situées dans la partie hachurée.

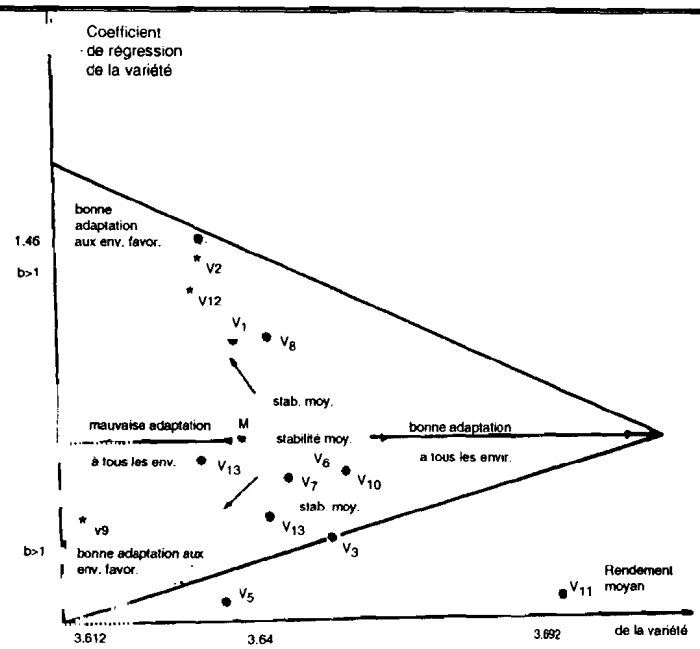

Fig. 4. : Finlay - Wilkinson : Interprétation des diverses situations possibles pour une variété selon son coefficient de régression et son rendement moyen.

Légende :

V_1 = Across 86.P.16.DR
V_2 = Early 86 P. 16 DR
V_3 = Farako-Bâ P16 DR HD
V_4 = Kamb. 86 P 16 DR
V_5 = Pool 16 DR Co
V_6 = Pool 16 DR CI
V_7 = Pool 16 DR C2
V_8 = Kam (1) 84 TZESR-WAcross 86.P.16.DR
V_9 = Kawanzie
V_{10} = DMR - ESRY
V_{11} = TZE Comp. 33 x 4 F4
V_{12} = DR Comp. Early
V_{13} = Safita-2 (RE)
M = Moyenne population

Conclusion

Après avoir examiné les méthodes d'analyse des relations génotypes x environnement et à la lumière des études relatées ici, nous pouvons retenir le coefficient de régression b comme paramètre de la régularité bien qu'il ne saurait être question de lui fixer une valeur optimum (Jacquot. 1974).

Pour les milieux favorables, les agriculteurs choisiraient les variétés ayant un b supérieur à 1; par contre dans les milieux défavorables, ils choisiraient plutôt des variétés avec un b inférieur à 1 et à potentiel de rendement acceptable.

En définitive, la valeur souhaitable pour le coefficient b de variétés est en fait une fonction du milieu de culture.

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Contribution à l'Evaluation de la Variabilité des Cultivars Traditionnels de Maïs du Centre de la Côte d'Ivoire.

K. ATTIEY

Institut Des Savanes, Bouaké, Côte d'Ivoire.

Résumé

L'évaluation de la variabilité génétique d'une collection permet de répertorier le matériel végétal local et introduit àpartir de ses caractéristiques à la fois générales et particulières pouvant intéresser les travaux de création et d'amélioration variétales. Ainsi 189 cultivars traditionnels de la région Centre Eburnéenne et 11 cultivars sélectionnés en provenance de l'étranger, ont été étudiés en 1989 pour 16 caractères. Par l'analyse en composantes principales, la classification ascendante hiérarchique, l'analyse factorielle discriminante et la Distance D2 de Mahalanobis, 5 groupes de cultivars ont été définis et décrits. Ces 5 groupes variétaux vont servir de base à un programme de création et d'amélioration variétales de maïs. Nombreuses associations significatives entre caractères d'intérêt agronomique ont été trouvées. Elles peuvent être attribuées, dans certains cas, à des effets génétiques (par exemple la pléiotropie), de sélection, à des effets multivariables (corrélations multiples), à des effets d'échantillonnage ou de déséquilibre génétique.

Introduction

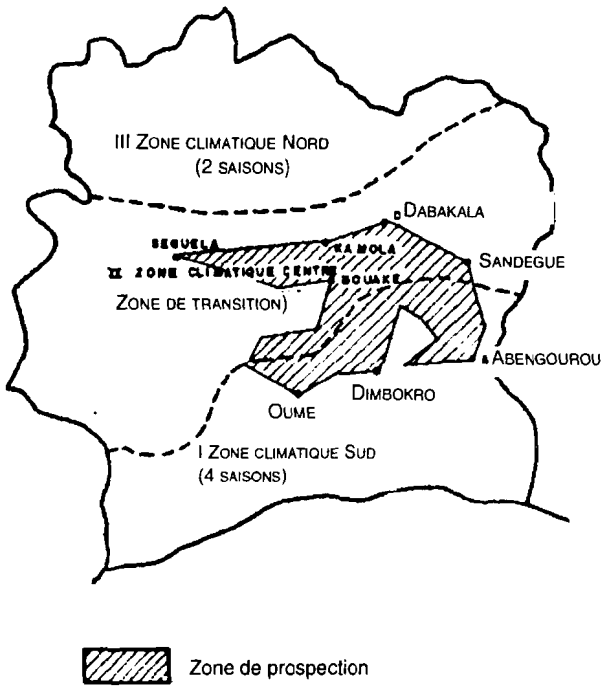
Une mission de prospection effectuée en avril 1989, a permis de collecter les principaux cultivars traditionnels de maïs du centre de la Côte d'Ivoire (Fig. 1). Dans cette région, on rencontre surtout du maïs blanc avec une tache de maïs violet dans la région de Katiola. Des grains violets se rencontrent dans les maïs blancs des régions avoisinantes (Dabakala, Bouaké).

Ce fut une récolte "en grenier", ce qui interdit, dans certains cas, toute désignation variétale ; 106 échantillons de maïs comprenant un ou plusieurs épis ont été pris en 70 points d'enquêtes.

Dans la présente communication, on procède à une analyse de la variabilité génétique de ces cultivars traditionnels de maïs quant à divers caractères (caractères agronomiques et caractères quantitatifs associés au rendement). On a ainsi cherché, par une approche morphologique qui fait appel à la biométrie, aux statistiques et à l'informatique, (i) à décrire et représenter les grandes orientations de la diversité de cette collection, qui comprenait aussi 11 cultivars adaptés et/ou vulgarisés en provenance de l'étranger, (ii) à regrouper les individus selon des critères de ressemblance.

L'évaluation a été faite à la station IDESSA/DCV de Bouaké, située en plein centre de la Côte d'Ivoire, dans le contexte écologique d'origine du matériel prospecté, ce qui permet l'utilisation immédiate des résultats des analyses ainsi qu'une meilleure signification des observations par rapport à toute expérimentation hors contexte.

Fig. 1 : Zones climatiques de Côte d'Ivoire



Matériels et Méthodes

Le matériel végétal utilisé comprend 189 lignées locales du centre de la Côte d'Ivoire, et 11 cultivars sélectionnés ou introduits (T11, Ci64, M162W x M164W, T3, CJB, CD, F7635, F7928, Pool 12, Pool 13 et Pool 18). Ce matériel a été semé en Juin 1989, épi à la ligne (une ligne de 5 m par entrée), selon un dispositif/en blocs randomisés à 2 répétitions, aux écartements de 0,80 m interlignes et 0,25 m intraligne. Le démariage a été effectué à un plant par poquet.

Les observations ont porté sur 16 caractères (décrits en annexe I) et les résultats, exprimés en moyenne par cultivar, sont soumis à une analyse en composantes principales (Dagnelie, 1975; Philipeau, 1986); celle-ci est une étape permettant la description phénotypique des cultivars en mesurant les corrélations qui existent entre les moyennes de chacun d'entre eux. Ensuite, l'analyse de ces résultats a eu pour but le classement des cultivars en groupes homogènes. Les données ont été soumises à une analyse factorielle discriminante, complétée par l'emploi de la distance de Mahalanobis qui donne une autre expression du voisinage ou de l'éloignement des moyennes des cultivars dans l'espace des variables (Tomassone, 1988).

Résultats et Discussions.

Association entre Caractère. La matrice de corrélation des caractères est rapportée dans le Tableau 1 et donne les relations suivantes : les caractères hauteurs

(hauteur de la plante et hauteur d'insertion de l'épi) et longueur des feuilles sont très liés. Les hauteurs sont positivement corrélées avec les autres caractères de développement et la structure de l'épi ; la tardivité est fortement liée positivement avec la hauteur de la plante et aussi avec la hauteur d'insertion de l'épi. La tardivité est positivement corrélée avec les autres caractères de développement ; la tardivité est négativement corrélée avec les caractéristiques du grain, le poids de 1000 grains, le nombre d'épis et le poids d'épis. En d'autres termes, il existe une liaison négative entre la productivité et la précocité. En effet, avec la précocité, le cycle végétatif se raccourcit, le nombre de feuilles et la taille de la plante diminuent, ce qui handicape les capacités de production de matière.

Les causes suivantes peuvent expliquer ces associations de caractères : la pléiotropie génétique assimilable à une corrélation physiologique, le linkage chromosomique, le déséquilibre gamétique, la sélection, l'association fortuite par dérive génétique ou plus simplement par effet d'échantillonnage, entre autres.

Tableau 1. Matrice des corrélations (Tous les coéfficients sont multipliés par 1000).

	ht	hme	lofe	lafe	loe	lae	nbre	logr	lagr	egr	fm	ff	nep	pep	p^{1000}	hum
hum	-181	-150	-139	22	9	6	-86	15	28	-7	-132	-147	194	294	-34	1000
p1000	-94	-160	109	118	160	395	-21	508	421	365	-348	-340	147	400	1000	
pep	59	-4	225	333	498	428	233	462	270	-8	-239	-254	596	1000		
nep	-99	-86	-61	113	100	-59	124	187	55	-104	-224	-254	1000			
ff	629	695	397	165	25	1	200	-378	-394	-243	982	1000				
fm	633	694	401	175	33	0	206	-377	-386	-241	1000					
egr	-133	-185	-13	71	138	177	42	76	226	1000						
lagr	68	-153	83	30	149	327	-196	442	1000							
logr	-148	-231	73	174	246	452	182	1000								
nbre	267	238	313	357	384	582	1000									
lae	255	180	380	382	373	1000										
loe	271	229	375	387	1000											
lafe	262	227	274	1000												
lofe	703	596	1000													
hme	930	1000														
ht	100															

Analyse de la Variabilité Morphologique. L'analyse en composantes principales présentée dans le Tableau 2 donne une estimation du pourcentage de variabilité représenté par chaque axe. Nous nous sommes limités aux quatre premiers axes pour décrire la variabilité totale des cultivars. En effet, ces axes représentent à eux seuls 67,5% de la variabilité, les deux premiers axes comportant l'essentiel de la variabilité totale.

Le premier axe décrit le développement végétatif général de et la "précocité". Cette composante est définie du côté positif par la taille de la plante (HT), la hauteur d'insertion de l'épi (HME), la longueur de la feuille de l'épi supérieur (LOFE), et les floraisons mâle (FM) et femelle (FF). En définitive, les cultivars projétés du côté positif semblent être de grandes plantes tardives. Du côté négatif, il s'agirait des plantes courtes et précoces (Fig. 2).

Le deuxième axe caractérise les composantes de base du rendement. Il oppose les cultivars à haut potentiel de rendement (épis complètement développés, poids de 1000 grains optimum) aux cultivars au rendement limté (Fig. 2).

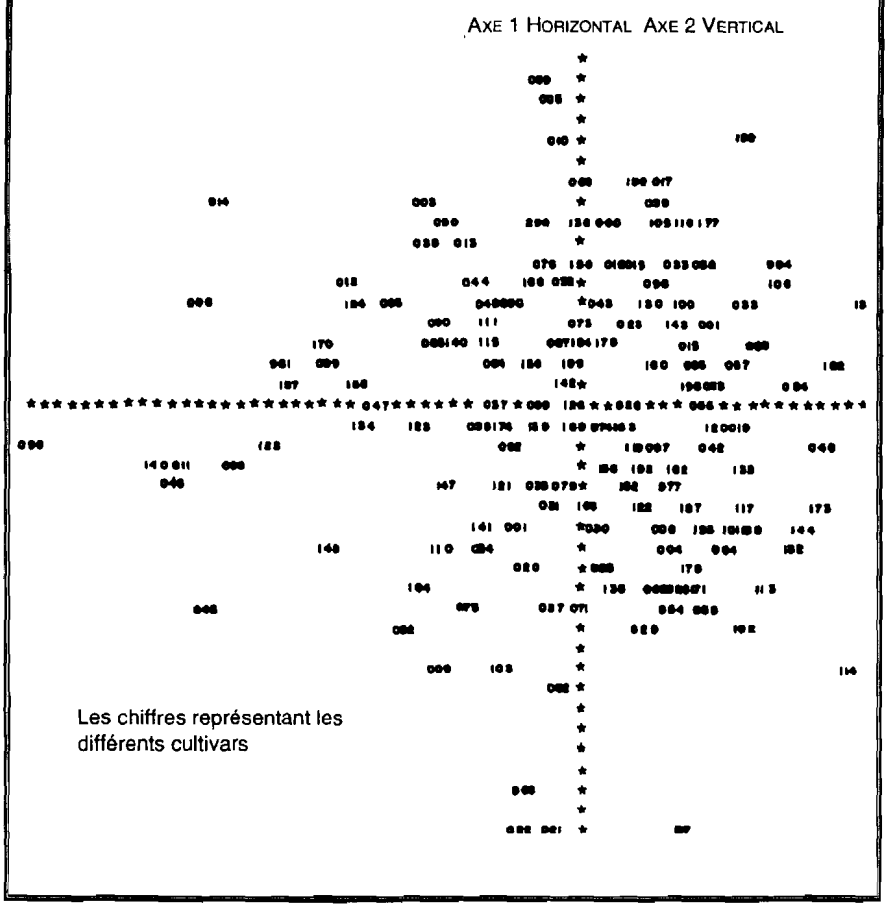
Les composantes principales 3 et 4 apportent un complément d'information permettant d'opposer à l'intérieur d'une même gamme de précocité, les plantes ayant un nombre élevé d'épis ou un nombre élevé de rangs par épi, donc les plantes avec un nombre élevé d'ovules formés et un bon pourcentage de fécondation aux plantes de fécondation défectueuse.

Tableau 2. Résumé de l'analyse en composantes principales.

Axe	Axe 1	Axe 2	Axe 3	Axe 4
% d'inertie totale	27,2	27,2	9,9	7,7
Variable	HT (+) 0,721	LAE (+) 0,598	NEP (+) 0,525	NRE (+) 0,434
contribuant	HME (+) 0,763	PEP (+) 0,581	EGR (+) 0,581	
à la variabilité	FM (+) 0,798	LOGR (+) 0,430	HUM (+) 0,268	
de l'axe	FF (+) 0,799	LOE (+) 0,425		
	LOFE (+) 0,384	P_{1000} (+) 0,351		

N.B. Le chiffre qui suit chaque caractère représente la contribution relative de ce dernier à la définition de l'axe.

Fig. 2 : Représentation Plan 1 2 des cultivars sur les moyennes



Répartition des Cultivars en Groupes Variétaux. La classification ascendante hiérarchique suivie de l'analyse factorielle discriminante appliquée aux deux premiers axes permettent de classer les 200 cultivars en cinq groupes variétaux (Fig. 3, Tableau 3). L'annexe II donne la répartition des 200 cultivars dans ces groupes dont les caractéristiques peuvent être résumées de la manière suivante : le groupe 1 est constitué de cultivars tardifs, de grande taille et de potentialités de rendement supérieures; le groupe 2 comprend des cultivars semi-précoces, de taille réduite et de bonnes potentialités de rendement ; le groupe 3 est composé de cultivars précoces, de taille réduite et d'assez bonnes potentialités de rendement; le groupe 4 est consitué de cultivars tardifs, de grande taille et d'assez bonnes potentialités de rendement ; le groupe 5 comprend des cultivars tardifs, de grande taille et de potentialité de rendement médiocres.

Perspectives de Recherche. La détermination de ces groupes variétaux va servir de base à un programme de création et d'amélioration des variétés de maïs pour le centre éburnéen. On peut schématiser le processus de la manière suivante.

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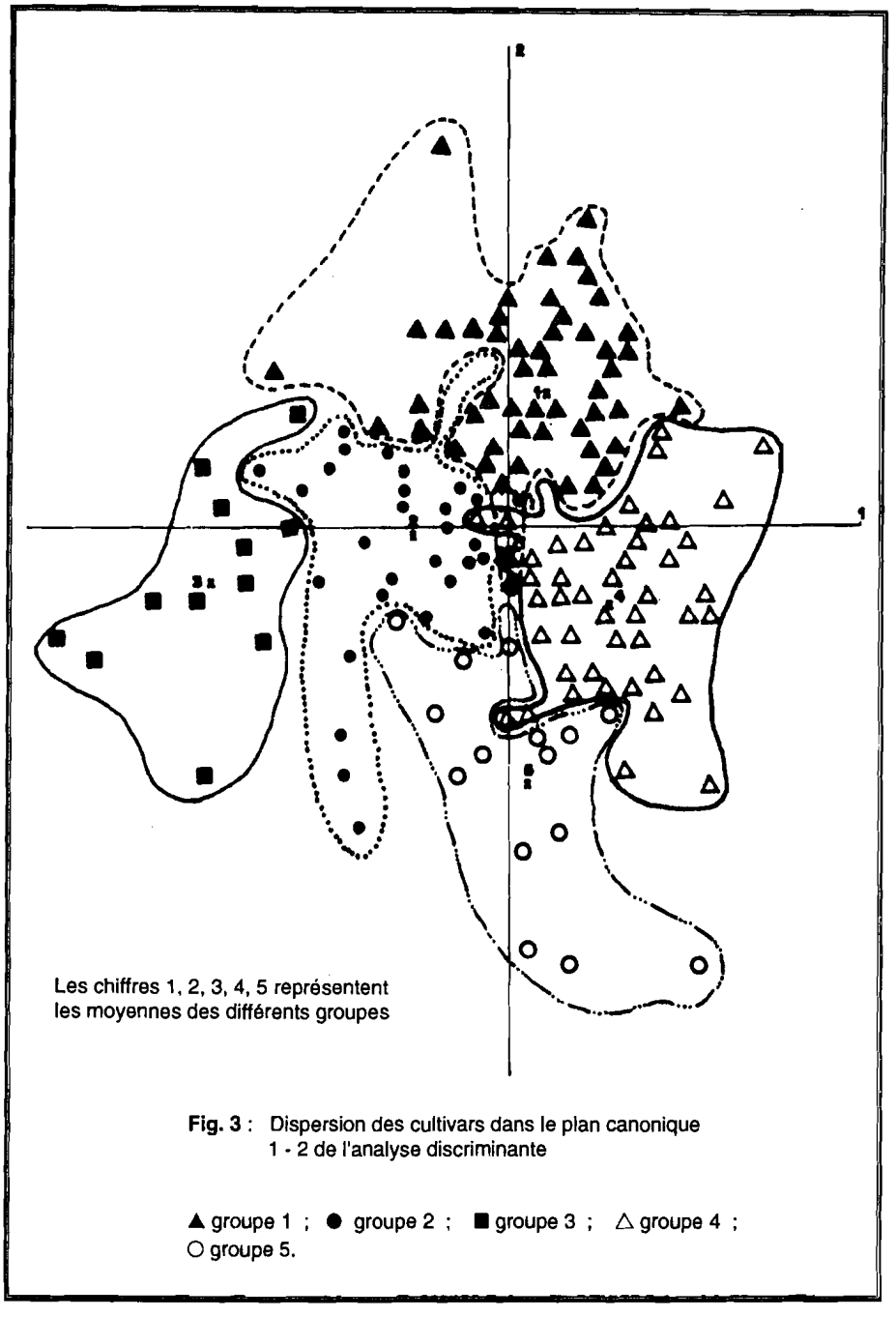

Fig. 3 : Dispersion des cultivars dans le plan canonique 1 - 2 de l'analyse discriminante

▲ groupe 1 ; ● groupe 2 ; ■ groupe 3 ; △ groupe 4 ; ○ groupe 5.

Pour chaque groupe, les cultivars peuvent être brassés en vue d'obtenir un composite. Ce brassage s'opérera par étapes successives, et en donnant un poids égal à chaque composante, le composite pesant le nombre de cultivars qui le constituent. Le brassage peut se faire selon le processus des polycross, chaque cultivar étant croisé manuellement avec tous les autres ; mais ce brassage par polycross devient très lourd quand le nombre des cultivars augmente (cas des groupes 1, 2 et 4).

Tableau 3. Moyenne des caractères des 5 différents groupes.

Caractères	$\bar{x}$				
	G_1	G_2	G_3	G_4	G_5
HT	277,896	251,783	216,077	287,754	250,176
HME	155,313	132,152	105,462	167,807	140,176
LOFE	98,778	94,257	86,331	97,827	87,406
LAFE	10,198	9,871	9,170	9,836	9,319
LOE	13,505	12,580	12,458	12,746	11,570
LAE	3,469	3,247	3,200	3,238	3,014
NEE	14,078	13,420	12,936	13,864	12,886
LOGR	9,207	9,095	9,174	8,550	8,176
LAGR	7,991	7,998	8,258	7,638	7,459
EGR	3,486	3,452	3,625	3,438	3,344
FM	69,134	65,435	57,615	71,263	70,529
FF	73,284	69,913	61,077	76,088	74,706
NEP	16,851	15,978	16,462	15,737	16,529
PEP	1,790	1,413	1,509	1,308	1,226
P1000	18,082	18,062	18,415	15,808	14,724
HUM	29,170	26,195	26,195	25,307	31,021

Une autre méthode, celle de Harrisson (Irish method) peut être utilisée. Elle consiste à semer, en isolement, une ligne de chaque composante comme femelle et un mélange mécanique de toutes les composantes comme mâles (les composantes femelles sont castrées manuellement). Ici, le problème de concordances des floraisons ne se pose pas, car les cultivars d'un groupe donné sont de précocité similaire.

Mais pourquoi constituer des composantes ? Les cultivars du centre éburnéen ont été multipliés dans des conditions de culture traditionnelle pendant de nombreuses générations et ont donc acquis une tolérance appréciable aux aléas du climat et de la culture. La première raison est donc de sauvegarder cet acquis sous la forme aisément maniable d'un composite. La deuxième raison est que ces cultivars représentent les formes actuellement les mieux adaptées au centre de la Côte d'Ivoire. Cette adaptation est précieuse pour atteindre l'un de nos objectifs majeurs de sélection, la stabilité du rendement et la large adaptabilité.

L'expérience montre que les écotypes, malgré ou à cause de cette bonne adaptation à la culture traditionnelle, ont des potentialités de rendement réduites et une base génétique faible. Leur brassage permet de pallier ces deux inconvénients en fournissant un composite de large base génétique et de rendement amélioré.

Le composite se prête particulièrement bien à une amélioration par les méthodes de la sélection récurrente (Marchand, 1975), méthodes très utilisées depuis les

premiers travaux du CIMMYT (Welhausen, 1965). En effet, il existe toute une gamme de techniques de sélection récurrente pour l'amélioration intravariétale (sélection massale, épi à la ligne modifiée, top-cross, full sib, S1) et intervariétale (top-cross, full-sib), portant sur tous les caractères intéressants, y compris le rendement.

Conclusion.

Deux des groupes variétaux déterminés (G2 et G3) apparaissent plus intéressants pour le centre éhurnéen. Ils comprennent la plupart des cultivars déjà sélectionnés, voire vulgarisés, c'est-à-dire des cultivars capables de couvrir de façon correcte la plupart des besoins des cultivateurs éburnéens. Il s'agit des cultivars semi-précoces (55 à 60 jours de floraison mâle) et précoces (40 à 52 jours de floraison mâle), ayant une hauteur d'insertion d'épi (1,20 m à 1,30 m) acceptable, et des potentialités de rendement correctes. Des composites CG2 et CG3, issus de ces groupes variétaux pourront être soumis à une amélioration intravariétale respective ou bien intervariétale (réciproque CG2 x CG3).

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Annex I.

Caractères quantitatifs observés.

- Date de floraison mâle en quantièmes depuis la date de semis (FM)
- Date de floraison femelle en quantièmes depuis la date de semis (FF)
- Hauteur totale de la plante du sol à la base de la première ramification de l'inflorescence mâle en cm (HT)
- Hauteur totale de la plante du sol à la base de l'insertion de l'épi supérieur en cem (HME)
- Longueur de la feuille de l'épi supérieur en cm (LOFE)
- Largeur de la feuille de l'épi supérieur en cm (LAFE)
- Nombre d'épis existants à la récolte (NEP)
- Poids d'épis existants à la récolte en kg (PEP)
- Humidité du grain à la récolte par un humidimètre Dickey-John (HUM)
- Longueur de l'épi en cm (LOE)
- Largeur de l'épi en cm (LAE)
- Nombre de moyen de rangs de l'épi (NRE)
- Poids de 1000 grains en g (P 1000)
- Longueur du grain en mm (LOGR)
- Largeur du grain en mm (LAGR)
- Epaisseur du grain en mm (EGR)

Annexe II Répartition de 200 cultivars dans les cinq groupes définis par l'utilisation conjointe d'une classification ascendante hiérarchique et d'une analyse factorielle discriminante.

GROUPE 1. (67 cultivars)	CeZ 82-6, CeZ 138-3, CeZ 96-2, CeZ 82-1, CeZ 106-1, CeZ 97-2, Nandala 1, CeZ 31-2, CeZ 82-3, CeZ 91-1, CeZ 85-1, CeZ 26-2, CeZ 101-1, CeZ 82-2, CeZ 90-1, CeZ 30-1, T3, CeZ 60-3, CeZ 26-1, CeZ 28-1, CeZ 28-2, CeZ 73-1, M16W x M164W, CeZ 126-3, CeZ 58-2, CeZ 80-3, CeZ 2-1, CeZ 65-2, CeZ 9-1, CeZ 91-1, CeZ 17-1, CeZ 88-3, CeZ 56-1, T11, CeZ 22-1, CeZ 1-1, CeZ 145-4, CeZ 145-1, CeZ 104-1, CeZ 128-1, CeZ 25-1, CeZ 162-1, CeZ 73-2, CeZ 73-4, CeZ 17-2, CeZ 145-3, CeZ 35-1, CeZ 96-3, CeZ 81-1, CeZ 116-2, CeZ 101-3, CeZ 96-6, CeZ 146-1, CeZ 88-1, CeZ 81-2, CeZ 135-1, CeZ 72-2, CeZ 75-1, CeZ 151-1, CeZ 151-2, CeZ 83-1, CeZ 36-1, CeZ 72-1, CeZ 94-2, CeZ 146-2, CeZ 145-6, CeZ 69-1.
GROUPE 2 (46 cultivars)	CeZ 20-2, CeZ 15-1, F 7635, CeZ 58-1, CeZ 45-1, CJB, CeZ 60-2, CeZ 22-3, CeZ 9-2, CeZ 22-2, CeZ 25-2, CeZ 29-2, CeZ 76-1, CeZ 31-3, CeZ 108-4, CeZ 107-1, CeZ 3-1, CeZ 51-3, CeZ 48-1, CeZ 98-2, CeZ 65-1, CeZ 55-6, CeZ 55-4, CeZ 27-1, CeZ 62-1, CeZ 146-3, CeZ 122-1, Nandala 2, CeZ 114-1, CeZ 82-3, CeZ 44-1, CeZ 97-1, CeZ 22-4, CeZ 138-6, F 7928, CeZ 127-2, CeZ 55-3, CeZ 57-7, CeZ 160-2, CeZ 160-2, CeZ 26-2, CeZ 2-2, CeZ 153-3, CeZ 82-4, CeZ 81-3, CeZ 106-2, CeZ 20-1.
GROUPE 3 (13 cultivars)	CeZ 2-3, CeZ 164-2, CeZ 55-5, CeZ 96-7, CI 64, CeZ 113-1, CeZ 2-5, CeZ 55-2, Pool 13, Pool 18, CD, Pool 12, CeZ 145-7.
GROUPE 4 (57 cultivars)	CeZ 82-1, CeZ 31-1, CeZ 116-1, CeZ 155-1, CeZ 29-1, CeZ 116-3, CeZ 52-1, CeZ 82-3, CeZ 51-1, CeZ 26-5, CeZ 121-3, CeZ 26-1, CeZ 103-1, CeZ 98-1, CeZ 78-1, CeZ 82-2, CeZ 108-2, CeZ 82-4, CEZ 24-1, CeZ 107-2, CeZ 121-2, CeZ 103-2, Kogbera, CeZ 120-1, CeZ 26-4, CeZ 138-1, CeZ 126-2, CeZ 159-2, CeZ 42-1, CeZ 40-1, CeZ 82-5, CeZ 104-2, CeZ 112-2, CeZ 103-3, CeZ 67-1, CeZ 163-1, CeZ 164-1, CeZ 145-5, CeZ 143-1, CeZ 96-1, CeZ 104-3, CeZ 131-1, CeZ 129-1, CeZ 124-3, CeZ 153-2, CeZ 11-1, CeZ 126-1, CeZ 131-1, CeZ 117-2, CeZ 125-2, CeZ 26-3, CeZ 59-1, CeZ 108-1, CeZ 108-5, CeZ 127-1, CeZ 108-3, CeZ 132-1.

GROUPE 5	CeZ 96-4, CeZ 56-2, CeZ 56-3, CeZ 54-1, CeZ 159-3, CeZ 121-1, CeZ 124-1, CeZ 113-3, CeZ 77-1,
(17 cultivars)	CeZ 120-2, CeZ 117-1, CeZ 54-2, CeZ 105-1, CeZ 47-1, CeZ 97-3, CeZ 123-2, CeZ 73-3.

Field Evaluation of Nigeria-made Granular Urea on Maize Production in the Semi-Arid Zone of Nigeria.

CHUDE, V.O., E.N.O. IWUAFOR and G. LOMBIN

Institute for Agricultural Research, Samaru, Ahmadu Bello University, Zaria, Nigeria.

Abstract

Field trials were conducted at five locations in the semi-arid zone of Nigeria during 1988-90 to evaluate the efficiency of Nigerian - made granulated urea fertilizer along with imported prilled urea and calcium ammonium nitrate (CAN) at rates of 0, 50, 100 and 150 kg N/ha applied as surface uncovered and surface covered. Source, rate and method interactions were not significant at all locations although there was significant method x rate, method x source and source x rate interactions at two out of the five locations. Generally, the Nigerian made urea gave higher grain and straw dry matter yields than prilled urea but slightly lower yields than CAN at all locations.

The optimum N requirement for maize in all the locations were observed at between 100 and 150 kg ha-1. Although grain yields were not affected by methods of application, there was evidence that surface covered seemed to be superior at the drier locations.

Introduction

Nitrogen is the most limiting nutrient element to cereal production in the semi-arid zone of Nigeria. (Jones and Wild 1973, Lombin, 1988). Most of the soils of the area which stretches from Latitude 10° to 14° N are derived from recent eaolian deposits. These soils are dominated by well-drained but shallow Entisols, Alfisols and Inceptisols (Fertilizer use Committee, 1989). They are coarse textured and consistently low in organic matter content, available phosphorus, effective cation exchange capacity and mineral nitrogen. As a result of the low soil test N, the production of cereals especially maize is only economical when nitrogen fertilizers are applied in combination with those of phosphorus and potassium. To ensure maximum uptake of fertilizers by crops and also avoid reduction in the availability of fertilizers due to unfavourable soil-fertilizer interactions, proper fertilizer placement, correct timing and efficient source are very crucial. Results of studies on effects of placement methods, timing and source of nitrogen fertilizer on maize yields and soil properties have been extensively reported in literature (Greenwood, 1949; Greenwood, 1951; Jones, 1974; Jones and Wild 1975; Bache 1965; Stockinger 1970; Balasubramanian 1978; Balasubramanian and Singh 1982; Lombin 1988). The concensus of opinion on the effect of timing N fertilizer is that there are no comparative advantages in splitting N fertilizer over single application on maize yield except at high rates of application.

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Similarly, no particular method of application seems to be superior to the other, but incorporation of N fertilizer into the soil remains the existing recommendation. In the savanna region, non-significant differences between ammonium sulphate, prilled urea and calcium ammonium nitrate on the yield of maize have been reported. However, considering the side effects of these N-sources on the soil, ammonium sulphate is known to acidify the soil more rapidly than urea and calcium ammonium nitrate. Moreover, reduction in the levels of exchangeable cations and increased solubilization of aluminium and manganese in ammonium sulphate-induced acidity is common place.

The urea evaluated in the semi-arid savanna before 1988 was the imported prilled type which has now been completely replaced by granulated urea a product of the National Fertilizer Company of Nigeria (NAFCON), Onne, Portharcourt Nigeria. As far as the authors are aware, no field evaluation of this N-carrier has been carried out. However, the manufacturers of granular urea have describe the product as an agronomically efficient and most economic fertilizer. In comparison to prilled urea, they claim that granular urea has a higher crushing strength and resistance to abrasion, higher N efficiency to field crops as a result of its superior placement property and reduced surface area per kg weight. The residual acidity is said to be comparable to that of calcium ammonium nitrate but lower than that of ammonium sulphate. Considering that NAFCON produces about 1,500 metric tons of granular type available to the Nigerian farmer, it was considered necessary to verify some of the manufacturer's claims through field evaluation of the product.

The objective of the study was to investigate the relative efficiency of Nigerian-made granulated urea and two other N-carriers.

Materials and Methods

Study Area. Five sites (Bagauda, Kafin-Maiyaki, Malumfashi, Daudawa and Gusau) representing different land resource areas and varying in climatic conditions and soil types were chosen for the investigation. Detailed description of the experimental sites is given in Table 1. The Daudawa and Malumfashi locations fall within the transitional zone between Sudan and Northern Guinea savanna while the other locations are in the Sudan savanna eone. Although the soils are inherently low in fertility, the locations selected are considered high in potential for cereal production.

Experimental Details. The trial was conducted during 1988-90 season. Three sources of N (NAFCON granulated urea, (46%) prilled imported urea (46%N) and calcium ammonium nitrate (26%N)) at rates of 0, 50, 100 and 150 kg N/ha were factorially combined with two methods of nitrogen application (surface covered and surface uncovered). The 24 treatment combinations were replicated three times in a randomised complete block design. The N was split, split applied, half at planting and the rest at 6 weeks after planting. Basal P and K at the rates of 60 kg/ha each and in the forms of single superphosphate and muriate of potash respectively were applied at planting. Sub plot size was 5 x 5.25m, consisting of seven ridges spaced at 75 cm apart. The alleys between sub plots were 0.5 m while those between blocks were 1.5 m. Maize (*Zea mays* L.) variety TZSR was planted on ridges at 25

cm spacing between plants, giving an estimated population of 53,000 plants/ha after thinning to one plant per stand. The net plot from where yields were estimated consisted of the three middle rows of each plot.

Table 1. Rainfall, parent material and soil classification of experimental sites.

Site	Latitude	Soil grouping parent material	3-year mean annual rainfall (mm)	USDA/FAO Soil classification
Bagauda	12°01'N	Loess overlying undifferentiated complex rocks	631	UdicUstochrept/ Dystric Gleysol
Kafin-Maiyaki	11°50'N	Loess overlying undifferentiated basement complex rocks	604	Haplustalf/Luvisol
Malunfashi	11°47'N	Less leached nature shallow soils overlying basement complex rocks	715	Haplustalf/Luvisol
Daudawa	11°31'N	Shallow soils on acid crystalline rocks	897	Haplustalf/Luvisol
Gusau	13°24'N	Well drained shallow soils on basement complex rocks	592	Fluventic Ustochrept/ Dystric Gleysol

Soil Samples. Pre-crop composite soil samples were taken from the top soil (0-15 cm) at each experimental site in the first year of the trial. The soils were air-dried and sieved to pass a 2 mm mesh sieve before analysis. Sub-samples were further ground and screened through a 100 mesh sieve for organic matter determination. Soil pH was measured in 1: 2.5 soil/solution ratio in water and 0.01 m CaCl2; organic carbon was estimated by dichromate wet combustion method of Walkley and Black; exchangeable cations were extracted with IN neutral ammonium acetate; Mg and Ca in solution were determined by atomic absorption spectrophotometer while K and Na was by the flame photometer. Exchangeable acidity was by titration method and effective cation exchange capacity was by summation. Total N was determined by the semi-microkjeldahl method (Bremner, 1960). Available P was extracted by the Bray nO 1 extraction and P in solution determined by the Molybdate Blue colour method as modified by Murphy and Riley (1962). Available Zn, Fe, Mn and Cu were extracted with O. IN HC1 and determined by atomic absorption spectrophotometer. Mineral N was determined using the IN KC1 extraction and distillation for NH+4 - N and NO-3 - N.

Results and Discussion

Data in Table 2 shows clearly that the soils were generally low in major nutrients, organic carbon, extractable Zn and Cu, but adequate in extractable Mn and Fe. Based on similar results obtained earlier, Lombin and Singh, (1986) associated the soils with low inherent fertility and productivity potential.

Table 2. Physico-chemical properties surface soils (0-15 cm) of the experimental sites (1988).

Soil variables	Daudawa	Gusau	Malumfashi	Bagauda	Kafin-Maiyaki
pH (H_2O)	5.2	5.3	6.0	5.8	6.0
pH ($CaCl_2$)	4.4	4.3	5.1	4.7	5.0
Organic carbon (g/kg)	1.20	3.6	3.5	4.0	4.3
Bray-1-P (mg/kg)	9.22	3.8	20.5	4.51	3.45
Exch K (cmol/kg)	0.18	0.14	0.13	0.13	0.13
Exch Ca (cmol/kg)	0.94	1.25	1.10	1.37	1.60
Exch Mg (cmol/kg)	0.26	0.41	0.32	0.47	0.64
Exch Na (cmol/kg)	0.06	0.07	0.03	0.03	0.06
Exch Acidity (cmol/kg)	0.04	0.40	0.01	0.60	0.14
Total N (g/kg)	0.23	0.32	0.60	0.30	0.42
NO_3 - N (mg/kg)	20.00	4.00	30.00	2.00	5.00
NH_4 - N (mg/kg)	21.00	5.50	25.00	3.50	6.50
ECEC (cmol/kg)	1.48	2.27	1.59	2.90	2.57
HCl - Zn (mg/kg)	1.06	1.00	1.60	2.00	2.20
HCl - Mn (mg/kg)	49.00	27.00	20.00	40.00	32.6
HCl - Fe (mg/kg)	200.00	140.00	56.00	120.00	100.00
HCl - Cu (mg/kg)	0.65	0.80	0.50	0.74	0.68
Textural class	Sandy Loam	Sandy	Sandy Loam	Loamy Sand	Loamy Sand

Effect of Treatment on Grain Yield. The mean effects of nitrogen rates at different sites for the individual years and the pooled analysis are shown in Table 3 while the analysis of variance showing mean squares is in Table 4. In the first year of the study, there was a linear relationship between nitrogen rates and grain yield at Kafin-Maiyaki, Malumfashi and Gusau. Although yields increased linearly with increase in N application, differences were significant only between 50, 100 and 150 kg N/ha and the control at Kafin-maiyaki and Gusau. At Malunfashi, differences were only significant between 100, 150 kg N/ha and the control. The highest grain yields of 2.68 2.26 and 2.75t/ha at the three locations respectively, were produced at 150 kg N/ha. Their correspon-ding response ratios (kg grain/kg N) were 17.8, 15.1 and 18.3 at the N rates giving maximum grain yield. This dramatic yield increase to high rates of N even in drier areas in 1988 may have been due to favourable rainfall obtained that year. Moreover, the soil test N values for the three location were critically low for maize (Table 1). In related studies, Balasubramanian and Singh reported that their calculated N rates for maximum maize grain yield was 177.5 kg N/ha at Kadawa in the Similar responses to N by maize were observed by Balasubramanian et al., (1978) and Jones (1973). The relationships between grain yield and N rates were not consistent in all the location in 1989. For examples, at Kafin-Maiyaki, the relationship, Gusau and Daudawa grain yields increased from 0 to 100 kg N/ha but dropped thereafter. At Bagauda, grain yield increased at all levels of N, although the increases did not attain any statistical significance. Similar results were obtained at the other four locations. In 1990, three out of the five trials failed due to drought. The rainfall at each of the three locations was below 600 mm.

Table 3. Maize grain yield (t/ha) response to nitrogen rates at different sites.

Location Treatments	1988	1989	1990	Mean
Kafin-Maiyaki				
O N/ha	0.857	0.150	F	0.503
50 N/ha	1.843	0.160	F	1.001
100 N/ha	2.539	0.150	F	1.344
150 N/ha	2.680	0.160	F	1.420
LSD (0.05)	0.740	NS	-	0.16*
Malumfashi				
0 N/ha	0.847	0.740	F	0.793
50 N/ha	1.577	0.870	F	1.223
100 N/ha	1.880	0.930	F	1.405
150 N/ha	2.260	0.840	F	1.550
LSD (0.05)	0.580	NS	-	0.18*
Gusau				
0 N/ha	0.188	0.36	F	0.589
50 N/ha	1.728	0.47	F	1.099
100 N/ha	2.394	0.50	F	1.447
150 N/ha	2.751	0.42	F	1.585
LSD (0.05)	0.60	NS	-	0.18*
Bagauda				
0 N/ha	-	3.320	2.071	2.695
50 N/ha	-	3.440	2.201	2.821
100 N/ha	-	3.680	2.270	2.975
150 N/ha	-	3.950	2.155	3.052
LSD (0.05)	-	NS	NS	NS
Daudawa				
0 N/ha	-	2.910	3.607	3.259
50 N/ha	-	3.130	3.567	3.349
100 N/ha	-	3.940	3.837	3.889
150 N/ha	-	3.290	3.954	3.622
LSD (0.05)	-	NS	NS	NS

* = Significant at 5% level of probability
NS = Not significant
F = Trials failed at all three locations due to drought

Table 4. Analysis of variance showing mean square values for maize grain yield at different sites averaged over 2 years.

Source of variation	df	Daudawa	Gusau	Malumfashi	Bagauda	Kafinmaiyaki
Replication	2	0.4349	0.2048	0.1828	3.390	0.0520
Year (yr)	1	10.054	75.9217*	27.1250*	44.001*	113.0066*
Method (M)	1	0.1388	0.0870	0.1831	0.026	0.3546
Rates (R)	3	1.0941*	4.3516*	5.195*	0.345	6.1397*
Source (S)	2	5.6422	0.6490	0.2063	1.869	0.2197
M x R	3	0.4284	0.0869	0.1476	0.220	0.0835
M x S	2	2.6912	0.2262	0.1427	0.257	0.0415
R x S	6	0.8357	0.5661	0.1499	1.910	0.2102
Yr xM	1	0.0003	0.5725	0.0031	1.166	0.0812
Yr x R	3	0.4073	0.7715	2.3410*	0.427	7.1783*
Yr x S	2	2.9483	0.0001	0.3924	0.165	0.2830
M x R x S	6	1.8710	0.1727	0.0691	0.518	0.0254
Yr x M x R	3	0.4750	0.0986	0.2920	1.604	0.1051
Yr x M x S	2	0.1970	0.4150	0.4320	2.045	0.1071
Yr x M x S	6	0.7011	0.1331	0.1206	0.624	0.1642
Residual	98	0.4105	0.1610	0.1641	1.001	0.0549

* Significant at 5% level of probability.

At Bagauda, maize responded to N up to 100 kg N/ha while at Daudawa, 150 kg N/ha gave the highest yield. The drop in yield above 100 kg N/ha at Bagauda may be due to toxicity effect at higher rates of N, especially in the event of limited soil moisture. For both locations, the yield differences among treatments were not significantly different. The pooled analysis showed that treatment effect was sifnificant at Kafin-Maiyaki, Malumfashi and Gusau only (Table 3). At all three locations, 150 kg N/ha gave the highest yield, but these were not significantly different from yields at 100 kg N/ha. The corresponding response ratios were 9.5, 10.3 and 10.6. The treatment effect at Bagauda and Daudawa were not significant, but there was evidence that the highest yields were attained at 150 kg N/ha at Daudawa and 100 kg N/ha at Bagauda. The optimum N rates for these soils seem to range from 100-150 kg N/ha.

Grain yields of maize in response to source and method of application averaged over years are shown in Table 5. There was no significant difference among the sources at all locations. However, clear evidence existed that CAN was superior at Kafin-Maiyaki, Malumfashi, Gusau and Daudawa, followed by Nigerian-made granular urea and prilled urea, in that order. At Gusau, prilled urea gave a marginal yield increase over CAN and granular urea. Although the effect of method did not attain significance at any of the locations, the surface covered method tended to give

higher maize yield. Among the first order interactions, source x rate, source x method and rate x method were significant at only Kafin-Maiyaki and Gusau. While increasing rates of granular urea and prilled urea resulted in increased yields, CAN drastically reduced yield at 150 kg N/ha at both locations. When applied covered, granular urea was superior to the other two sources; but the reverse was the case when N was applied surface uncovered. The use of CAN followed by granular urea gave the highest grain yield at Kafin-Maiyaki. The situation was different at Gusau; when applied surface covered, Can produced the best crop, followed by prilled urea. Conversely, prilled urea gave the highest yield when applied surface uncovered followed by CAN. The N rate and methods were linearly related at the two locations suggesting that both methods are comparable at all the N rates tested. This study has shown that the Nigerian made granulated urea is as effective as any N fertilizer for maize grain production.

Table 5. Maize grain yields (t/ha) response to source and method of N application at different sites averaged over 2 years.

Treatment	Kafin-Maiyaki	Malum fashi	Gusau	Bagauda	Daudawa
Source					
Granulated urea	1.107	1.187	1.094	2.802	3.691
Prilled urea	1.016	1.161	1.223	2.874	3.594
CAN	1.148	1.285	1.326	2.804	3.746
LSD (0.05)	NS	NS	NS	NS	NS
Method					
Surface covered	1.141	1.247	1.239	2.740	3.508
Surface uncovered	1.040	1.176	1.190	2.713	3.446
LSD (0.05)	NS	NS	NS	NS	NS
Interaction					
Source x Rate	*	NS	*	NS	NS
Source x Method	*	NS	*	NS	NS
Rate x Method	*	NS	*	NS	NS
Source x Method x Rate	NS	NS	NS	NS	NS

* = Significant at 5% level of probability
NS = Not significant.

Table 6. Maize stover yield (kg/ha) response to nitrogen rates, source and methods at different sites averaged over 2 years.

	Kafin-Maiyaki	Gusau	Bagauda	Daudawa
Rate (kg N/ha)				
0	1491	2800	1938	4890
50	3062	4675	3733	5452
100	2993	5513	3714	5145
150	3373	5917	3658	4968
LSD (0.05)	284	502	474	NS
Source				
Granulated urea	2371	4348	3465	5204
Prilled urea	2519	4662	2893	5163
CAN	3300	5169	3425	4974
LSD (0.05)	NS	NS	NS	NS
Method				
Surface covered	2682	4975	3465	5031
Surface uncovered	2778	4478	3056	5195
LSD (0.05)	NS	NS	NS	NS
Interaction				
Source x Rate	NS	NS	NS	
Source x Method	NS	NS	NS	
Source x Rate	NS	NS	NS	
Source x Rate x Method	NS	NS	NS	

NS: Not significant

Effect of Treatment on Stover Yield. The pooled data for stover yield is shown in Table 6. The use of N significantly increased maize stover yields at Kafin-Maiyaki, Gusau and Bagauda but not at Daudawa. Increases in the mean stover yield of N-treated plots over control were 51, 50 and 58% for Kafin-Maiyaki; 40, 49 and 52% for Gusau; 48, 48 and 47% for Bagauda at 50, 100 and 150 kg N/ha, respectively. The nitrogen level for maximum stover yield was 150 kg N/ha at Kafin-Maiyaki and Gusau, and 50 kg N/ha at Daudawa and Bagauda. However, using a mean response function, 100-150 kg N/ha is a more rational rate for the production of maize in the study area.

Conclusion

The study has confirmed earlier findings to the effect that N is critically low in soils of the semi-arid region to the extent that rates of between 100-150 kg N/ha are necessary for optimum maize production. The source of N and method of application did not have any dramatic influence on the N use efficiency. The suggestion, therefore, is to the effect that the Nigerian-made granular urea is as efficient and effective as either calcium ammonium nitrate or imported prilled urea.

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Response of Maize to Various Rates of Zinc Fertilizer In the Semi-Arid Zone of Nigeria.

IWUAFOR, E.N.O., V.O. CHUDE, I. AMAPU.

Department of Soil Science, Institute for Agricultural Research, Samaru, Ahmadu Bello University, Zaria, Nigeria.

Abstract

Field trials were conducted at five locations in the semi-arid zone of Nigeria during 1988-90 to study the effects of various rates of zinc fertilizer on maize yield. The treatments were absolute check, zinc check, 1, 2 and 3 kg Zn/ha. Maize grain and straw dry matter yields were increased with increasing zinc rate, up to 2 kg Zn/ha across all locations. It was evident that when 0.1NHCl extractable soil zn fell below 1.0 mg Zn/ha, response to added zn was obtained. The optimum zn fertilizer for the soils studied ranged between 1-2 kg Zn/ha.

Introduction

The semi-arid region of the Nigerian savanna as conceived in this paper comprises of the Sahel zone (Lat. 12-14° N) and Sudan (Lat 11-12° N). In these agro-ecological zones, rainfall equals or exceeds potential evapo-transpiration for between 2-5 months in the year. The area constitutes about 30% of the estimated 740,000 km2 of the Nigerian savanna.

Alfisols and inceptisols/Entisols are the dominant soil types which are formed largely on drift materials overlying basement complex. The soils are well-drained and coarse textured. They are inherently low to very low in organic matter, CEC, clay, which is predominantly kaolinitic and are moderately acid. According to Martens (1968) and John (1972) these conditions are often associated with low levels of plant available zinc. Lombin (1983) reported values of 0.69-4.41 mg/kg 0.1 N HCl extractable zinc for some Nigerian savanna soils. Values of 1.0-9.5 mg/kg 0.1N HCl extractable zinc were reported for some soils of the dry Nigerian savanna (Pam, 1990). Osiname (1972); Osiname *et al.* (1973) also observed low zinc levels in some soils of the derived Nigerian savanna. Zinc may, therefore, be a limiting factor to maize production in the savanna in general, especially as high-yielding cultivars are now commonly used under intensive culture.

Information of the response of crops to zinc in the zone is meagre. There are, however, reports on the occurrence of zinc deficiency on maize in rainfed agriculture and on rice and wheat under irrigated agriculture in northern Nigeria (Lombin, 1989). Osiname *et al.* (1973) reported significant maize response to zinc in areas on the sandy Inceptisols of the Western Nigeria derived savanna.

This study, therefore, assessed the level of zinc responses of maize in the southern fringes of the semi-arid zone where maize can thrive.

Materials and Methods

Field experiments were conducted for three years at Gusau, Kafin-Maiyaki and Malumfashi and for two years at Bagauda and Daudawa (Table 1). Zinc at the rates of absolute check (AC) 0, 1.0, 2.0 and 3.0 kg Zn/ha, as zinc sulphate, were investigated using randomized complete block design with three replications. Each plot received a basal application of N, P and K fertilizers at the rates of 120 kg N, 26 kg P and 50 kg K/ha as Urea, single superphosphate and muriate of potash, respectively. All P and K and half of N were surface broadcast at land preparation. The remaining N and all the zinc treatments were given at 4 weeks after planting by band application. Three maize seeds (var. TZSR) were planted per hill at 75 cm inter-and 25 cm intra-row spacing and thinned to one seedling/hole at 2 weeks after emergence, giving a plant population of 53,300 plants/ha. Weeds were controlled by hoe weeding.

Composite surface soil samples (0-15 cm) were collected from each site prior to land preparation for the purpose of characterization. Each sample was air-dried, sieved to pass through a 2 mm mesh and analysed for organic C by the Walkley Black method (Allison, 1965), exchangeable bases using NH40AC extraction method (Chapman, 1965), soil pH in 1:1 soil to water using glass electrode, available P by the Bray N0. 1 method. Available Zn was extracted with 0.1N HCl solution. Ear leaf samples were digested with $HClO_4$-H_25O_4-HNO_3 acid mixture using Aluminium block digestor (Juo, 1979). Phosphorus was determined with a spectrophotometer; potassium, calcium, magnesium, iron and Zinc were measured by atomic absorption spectroscopy. Total N wad determined by the macro-kjeldahl technique as described by Bremner (1965). Particle size analysis was carried out by the hydrometer method as described by Day (1965). Grain and straw dry matter yields were computed at harvest.

Results and Discussion

Soil Nutrient Status. Results of analysis of the soil samples taken prior to land preparation indicate that the experimental sites were generally low in fertility (Table 2). This is a common feature of major upland soils of the savanna ecological zone. The low available Zn values (0.97-2.20 mg/kg) are expected, considering the sandy nature and low organic content of the soils. It is imperative, therefore, that judicious use of adequate amounts of fertilizer is important for improved and sustained productivity of the soils.

Grain and Stover Yields. Maize response to zinc fertilizer at the various sites for all the years is shown in Table 3. There were generally grain yield increases with increasing levels of applied Zn, up to 2 kg Zn/ha, beyond which there was no benefit from Zn application. Significant responses were obtained only at Bagauda and Gusau. With the relatively low level of soil Zn, the results are not unexpected. According to Agarwala *et al.* (1980) the response of maize to zinc fertilizer is dependent upon the native Zn status. The zinc status at Daudawa and Gusau were below the critical level at the beginning of the investigation. The lack of significant response at Bagauda, Kafin-Maiyaki and Malumfashi may suggest that 0.1N HCl

Table 1. Rainfall, parent material and soil classification of experimental sites.

Site	Latitude (°N)	3-year mean precipitation (mm)	Soil grouping and parent material	USDA/FAO soil classification
Bagauda	12°01'N	631	Loess overlying undifferentiated basement complex rocks	Inceptisol (Udic Usto chrept Dystric claysol)
Daudawa	11°31'N	897	Shallow soils on acid crystalline rocks	Alfisol (Haplustalf/loamsol)
Gusau	13°24'N	592	Well drained shallow soils on basement complex rocks	Inceptisol (Fluventic ustochrept/Dystric Gleysol)
Kafin-Maiyaki	11°50'N	604	Loess overlying undifferentiated basement complex rock	Alfisol (Haplustalf/Luvisol)
Malumfashi	11°47'N	715	Less leached mature shallow tafl/soils overlying basement complex rocks	Alfisol (Haplus-Luvisol)

extractable Zn greater than 1.0 mg/kg was sufficient to meet the zinc needs of the maize crop at these locations. The relatively low yields obtained at some of the locations and the total crop failure at three of the five sites in 1990 were due to severe moisture stress during the grain filling stage (Table 3).

Table 2. Soil characteristics of experimental sites.

Properties	Bagauda	Daudawa	Gusau	Kafin-Maiyaki	Malumfashi
Organic C (g/kg)	3.8	8.9	3.6	4.0	3.2
Soil pH (H20)	5.8	5.7	5.2	5.9	6.1
Total N (g/kg-1)	0.32	0.51	0.33	0.36	0.40
Bray P - 1 (mg/kg)	4.51	8.32	3.8	2.05	5.20
Exchangeable Ca (cmol/kg)	1.29	0.94	0.98	1.62	1.22
Exchangeable Mg (cmol/kg)	0.52	0.31	0.44	0.56	0.32
Exchangeable K (cmol/kg)	0.13	0.18	0.14	0.11	0.15
0.1N Extractable Zn (mg/kg)	1.93	1.04	0.97	2.20	1.60
Sand (g/kg)	860	750	900	860	810
Silt (g/kg)	60	120	60	50	100
Clay (g/kg)	100	130	40	90	100
Textural class	Loamy sand	Sandy loam	Sand	Loamy sand	Sandy loam

Straw (stover) yield followed a similar trend as grain yield (Table 4). In general, Zn application significantly increased straw yield up to 1-2 kg Zn/ha. Osiname (1973) and Ritchey (1986) reported critical values of soil Zn at between 1.0-1.4 mg Zn/ha.

Nutrient Concentration in Ear Leaf. The concentration of nutrient elements in the ear leaf sampled at 50% silk stage is shown in Table 5. Zinc concentration increased with increasing addition of zinc fertilizer. Significant increases were observed at all locations with the use of 2 and 3 kg Zn/ha. The effect of zinc fertilizer on ear-leaf contents of P and Fe were not consistent, but at most of the locations ear leaf P was lower at higher rates of applied zinc. At Daudawa and Gusau, P concentration was significantly reduced at high levels of Zn fertilizer. This inverse relationship, which has been widely reported (Rudgers, *et al.*, 1970; Farah and Soliman, 1986) may be due to P-Zn interaction in the soil which makes the P less available. It could also be due to a metabolic disorder within the maize plant due to imbalance between the two nutrient elements.

Table 3. Maize grain yield response to zinc fertilization at different locations.

Treatments	1988	1989	1990	Mean
Bagauda				
Absolute check (AC)		3.28	1.56	2.42
0 kg Zn/ha	-	3.64	1.63	2.63
1 kg Zn/ha	-	3.88	1.51	2.70
2 kg Zn/ha	-	3.76	2.22	2.99
3 kg Zn/ha	-	3.91	1.65	2.78
LSD (0.05)	-	NS	NS	NS
Daudawa	-	1.74	1.48	1.61
AC	-	1.74	1.48	1.61
0 kg Zn/ha	-	2.62	2.95	2.78
1 kg Zn/ha	-	3.04	3.00	3.02
2 kg Zn/ha	-	3.22	3.18	3.20
3 kg Zn/ha	-	2.90	2.45	2.68
LSD (0.05)	-	0.61	0.60	0.47
Gusau				
AC	2.89	0.16	+F	1.57
0 kg Zn/ha	3.19	0.72	F	1.95
1 kg Zn/ha	3.17	0.85	F	1.97
2 kg Zn/ha	2.39	0.63	F	1.51
3 kg Zn/ha	1.54	1.47	F	1.38
LSD (0.05)	0.67	0.51	F	4.5
Kafin-Maiyaki				
AC	2.04	0.11	F	0.45
0 kg Zn/ha	2.74	0.34	F	1.07
1 kg Zn/ha	2.60	0.53	F	1.54
2 kg Zn/ha	2.74	0.59	F	1.56
3 kg Zn/ha	1.69	0.32	F	1.00
LSD (0.05)	NS	NS		NS
Malumfashi				
AC	1.33	0.77	F	1.02
0 kg Zn/ha	1.63	1.07	F	1.35
1 kg Zn/ha	1.99	0.86	F	1.42
2 kg Zn/ha	2.06	0.95	F	1.51
3 kg Zn/ha	1.82	1.06	F	1.44
LSD (0.05)	NS	NS	F	NS

+F. = Trials failed in 1990 due to drought.

Table 4. Maize straw yield response to zinc fertilizer at different locations averaged over 2 years.

Zn rate (kg Zn/ha)	Bagauda	Daudawa	Gusau	Kafin-Maiyaki	Malumfashi
AC	4.15	5.85	3.42	3.95	3.51
0	4.91	6.71	3.67	4.34	3.90
1	6.25	7.11	3.82	5.57	4.55
2	6.44	7.14	4.81	5.73	4.55
3	6.55	4.58	2.49	5.54	4.86
LSD (0.05)	1.12	1.35	1.09	1.21	7.58

Table 5. Effect of zinc fertilize on the concentration of P, Zn and Fe in maize ear leaf, 1989.

Treatment	P (%)	Zn	Fe
		mg/kg	
Bagauda			
Absolute check (AC)	0.11	24.43	295
0 kg Zn/ha	0.16	26.10	258
1 kg Zn/ha	0.16	31.63	308
2 kg Zn/ha	0.16	33.63	263
3 kg Zn/ha	0.13	36.25	204
LSD (0.05)	0.06	6.59	61.36
Daudawa			
AC	0.33	19.25	288
0 kg Zn/ha	0.59	22.38	298
1 kg Zn/ha	0.43	25.30	253
2 kg Zn/ha	0.45	28.60	250
3 kg Zn/ha	0.39	31.23	301
LSD (0.05)	0.08	8.62	18.34
Gusau			
AC	0.36	16.17	245
0 kg Zn/ha	0.48	24.10	303
1 kg Zn/ha	0.44	30.48	189
2 kg Zn/ha	0.48	35.68	168
3 kg Zn/ha	0.38	37.25	185
LSD (0.05)	0.08	0.20	31.34
Kafin-Maiyaki			
AC	0.35	29.90	195
0 kg Zn/ha	0.43	29.90	195
1 kg Zn/ha	0.40	31.78	215
2 kg Zn/ha	0.42	35.15	200
3 kg Zn/ha	0.40	34.23	345
LSD (0.05)	0.12	7.35	5.64
Malumfashi			
AC	0.30	18.30	250
0 kg Zn/ha	0.37	23.23	308
1 kg Zn/ha	2.45	29.22	275
2 kg Zn/ha	0.49	31.50	240
3 kg Zn/ha	0.62	31.90	380
LSD (0.05)	0.05	8.72	61.53

Conclusion

The results of the study indicate that Zn deficiency is already incipient at Daudawa and Gusau. It has also been shown that responses to zinc in these soils would be expected when the 0.1N HCl extractable zinc falls below 1.0 mg/kg. Based on the overall results, between 1 to 2 kg Zn/ha is suggested to meet the zinc needs of good maize crop in the study areas.

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Determination of Optimum Harvesting Date for Seed Maize Using Some Seed Characteristics.

ERNEST A. ASEIDU.

Ghana Grains Development Project, Crops Research Institute, Kumasi, Ghana.

Abstract

Optimum harvesting date is required for the production of good quality seed. It is generally accepted that seed harvested earlier or later than optimum date are invariably of poor quality. An experiment was conducted in the major season of 1989 at Fumesua (Forest zone), Ejura (Transitional zone) and Nyankpala (Guinea savannah zone) to determine optimum harvesting dates for seed maize. Seeds of an early-maturing variety (Safita-2) were harvested at 80, 90, 100 and 110 days after planting. Also, seeds of medium-maturing variety "Aburotia" were harvested at 90, 100 110 and 120 days after planting while those of late-maturing "Dobidi" were harvested at 100, 110, 120 and 130 days after planting.

Optimum seed germination occurred after maximum seed dry weight had been attained. Maximum seed germination were observed between 80-100 days for Safita-2, 100 days for Aburotia and 100-110 days for Dobidi. Germinability of seeds harvested at Nyankpala was low as a result of excessive flood that caused high humidity in the area. Seeds harvested earlier than these days were generally lower in weight and percentage germination. Undue delay in harvesting significantly led to the reduction of seed moisture and yield. The transitional zone was more productive in terms of seed yield than the Forest and Guinea savanna zones.

Introduction

Crop harvesting is perhaps the most critical step in the overall seed production process. The timing of harvest is important because any delay after the seeds have attained physiological maturity increases the possibility of their deterioration as a result of adverse climatic conditions (Cadwell, 1972; Anderson and Daker, 1983). Seeds attain physiological maturity at moisture contents ranging from 32-35% for cereals and 50-55% for leguminous crops and cotton. Following physiological maturation, seeds continue to dry down until they reach harvest maturity-- the moisture content at which they can be effectively threshed with mechanical harvesters. This infers that frequent rainfall, combined with high temperatures, result in rapid losses of viability and vigor of seed in standing crops (Delouche, 1972).

The objectives of the study was, therefore, experiment were to determine the effects of harvesting period on seed quality, yield and other characteristics in various agro-ecological zones of Ghana.

Materials and Methods

The experiment was conducted at three locations in Ghana in 1989 to evaluate seed performance of three varieties of maize, namely Safita-2 (90-day white dent), Aburotia (105-day, white dent) and Dobidi (120-day, white dent) harvested at four different dates as follows:

Safita-2 harvested 80, 90, 100 and 110 days after planting;
Aburotia harvested 80, 100, 110 and 120 days after planting,
and Dobidi harvested 100, 110, 120 and 130 days after planting

The experimental design used was a split-plot, with four replications. Variety constituted the main plots and harvesting dates constituted the sub-plots. A sub-plot consisted of 4 rows of 5 m length and 80 cm between rows. One maize plant was maintained per hill spaced 40 cm apart. The trials were sown in the 4th week of April, 1989 in Fumesua (Forest zone) and Ejura (transition zone) and in the 2nd week of June in Nyankpala (Guinea savanna zone).

Seed characteristics observed at or soon after harvest included germination count based on 50 seeds per plot and in accordance with the seed testing rules of the Association of Official Seed Analysts (1981); 1000-seed weight at 15% moisture content; seed moisture content at harvest using a moisture tester, and total grain yield at 15% moisture content and 80% shelling percentage. The seed yield was then computed after discarding grains that did not meet seed standards.

Results and Discussion

a) ***Seed Moisture Content***. The effect of variety and harvesting date on seed moisture content is presented in Table 1. Percent seed moisture content was observed to drop progressively from the initial harvesting dates at all three locations. The initial moisture content at Nyankpala was observed to be exceptionally high, probably as a result of prolonged growth period due to excessive floods experienced that year in the Guinea savanna. During the process of seed development, the moisture content is known to increase after fertilization to a high level and thereafter declines as dry matter acumulates into the seed. After the accumulation of dry matter, seed moisture content begins to decline until it equilibrates with the environmental relative humidity.

b) ***Seed Germination***. Germination percentages observed at Fumesua and Ejura were satisfactorily high (Table 2). However, germination count at Nyankpala was unusually low, probably as a result of the excessive flood that occurred that year during plant growth and seed development. At Fumesua, the highest germination score of 92% in respect of Safita-2 was observed when the maize crop was harvested 100 days after planting. Thereafter, germination declined to only 61% at the final harvest, 110 days after planting.

Table 1. Mean effect of variety and harvesting date on maize seed moisture content (%), 1989.

Maize variety	Harvesting (DAP)*	Fumesua	Ejura	Nyankpala
Safita-2	80	27.4	30.7	41.2
	90	27.5	20.2	28.5
	100	20.4	23.8	25.5
	110	18.9	23.3	23.6
Aburotia	90	23.3	33.8	46.7
	100	22.4	23.3	32.1
	110	21.2	25.4	26.1
	120	18.5	23.2	25.8
Dobidi	10	23.1	30.2	48.8
	110	20.8	27.2	30.5
	120	21.4	24.0	25.4
	130	18.4	24.7	22.0
CV (%)	-	7.3	3.9	6.1
LSD (0.05)	-	2.2	1.5	2.1

DAP* = Days after planting.

At Ejura, seeds of Safita-2 harvested early at 80 or 90 days after planting were high at 90 and 81%, respectively. Delaying the harvest until 100 and 110 days after planting resulted in reduced germination to a level significantly lower than when seeds were harvested 80 days after planting (Table 2). A similar observation was made by Simpson and Stone (1935).

Seed harvested at 80 and 90 days at Nyankpala were low in germination as a result of delayed development due to flood stress. Delouche (1980) observed that seed germinability increases progressively until physiological maturity is attained.

The variety Aburotia did not show any significant decline in germination in any of the locations, probably as a result of its improved husk cover.

At Fumesua, the germination percentage of the variety Dobidi was significantly high at the first harvest but declined subsequently, probably as a result of unfavourable weather such as high temperature and high relative humidity.

c) ***1000-Seed Weight.*** Generally, values of 1000-seed weight were relatively low for the early harvest and increased in later harvests for virutally all the varieties and locations (Table 3).

For example, 1000-seed weight of Safita-2 harvested 80 or 90 days after planting at Fumesua and Ejura were significantly lower than when harvested at 100 or 110 days. A similar trend was observed at Nyankpala, but the differences were not statistical significant.

Table 2. Mean effect of variety and harvesting date on maize seed germination (%), 1989.

Maize variety	Harvesting (DAP)*	Fumesua	Ejura	Nyankpala
Safita-2	80	80	90	29
	90	70	81	49
	100	92	78	58
	110	61	73	54
Aburotia	90	86	86	55
	100	90	88	50
	110	75	85	49
	120	75	87	54
Dabidi	10	87	72	38
	110	72	68	43
	120	62	64	36
	130	62	68	32
CV (%)	-	15.9	12.4	36.0
LSD (0.05)	-	17.0	13.6	23.0

DAP* Days after planting.

Seed and Grain Yield. In general, yields declined with delay in harvesting. For instance, when harvesting of Safita-2 was delayed from 80 to 110 days, seed yield declined by 50% at Fumesua, 15% at Ejura and 46% at Nyankpala. Also delay in harvesting of Aburotia variety from 90 to 120 days led to decline in seed yield by 31% at Fumesua, 12% at Ejura and 18% at Nyankpala. In addition, delay in harvesting of Dobidi from 100 days to 130 days led to decline in seed yield by 33% at Fumesua, 14% at Ejura and 31% at Nyankpala. Mean percent seed loss across locations was 37% for Safita-2, 20% for Aburotia and 21% for Dobidi. The greater loss suffered by a result of Safita-2 was a early maturity when it suffered damage by birds. In addition, because the variety matured at the time the rains had not ceased, it suffered ear losses due to high humidity. Among locations, the greatest seed loss was at Fumesua (33% due to its warm and humid weather), Nyankpala (31%, due to flood) and Ejura (14%).

Table 3. Mean effect of maize variety and harvesting date on 1000-seed weight (g), 1989.

Maize variety	Harvesting (DAP)*	Fumesua	Ejura	Nyankpala
Safita-2	80	229	200	288
	90	229	246	278
	100	264	315	325
	110	280	313	303
Aburotia	90	230	236	250
	100	258	308	278
	110	268	313	290
	120	274	312	303
Dobidi	100	278	312	308
	110	324	355	315
	120	311	323	313
	130	308	331	360
CV (%)	-	9.6	11.3	18.8
LSD (0.05)	-	36.7	47.2	77.6

DAP* = Days after planting

Table 4. Mean effects of variety and harvesting date on maize seed total grain yields (kg/ha), 1989.

Maize Variety	Harvesting (DAP)*	Fumesua		Ejura		Nyankpala	
		Seed	Grain	Seed	Grain	Seed	Grain
Safita-2	80	3011	4228	4423	6322	2977	4137
	90	2899	4035	4302	6181	2738	4462
	100	2180	3890	3676	5781	2235	4492
	110	1501	3170	3764	5726	1619	4496
Aburotia	90	3809	5100	4325	5871	2834	3885
	100	2895	4355	3994	5660	2814	4647
	110	2322	3983	3880	5704	2997	5040
	120	2640	3915	3826	5072	2338	3897
Dobidi	100	2857	5203	4373	6603	3069	3927
	110	2881	4765	4819	7306	4234	5991
	120	3373	4807	4204	6126	3305	5101
	130	2355	3600	3729	5345	2179	4376
CV (%)		26.2	16.2	21.3	15.0	22.8	16.2
LSD (0.05)		1011	975	1236	1267	895.2	1038.7

DAP* Days after planting.

Conclusion

It is evident from the results presented that the optimum harvesting date for seed maize is when the occurrence of the best seed germination is achieved in combination with high seed weght, low see moisture content and minimal seed loses. On the basis of this criterium, it is conducted that the optimum harvesting dates for seed maize in the study are 100 days after planting for Safita-2, 100-110 days for Aburotia and 110 days for Dobidi.

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Response of Improved Maize and Sorghum Varieties to Different Seed Treatments on-Station and in Farmers' Fields in the Lowland Savanna of North Cameroon.

TALLEYRAND, H., A. EBETE, T. NGOUMOU and W. KATSALA.

NCRE Cereals Agronomy Unit, Institute of Agricultural Research, Garoua, Cameroon

Abstract

A set of 20 on-station and on-farm trials were conducted from 1985 to 88 in the lowland savanna of North Cameroon to determine the effects of different sources and rates of chemical seed treatments on the performance and yields of several improved varieties of maize and sorghum at several locations. It was found that the use of seed treatments was beneficial in substantially increasing the yields of maize (101%) and sorghum (130%), with Marshal 25 ST and Furadan 10 G performing best. Preliminary economic analysis suggested a 33:1 benefit/cost ratio in favor of the use of Marshal over that of Thioral which is widely used by farmers in the region.

Introduction

The lowland savanna of North Cameroon includes all the area located North of 7° latitude. The most important factor affecting crop yields in the area is insufficient and/or erratic rainfall (Rodriguez, 1986). Maize (*Zea mays* L.) and sorghum (*Sorghum bicolor* L. Moench) are the two main food crops in the region. Both crops are grown by small-holder farmers, usually in rotation with cotton or legumes. Since 1982, intensive agronomic research has been on-going towards increasing yields and productivity. One major constraint for the successful production of maize and sorghum by farmers, inspite of new and improved varieties, is the relatively high incidence of soil insects pests and particularly termites (Suh, 1987; Talleyrand *et. al.* 1985-88). Other soil organisms are known to constrain crop production in the lowlands savanna of the country. Consequently, the present study was initiated to determine the effect of different seed treatments on the yield performances of some improved maize and sorghum varieties.

Materials and Methods

A set of 20 (on-station) trials involving chemical seed treatments and improved maize and sorghum varieties were conducted at six locations from 1985-88. Trials were designed in randomized complete blocks, with four replications.

The seed treatments used were:

a) Thioral (25% TMTD and 25% heptaclore), which is commonly used by the farmers;

b) *Marshal 25 ST* (carbosulfan);
c) *Furadan 10 G* (Carbofuran) applied as a spot treatment in the hills on the seeds.

The five maize varieties used included TZPB, Mexican 17E, Safita-2 B, CMS-8501, and CMS-8507. Four sorghum varieties were used: CS-95, CS-61, CS-63 and S-35. The trials were located at Sanguere (with 900 mm of rainfall per annum), Djalingo (920 mm) Kismatari (900 mm), Soucoundou (700 mm) and Makebi (650 mm) for maize. The experimental sites for sorghum were Sanguere, Djalingo, Kismatari, soucoundou and Guetale (with 650 mm of rain per annum). The soils at both locations are classified as Alfisols. Rainfall, which follows a monomodal pattern, usually starts in May and ends in September.

All the maize trials were planted in June and harvested in October. A population density of 50,000 plants/has was maintained with fertilization rate of 150 N + 60 P205 + 60 K20 kg/ha. Each plot consisted of eight 5 m rows spaced 80 cm apart. For sorghum, the trials were planted in early July and harvested in October. A population density of 83,333 plants/ha was maintained with 80 N + 40 P205 + 40 K20 kgs/ha of fertilizers applied. The plot size and arrangement was the same as described for maize.

On-Farm Testing. In addition to the trials described above, a series of on-farm investigations were also carried out in 12 villages (Table 3) located in West and South-East Benoue in the Sudan-Guinea savanna to compare the effect of 2 seed treatments (Thioral vs Marshal 25 ST) on the performance of three improved maize varieties (TZPB, CMS-850 and CMS-8507). The experimental design was a randomized complete block and using the system of "blocs disperses" whereby each location represented one replication. Each (farmer's) field measured 2500 m2 (50 x 50 m) and each plot consisted of 20 rows of 24 m width and 80 cm between rows. The ultimate objective was to compare the results obtained with seed treatments on-station with those from farmer's fields.

Results and Discussion

a) ***On-Station Trials.***

There was a generally high response to the use of seed treatments (Tables 1 and 2). Relative to untreated checks, Thioral yielded 22% more maize grain for variety TZPB compared with 73% for Marshal and 110% for Furadan. The comparable effect of seed treatments on sorghum variety CS-95 was 48% for Thioral, 96% for Marshal and 130% for Furadan.

In general, plots treated with Furadan and Marsahl out yielded significantly those receiving Thioral. The use of either Furadan or Marshall Thioral (which is widely used by the farmers as seed treatments for maize and sorghum) did not offer, in most cases, an effective protection against soil insects, termites and the insect *Spodoptera exempta* (which caused widespread damage to the seedlings following prolonged dry spells in 1987 and 88).

Table 1. Effect of seed treatment on the grain yield of TZPB maize at selected locations in Cameroon.

	Sanguere (1987)		Djalingo (1987)		Djalingo (1988)	
Seed treatments	(t/ha)	RGY(%)*	(t/ha)	RGY(%)	(t/ha)	RGY(%)
Control (N° seed treatment)	3.80	100	4.00	100	4.13	100
Thioral (200 g/100 kgs. seeds)	4.00	105	4.20	105	5.05	122
Marshal 25 ST (1 kg/100 kgs. seeds)	4.60	121	4.80	120	6.54	158
Marshal 25 ST (2 kg/100 kgs. seeds)	4.90	129	5.90	148	6.90	167
Marshal 25 ST (3 kg/100 kgs. seeds)	5.10	134	6.10	152	7.13	173
Furadan 10 g (5 kgs/ha)	6.20	163	6.12	153	8.11	196
Furadan 10 g (10 kgs/ha)	7.20	189	6.30	158	8.30	201
LSD (0.05)	0.77		0.90		0.43	
CV (%)	12		13		8	

* RGY = relative grain yield.

Table 2. Effect of seed treatment on the grain yield of CS-95 sorghum at selected locations in Cameroon.

Seed treatments	Sanguere (1987)		Djalingo (1987)		Djalingo (1988)	
	(t/ha)	RGY(%)*	(t/ha)	RGY(%)	(t/ha)	RGY(%)
Control (N° seed treatment)	1.93	100	3.00	100	1.31	100
Thioral (200 g/100 kgs, seeds)	2..85	148	3.95	132	1.53	117
Marshal 25 ST (1 kg/100 kgs, seeds)	3.15	163	4.60	153	1.97	150
Marshal 25 ST (2 kg/100 kgs, seeds)	3.48	180	4.80	160	2.15	164
Marshal 25 ST (3 kg/100 kgs, seeds)	3.80	196	5.00	166	2.28	174
Furadan 10 g (5 kgs/ha)	4.25	220	5.10	170	2.50	190
Furadan 10 g (10 kgs/ha)	4.43	230	5.30	177	2.65	202
LSD (0.05)	0.73		0.92		0.17	
CV (%)	10		14		7	

* RGY = relative grain yield.

In the plots treated with Marshal and Furadan, maize had no appreciable negative effect on seedling emergence, plant stand, seedling vigor, growth, lodging or grain yields. No replanting was necessary by the use of both seed chemicals. By comparison, in the untreated plots or by the use of Thioral, there were, in many cases, reduced/poor plant stand, less seedling vigour, as well as reduced growth and grain yield.

Values of 1000-grain weight in respect of maize treated with Marshal and Furadan was about 13 and 20% higher than recorded for untreated checks, respectively. Although no measurement was made, it appeared from visual observation that both maize and sorghum protected with either Marshal or Furadan were more tolerant to

water stress than the untreated plots. On the average, the response of sorghum to seed treatment was greater than in maize.

b) ***On-Farm Trials.*** Results obtained from the on-farm study are presented in Table 3. It is evident from the results that plots treated with Marshal 25 ST (1 kg/100 kg seed) produced significantly higher maize yield than the use of Thioral (200 g/100 kgs seed). Yield increases resulting from the use of Marshall were 0.75 ton/ha for TZPB maize, 0.82 ton/ha for CMS-8507 and 0.87 ton/ha for CMS-8501. Plant stand in plots receiving Thioral were significantly lower than those receiving Marshal. The results, thus, generally confirm those obtained from the on-station trials, including the superiority of Marshal 25 ST over Thioral.

Table 3. Effects of two seed treatments on grain yield of three maize varieties at 12 locations of Benoue region of Cameroon, 1998 (ton/ha).

Treatments*	Fignole	Gode	Poli	Doukea	Ndourou	Mbam	Ngoumi	Mbitoum	Laouyou	Mbordo	Lagaye	Mbodo-ro	Mean
TZPB + Thioral	3.38	3.35	3.57	3.77	5.60	4.58	3.57	3.13	3.92	4.62	2.64	3.25	4.78
TZPB + Marshal	4.98	4.33	3.38	5.02	5.79	4.74	3.76	4.20	4.61	5.62	3.88	4.18	4.53
CMS-8501 + Thioral	4.04	4.05	3.09	6.12	5.50	4.95	3.59	4.43	4.28	5.17	3.52	3.29	4.25
CMS-8051 + Thioral	4.70	4.56	3.91	6.14	6.63	5.49	5.21	5.60	5.15	5.57	4.32	4.27	5.12
CMS-8507 + Thioral	3.30	4.18	3.42	2.99	5.54	4.89	4.13	4.01	3.98	5.45	3.82	3.14	4.07
CMS-8507 + Marshal	4.06	4.54	4.20	5.17	6.52	5.26	4.93	5.09	5.10	5.74	4.02	4.15	4.89

LSD (0.05) = 0.16 ton/ha for seed treatment ; 0.26 ton/ha for variety ; 0.52 ton/ha for location
CV (%) = 12 %

* Marshal 25 ST (Carbosulfan) at 1 kg of the product/100 kg of maize seeds. Thioral was used at the rate of 60 g/30 kgs of maize seed.

c) ***Other Observations.*** Preliminary economic analysis based on the results of on-farm trials indicate a cost-benefit ratio of 33 to 1 in favor of the use of Marshal at 1 kg/100 kg seed. Considering its cost and the ease of its application as well as its relatively low toxicity, Marshall holds more attraction relative to Furadan which handling is more difficult and hazardous.

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Incidence of Blights and Races of Excerohilum Turcicum in Cameroon.

CLAUDE NANKAM.

Institute of Agricultural Research, Bambui Station, Bamenda, Cameroon.

Abstract

Excerohilum turcicum (Pass.) Leonard & Suggs. and *Bipolaris maydis* occur in high frequencies (80% and 22%, respectively) in Cameroon. Three races (1, 2 and 3) and their distribution in the maize growing zone of the country are discussed.

Introduction

Maize is the most important cereal grown all over Cameroon, although the high altitudes remain the main growing areas. For example, from Fig. 1, zone 1 alone produces about 70% of the total production of the country.

Fajemisin (1985) has reported that maize diseases remain the major yield reducing factor in farmers' fields, causing 15-50% yield loss annually. In Cameroon, for instance, maize diseases are important in number and intensity; leaf blights and rusts being the most prevalent, beside maize streak virus (Nankam, 1989). Heavy attack of *Excerohilum turcicum* and *Bipolaris maydis* was observed in 1988 and 1989, respectively, at Nkolbisson (600 m) and Foumbot (1100 m). Likewise, *Puccinia polysora*, the lowland rust, is being observed more and more in the higher altitudes.

The objective of the study was to estimate the relative prevalence of *Bipolaris* and *Excerohilum* species in leaves of maize plants in the field; to determine pathogenic races existing in Cameroon for both pathogens, and to obtain an estimate of the prevalence of each race and the mating types among isolates.

Materials and Methods

In 1989, maize fields were inspected and sampled for lead inhabiting species of *Bipolaris* and *Excerohilum* in 14 localities of four Provinces in Cameroon. Leaves exhibiting disease symptoms were collected. Although the sampled leaves were the lowest on the plant, they were not senesced. The leaf samples were dried in a plant press and kept at room temperature until they could be incubated for isolation of *Bipolaris* and *Excerohilum* species.

Pieces of leaves 3-5 cm long and 2-3 cm wide were cut out and surface-sterilized by immersion for 3-5 minutes in 10% sodium hypochlorite solution. The leaf pieces were rinsed in tap water and incubated on wet filter paper in petri dishes at room temperature. After 2-4 days, the incubated leaf pieces were examined under a stereo microscope at 50X for conidiophores and conidia of large-spored species of

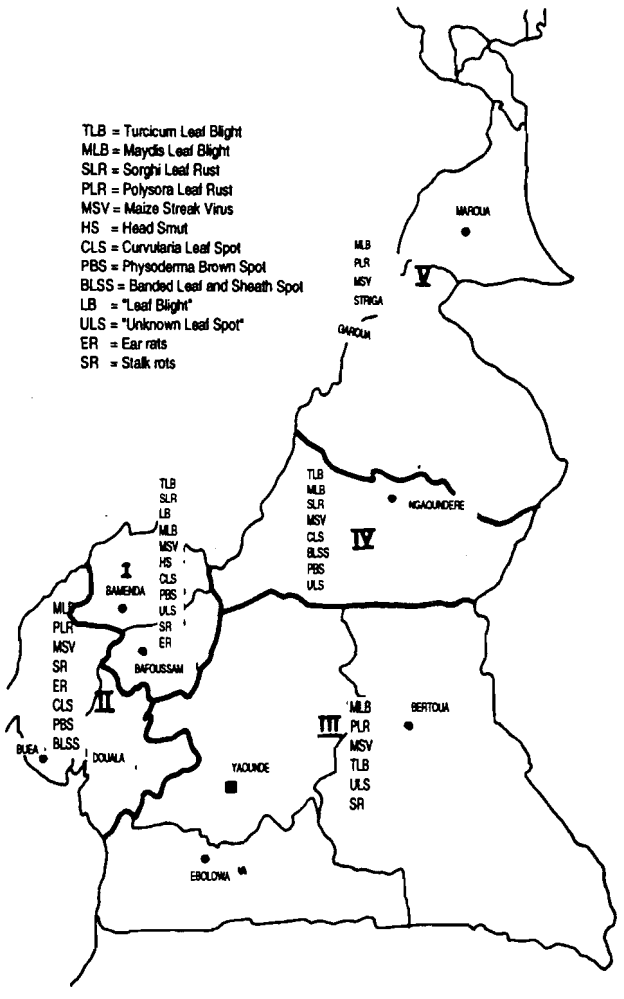

Fig. 1. Distribution and relative importance of maize diseases in Cameroon.

Bipolaris and *Excerohilum*. Pure culture of each type and for each locality was obtained by picking conidia direclty from conidiophores with a sterile needle and transferring to potato dextrose agar (PDA) then transferring once to either PDA or corn meal agar (CMA) to ensure purity.

Inocula for tests of virulence of *Excerohilum* isolates were prepared by washing conidia from 7 to 10-day-old cultures on PDA or CMA. The conidial suspension was sprayed onto maize seedlings at the 4-6 leaf stage using a hand sprayer. The sprayer was washed abundantly in tap water and rinsed with 70% ethanol between inoculations. The inoculated plants were incubated in the growth chamber at 25°C under continuous fluorescent light and relative humidity around saturation (100%). Inoculated plants were examined after 14 days for disease reactions.

Three dominant genes which condition chlorotic-type lesion resistance to *Helminthosporium turcicum* (Hooker, 1977; Hooker and Perkins, 1980) and three races (Bergquist and Masias, 1974; Smith and Kinsey, 1980; Turner and Johnson, 1980) have been identified.

Four differentials of the inbred line H4460 with specific genes of resistance, Htl, Ht2 or Ht3, were used for race characterization of the isolates. (These genotypes were obtained from Dr. Paul Christensen of DEKALB-PFIZER GENETICS). Because of lack of differentials with specific genes of resistance to *B. maydis*, isolates of these pathogens are yet to be characterized.

Table 1. Phenotypic response of four maize genotypes inoculated with 14 isolates of *E. turcicum* 15 days after inoculation.

Sites/Isolates	Altitude (MASL)*	GENOTYPES			
		H4460	H4460Ht1Ht1	H4460Ht2Ht2	H4460Ht3Ht3
Batie	1900	N	C	N	N
Foumbot	1050	N	N	N	C
Mbang-Mbirni	1200	N	N	C	N
Befang	600	N	N	C	C
Upper-Farm	1980	N	C	C	C
Nkolbisson	700	N	N	C	N
Mfonta	1200	N	C	C	N
Santa	1700	N	C	N	C
Bansoa	1400	N	N	C	C
Babungo	1100	N	N	C	C
Mbiame	1800	N	N	C	C
Bafou	1400	N	N	N	C
Ngondzen	2000	C	C	N	C
Ndonkole		C	C	C	C

C = Chlorotic lesions
N = Necrotic lesions
* MASL = Metres above sea level

Results and Discussion

a) ***Incidence***. *Excerohilum turcicum* and *Bipolaris maydis* occurred at high frequencies of 80 and 22%, respectively, in leaves collected from 14 localities. *B. maydis* was isolated from samples collected at Nkolbisson, Foumbot, Babungo and Mbang-Mbirni, which are located in the mid-altitude (or lowland) zones. *E. turcicum* occurred both in the highland and lowland (Nkolbisson) environments.

b) ***Race Characterization***. The Ht gene has been shown to condition resistance to races 1 and 3 but not to race 2, whereas the Ht2 and Ht3 genes condition resistance to races 1 and 2 but not to race 3. Table 1 presents the phenotypic response of the four genotypes when inoculated with 14 isolates of *E. turcicum*. A chlorotic lesion is a resistance reaction whereas the necrotic lesion indicates susceptibility (Hooker, 1961; 1963).

A virulence formula and designated race of each isolate were determined (Table 2) based on the Smith and Kinsey (1980) theory which states that the virulence formula of a race is X/Y, where X represents effective gene(s) and Y non-effective gene(s).

Highland leaf blight caused by *E. turcicum* is one of the most prevalent maize diseases in the maize growing areas of Cameroon and has been demonstrated to reduce yield considerably (Nankam, 1990). The appellation highland leaf blight seems not to hold, since the disease is also found in lowland environments (Nkolbisson, 600 m. and Befang, 700 m.).

Table 2. Virulence formula and designated races of the isolates.

Sites/isolates	Altitude (MASL)*	Virulence formula	Races
Batie	1900	Ht1/Ht2Ht3	3
Foumbot	1050	Ht3/Ht1Ht2	2
Mbang-Mbirni	1200	Ht2/Ht1Ht3	2
Befang	600	Ht2/Ht3Ht1	2
Upper-Farm	1980	Ht1/Ht2Ht3	1
Nkolbisson	700	Ht2/Ht1Ht3	2
Mfonta	1200	Ht1/Ht2Ht3	1
Bansoa	1400	Ht2/Ht3Ht1	2
Babungo	1100	Ht2/Ht3Ht1	2
Mbiame	1300	Ht2/Ht3Ht1	2
Bafou	1400	Ht3/Ht1Ht2	2
Ngondzen	2000	Ht1/Ht3Ht2	3
Santa	1700	Ht1/Ht3Ht2	3
Ndonkole	-	Ht1/Ht2Ht3	1

* MASL = Metres above sea level.

The three races described exist in Cameroon. Race 1 appears confined to two experimental farms, about 30 km away from each other: Upper-Farm (1980 m) and Mfonta (1200 m). Race 3 has been found in three environments not very different in altitude: Ngondzen (2000 m), Batie (1900 m) and Santa (1700 m). Race 2 is the most widespread and found in lowland environments (Befang, 600m; Nkolbisson, 700 m), intermediate zones (Foumbot, 1050 m; Babungo; 1100 m; Mbang-Mbirni

1200 m) and in the highlands (Bansoa, 1400 m; Bafou, 1400 m; Mbiame, 1800 m). Selection at Foumbot is for resistance to Race 2 while at Mfonta, it is for Race 1; the two locations presently serve as the highland breeding nurseries. It would be desirable for promising lines selected at either location to be tested at both sites and at Santa (1700 m) for resistance/tolerance to Race 3.

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Development of *Striga hermonthica* Tolerant, Open-pollinated Maize Varieties in Africa.

SOON-KWON KIM.

IITA/Ibadan, Nigeria.

Abstract

Breeding for *Striga* tolerance and resistance (STR) in maize was initiated in Nigeria by IITA scientists in 1982. Tolerant hybrids were selected at Mokwa in Niger State under a heavy natural infestation of *Striga hermonthica* in 1983. Seeds of the tolerant hybrids have been marketed in Nigeria since 1985. Selection of tolerant open-pollinated (OP) varieties of maize was not successful due to lack of uniform infestation. In 1988, an infestation technique involving the use of low level of nitrogen (less than 60 kg/ha), a large quantity of *Striga* seeds (20,000 germinable seeds per square meter) and ridging was developed. Maize breeding efforts for STR have doubled through the annual use of two breeding cycles inside the screenhouse and one cycle at the Mokwa hot spot. Eight synthetics with moderate levels of tolerance have been developed and selection for the improvement of the level of *Striga* tolerance has been achieved. Three international observation trials involving STR OP varieties, STR hybrids and STR inbreds were offered to interested national programmes during the 1991 cropping season. A modified single-seed descent method which involves planting ear-to-hill inside the screenhouse and ear-to-row in the field have been effective in improving *Striga* tolerance, yield potential, disease and insect resistance, simultaneously.

Introduction

The parasitic weed, *Striga hermonthica* is considered a major production constraint of maize in the potentially high-yielding savanna belt of sub-Saharan Africa. It causes yield losses estimated at 7 billion US dollars annually (Lagoke *et al.*, 1988). Maize, as a new crop in the savanna, has a great potential to boost food production. Drought, *Striga* and maize streak virus, are the major production constraints. *Striga* attacks cereal crops including sorghum, millet and maize and it is the most widely distributed genus. Maize is the most susceptible cereal since it has a very short history of cultivation in the savanna belt (Kim, 1991a; and 1991e). The IITA Maize Programme started screening maize germplasm against *Striga* in 1982 at Gusau in Sokoto State of Nigeria and found sources of tolerance in 1983 in the US Corn Belt materials tested at Mokwa (Kim *et al.*, 1984 and 1985, Kim and Winslow 1991b). *Striga* infestations at both Gusau and Mokwa were under natural conditions and high infestation observed in one year at the initial stage did not occur in the succeeding years (Efron *et al.*, 1986). Therefore, progress in resistance and tolerance breeding has been slow due to lack of uniform and high infestation (Kim, 1988; Kim and Akintunde, 1989; Kim and Winslow, 1991a). Similar observations of the disappearance of natural *Striga* infestation in experiment stations and commercial farms have been reported (Aggarwal, 1988; Kim, 1988; Kim, 1991a).

The development of artificial infestation has been a prerequisite for tackling the *Striga* problem. In 1988, the IITA Maize Programme identified some causes of the declining natural infestation in the experiment stations. High nitrogen application appeared to be one of the causes. After a series of studies with nitrogen levels, *Striga* seed quantities, methods of land preparation and infestation, periods of preconditioning and evaluation methods, less than 60 kg/ha of nitrogen and a high quantity of *Striga* seeds (approximately 10,000 seeds per maize plant) were identified as important in achieving high and uniform infestation (Kim and Akintunde, unpublished). Under field conditions, planting on ridges resulted in higher *Striga* infestation than flat land cultivation (Kim and Winslow, 1991a).

Striga significantly affects agronomic traits and yield of maize varieties in Africa. The result of eight different experiments showed that the average yield reduction of susceptible varieties was 67% with a range of 41 to 91% (Kim, 1991b). Among the yield components, number of ears was the most adversely affected. Susceptible plants showed changes in leaf colour (chlorosis), scorching, plant height reduction and severe lodging.

A genetic study on the inheritance of *Striga* tolerance using 10 x 10 inbred diallel crosses revealed that *Striga* tolerance was governed mostly by general combining ability (GCA) effects (66%). Tolerance was controlled by polygenes with additive gene action and was therefore inherited quantitatively (Kim, 1991c). Among the ten inbred lines used, TZi 12 conferred the highest GCA value for *Striga* tolerance. Another diallel study involving the same 45 crosses (under artificial infestation) showed that *Striga* emergence was governed mainly by specific combining ability (SCA) effects (65%) with a negligible influence of GCA effects (16%) (Kim, 1991d). Emergence appeared to be controlled by genes different from those for *Striga* tolerance.

Studies with 13 different collections of *Striga hermonthica* and three cereal hosts, maize, sorghum, and millet, revealed that maize was more susceptible than the other two cereals. Significant interactions were present between the parasite collections and the three cereal hosts. Both inter -and intra-strain variations were also observed among the collections. Tolerant varieties of maize and sorghum reacted horizontally across the 13 collections, while two millet varieties reacted vertically (Kim, 1991e).

Striga Seed Collection

A large quantity of *Striga* seeds was collected from *Striga* endemic areas. Matured *Striga* plants were cut at about two weeks after the last flowering and dried on polythene sheet for a week, turned over a couple of times and later threshed by hand. The seeds were sieved with 250 cm sieves and the cleaned seeds were collected and put in sealed jars. They were stored at room temperature. One hectare infestation required about 2 kg of clean *Striga* seeds. It was found that *Striga* plants, with maize as the host, produced a smaller amount of seeds than with sorghum and millet as hosts. Because maize is a new crop in the savanna belt and *Striga hermonthica* has evolved with millet and sorghum, collection of *Striga* seeds from sorghum and millet is highly desirable. Well dried *Striga* seeds showed relatively low germination initially but germinability increased with time. Six-month old seeds showed about 75 percent germination (Kim and Winslow, 1991a).

Land Preparation

After conventional tillage of the land, ridges (75 cms apart) were made. A metal bed firmer was used to firm the ridges and, at the same time, open a 10-cm V-shaped furrow on top of the ridge. Rows were 5 m in length. The first 2 m of each row was used for infestation while the last 2 m served as the non-infested control with a 1-m gap in between to prevent contamination of the control plots. The plots were maintained that way for several years.

Fertilization

A low level of nitrogen was important to ensure a high *Striga* infestation; approximately 30 kg N/ha was applied with the recommended quantity of P205 and K20. If soil fertility is high, it may not be necessary to apply any nitrogen at planting. Low nitrogen during the first three weeks of maize growth might enhance haustorial development of *Striga*. Additional 30 kg of nitrogen was applied 5 weeks after maize emergence in the form of calcium ammonium nitrate (CAN). Four litres of atrazine were applied as a pre-emergence herbicide immediately after planting of maize.

***Striga* Infestation and Maize Planting**

0.2 gram of *Striga* seeds (40,000 seeds with 75% germination) was thoroughly mixed with 90 grams of fine dried sand in an envelope before infestation. This mixing could be done mechanically with a larger volume of seed. The sand-mixed *Striga* seeds were uniformly drilled by hand into the first 2 m of a 5-m row. Immediately after drilling, the infested row was covered with soil at a 5-cm depth. Maize seeds were planted by hand one or two weeks after planting of the *Striga* seed to allow preconditioning of the *Striga* seed. Both infested and non-infested plots were planted at the same time by two different groups of people, and steps were taken to prevent *Striga* seed movement from the infested to the non-infested plot. The maize plants were spaced 75 and 25 cm, respectively between rows and between hills. Two seeds of maize were sown and thinned to one plant per hill two weeks after planting.

Estimate of STR Level

Selection and improvement of STR could be achieved only under uniform *Striga* infestation. Among various criteria used, *Striga* symptom ratings based on a 1 to 9 scale (1= no symptoms, 9 = severe symptoms) appeared to be the most reliable way of assessing host tolerance to the parasite (Table 1). The use of numbers of emerged *Striga* plants by most researchers, so far, has led to misinterpretation of the progress in *Striga* research world-wide, except for single gene controlled strain-specific type of resistance. The most critical damage of the host plant by *Striga* occurs before *Striga* emergence and correlation coefficients between *Striga* emergence and grain yield are very low. Therefore, host plant tolerance should be based on grain yield and agronomic traits including stover weight and plant height.

Table 1. *Striga* syndrome ratings used for measurement of tolerance of maize to *Striga.*

Rating	Description of host response
1	No damage symptoms with normal maize growth, no plant height reduction, no blotch, no chlorosis or scorching, no *Striga* infection. A single gene resistance or immune type of resistance could be rated as 1.
2	No apparent reduction in plant height, mild blotches and mild chlorosis.
3	Definite blotches and chlorosis, not spread to entire plant and approximately 5 percent reduction in height and ear size.
4	About 10 percent reduction in height and ear size, mild leaf chlorosis and scorching.
5	About 20 percent reduction in height and ear size, some leaf chlorosis and scorching.
6	About 30 percent reduction in height and ear size, some leaf chlorosis and scorching.
7	About 40 percent reduction in height and ear size, severe leaf scorching and stalk lodging; plants often show symptoms of wilting.
8	About 50 percent reduction in height and ear size, very poor tassel and ear development with husk open, thin stalk and severe lodging and wilting at early stage.
9	Symptoms of damage; above 60 percent reduction in height and ear size, severe scorching; plants die at early stage and do not produce tassel and pollen.

The above rating scale may be used to record the average rating of each plot under uniform and high *Striga* infestation. However, under non-uniformly infested conditions, only infested plants with *Striga* symptoms can be used to asses host tolerance. Non-infested plants could have escaped the infestation. Some entries may show severe leaf scorching without any *Striga* emergence, while others may show tolerance symptoms with multiple *Striga* emergence. Correlation coefficient (r) between Striga syndrome rating and *Striga* emergence count have been found to be low and non-significant. A diallel study involving 10 inbred lines under artificial *Striga* infestation showed r= - 0.061 (Kim, 1991d). Studies on correlations among *Striga* emergence, *Striga* rating, stover weight and grain yield of maize are underway. For the mean time, host plant response data based on a 1 to 9 *Striga*

syndrome rating scale (as described above) is hereby proposed. The best time to take *Striga* ratings is 15 weeks after mid-silking.

Striga Tolerance and Resistance (STR) Breeding

Breeding for STR involves the accumulation of polygenes for yield as well as against major biotic constraints such as maize streak virus (MSV) and *Striga*. Most materials used to develop STR varieties and hybrids possess resistance genes to MSV. Because of the nature of the genes involved in tolerance to *Striga*, selection is effective only under uniformly infested conditions of inoculum (*Striga* seeds). STR plants may have similar levels of underground attachment of *Striga* as well as similar or fewer numbers of *Striga* emergence of their susceptible counterparts. Average ratings of each family row compared to adjacent non-infested control plots can be used to assess the level of STR. Only STR lines should be selected and recombined.

Breeding Procedures

In the 1988 first (A) season, 18 OP varieties were tested in a large screenhouse, 250 m2 under artificial infestation. Almost all varieties were highly susceptible to *Striga hermonthica* (Kim and Akintunde, 1989). The results confirmed the earlier observation of high susceptibility of most OP varieties which were selected at Mokwa and other locations under natural infestation in farmers' fields as well as other testing sites (Kim *et al.*, 1984, 1985, and Kim 1991a). Among maize racial groups, Tuxpeno, Nal-Tel, and Chapalote showed high susceptibility. Perennial maize *(Zea diploperrenis)*, Teosinte and Tripsacum had levels of underground *Striga* attachment which were similar to those of normal maize, but they showed less emergence above ground (Kim et al., unpublished).

Selected OP varieties with high yield potential and resistance to maize streak virus (except Tuxpeno sequia) were crossed with *Striga* tolerant sources which were planted in the same screenhouse (Table 1). Sources of tolerance were TZi 12 and TZi 11 inbreds for white grained OP varieties and TZi 25 for yellow grained varieties. After the first backcross during the 1988 B season with the susceptible recurrent parents, all families were selfed during the 1988 C season. After testing of S1 families at Mokwa in the 1989 A season, selected families tolerant to *Striga* were used to make the second generation backcrosses in Ibadan during 1989 B season. An IITA drought tolerant population, TZDT-SR was also crossed with selected STR sources, TZi 12 and TZi 3. The S1 and half sib testing and recombination schemes were adopted to improve STR levels as well as yield potential of the original OP varieties. Since 1988, three cycles of breeding have been conducted in Nigeria (one cycle of testing at Mokwa during the main growing season and two cycles of additional screening for STR inside the screenhouse at IITA headquarters, Ibadan) and recombination of selected families in the field. Details of the breeding history of STR are summarized in Table 2.

Table 2. History of OP breeding for STR.

Year	Season	Site	Breeding procedures
1988	A	Ibadan screen-house (SH)	Screened OP varieties under *Striga* and crossed susceptible plants to STR lines.
	B	Ibadan - SH	Backcrossed with the original OP variety.
	C	Ibadan - field (non infested)	Selfed BCI generation
1989	A	Mokwa-hot spot	Tested BCI SI for STR and yield.
	B	Ibadan - SH	Backcrossed Mokwa selected STR families to the original variety.
	C	Ibadan SH	Screened BC2 materials for STR.
		Ibadan - field (non-infested)	Screened BC2 materials for streak resistance (SR) and sibbed all STR and SR families.
1990	A	Mokwa-hot spot	Tested sibbed families for STR and yield.
	B	Ibadan-SH	Screened Mokwa selected families for STR.
		Ibadan-field (non-infested)	Recombined half-sib STR families.
	C	Ibadan-SH	Rescreened the recombined STR families for STR.
		Ibadan-field (non-infested)	Recombined SH selected STR families and also developed SI families.

In the 1989 A season, a total of 788 families of STR OP families were tested at Mokwa under artificial *Striga* infestation. One hundred and eighty-one families (23%) were selected (Table 3). Average *Striga* ratings (based on a 1 to 9 scale, where 1 = highly resistant, 9 = highly susceptible) were 3.9 for families tested and 2.9 for selected ones, indicating an increase of *Striga* tolerance of about 26 percent through the selection. Average numbers of emerged *Striga* plants per square meter were 12.3 for all families and 8.6 for the selected families, again, indicating the effectiveness of selection in reducing *Striga* emergence. However, other data with 681 inbreds and inbreeding lines showed that *Striga* numbers of all lines (681) and selected lines (141) were 8.7 and 12.5 per m2, respectively, indicating that different genes control host plant STR level and *Striga* emergence (Kim, unpublished). A

genetic study on *Striga* emergence using 10 x 10 inbred diallel crosses also supported the finding that different genes are involved in STR (Kim, 1991d).

Table 3. Summary of selected OP families under *Striga* infestation at Mokwa, 1989.

Pedigree	N° of families		*Striga* rating (1-9)		N° *Striga* at 10WAP (1 m²)	
	Tested	Slected	Tested	Slected	Tested	Slected
Syn. 1/4	128	46	3.8	3.2	13.5	7.5
Syn. 5/6	48	11	4.7	3.4	13.9	6.4
TZB-SR	286	64	2.8	2.4	9.3	9.6
OP-STR	326	60	4.3	2.5	12.4	10.9
Total or mean	788	181	3.9	2.9	12.3	8.6

Striga rating (1 to 9): 1 = high tolerance/resistance, 9 = high susceptibility, N°. of *Striga:* numbers of emerged *Striga* plants on 1 m2.

In the 1990 A season, a total of 738 families of eight OP varieties which were previously crossed with STR sources were planted at Mokwa in 2 m rows with and without *Striga* infestation. A 1 m gap was left between the infested and non-infested portions of each 5 m row. A randomized complete block design with two replications was used (Table 2). Both susceptible and tolerant materials were planted inside the same block as check and along the block to monitor the level of infestation. Based on the comparative host plant damage ratings as well as yield potential from the uninfested counterpart, 170 promising families were selected (Table 4). Because of the limited amount of seeds and relatively smaller number of families selected (mostly less than 30), the same materials were later planted in the field at IITA headquarters in Ibadan without *Striga* infestation, but with maize streak virus (MSV) infestation. At flowering, families with resistance to MSV, stem borers and lodging were selected and sib-pollination was done within each family. At harvesting, families resistant to streak, *Puccinia polysora* rust and *Bioploris maydis* blight, and ear rot complex were selected and kept until the results from Mokwa were obtained. Selection intensity was low because of the key objective of *Striga* tolerance and resistance.

During the 1990 second rainy season (B), only selected families from Mokwa were re-screened inside the screenhouse at IITA, Ibadan, under *Striga* infestation. Maize seeds of families sib-mated during the A season in Ibadan and 656 ears of the 170 selected families of maize from Mokwa were used (Table 4). Each family had an average of 3.9 ears. The ears were planted ear-to-hill inside the screenhouse and

ear-to-row in the field. Two weeks after the planting of the materials in the screenhouse, remnant seeds of the same selected families (ears) were planted in the field without *Striga* infestation. Host plant *Striga* syndrome ratings were taken from the screenhouse materials at around flowering time and the materials with ratings of 5 and above were rejected and only selected STR families with good agronomic traits were recombined as half-sibs. Average *Striga* ratings of eight OP varieties were higher than those of the previous cycle at Mokwa. Although all the screenhouse tested materials were selected at Mokwa for STR, the same materials showed further segregation inside the screenhouse because of additional sibbed ears and also probably due to higher *Striga* infestation in the screenhouse than the Mokwa field infestation.

During the 1990 dry season (C), a total of 273 half sib families (781 ears) of the OP varieties were replanted (Table 4) inside the screenhouse under *Striga* infestation (ear-to-hill) and in the field with streak infestation (ear-to-row). Only families selected for STR and streak resistance (SR) were recombined in the field. Preliminary *Striga* data from the screenhouse indicated that the level of STR had improved, further demonstrating the effectiveness of the recurrent selection scheme in STR breeding in maize. This confirms that additive genes play a major role in the inheritance of STR in maize (Kim, 1991c). At the same time, results of streak virus rating showed that almost all families were resistant to MSV. The high levels of streak resistance was not surprising because both *Striga* susceptible varieties and STR donor sources were streak resistant. In addition to half sib recombination, selected families would be selfed for S1 testing at Mokwa during the 1991 growing season.

Table 4. Number of selected families and ears of eight OP varieties under *Striga* infestation at Mokwa during 1990 A rainy season (field) and IITA headquarters in Ibadan during 1990 B and C seasons (screenhouse with infestation and field without infestation).

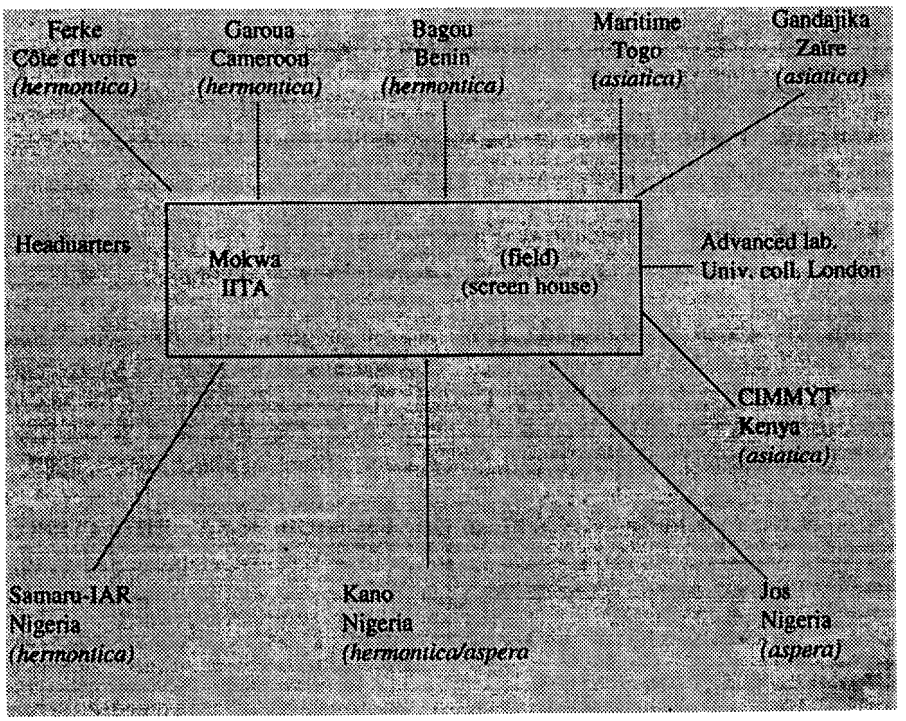
Variety	Mokwa A		Ibadan B		Ibadan C	
	Tested families	Selected families	Tested ears	Selected families	Tested ears	Selected families
STR Syn-W-I	189	38	153	46	154	65
STR Syn-Y-1	26	10	41	26	69	22
STR 28-SR	78	23	69	41	115	33
STR TZB-SR	54	8	44	26	58	32
STR TZPB-SR	94	19	73	34	34	19
STR TZPB-SR	116	25	106	31	121	54
STR TZSR-W	76	23	98	30	95	47
STR Suwan-1	105	24	72	39	135	70
Total or mean	738	170	656	273	781	342

A = major season C = dry season (under irrigation)
B = minor season.

In 1991, the first International Trials involving STR OP varieties would be offered to national programmes. In addition, two other International Trials involving STR hybrids and STR inbreds would be offered to interested national programmes. Because of the encouraging preliminary observations made in 1990 under both artificial infestations at Mokwa, Nigeria (kim, unpublished) and Sanguéré, Cameroon (C. The, unpublished) and natural infestation in a few farmers' fields in Nigeria (G. Weber and S. Lagoke, unpublished), the FAO Pan-African *Striga* Project and the SAFGRAD Maize Network plan to offer the same STR materials to interested national programmes for on-farm testing in the 1991 cropping season.

Multi-location testing of the STR materials will be intensified so as to improve the stability of STR (Table 5). The IITA Maize Programme plans to establish additional testing sites with national programmes in Samaru (*hermonthica*, S. Lagoke), Kano (*hermonthica* and *aspera*) and Jos (*aspera*) in Nigeria, Sinematialie or Ferkessedougou in Côte d'Ivoire (*hermonthica*, K. Attiey), Garoua in Cameroon (*hermonthica*, C. The and Talleyrand), Togo (*asiatica*) and Benin (*hermonthica*). Inter-Centre collaboration with CIMMYT and ICRISAT *Striga* research teams will be further strengthened. In addition, IITA *Striga* team also collaborates with several advanced laboratories including the University College of London. So far, the indications are that the IITA STR materials resistant to *S. hermonthica* are higly susceptible to *S. aspera* in Nigeria (Kim, 1988). However, some of the STR sources such as TZi 30 have shown resistance to *S. asiatica* in North Carolina, USA (Ransom *et al.*, 1991).

Table 5. Multi-locational testing sites of IITA *Striga* tolerant maize materials.



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A multi-disciplinary *Striga* research team involving breeders, agronomists, *Striga* biologists, physiologists, pathologists, entomologists, weed specialists and economists is making efforts to understand the long standing *Striga* problems in Africa. An integrated approach to combat *Striga* is still being searched for. Any national programme interested in *Striga* research is welcome to collaborate with the IITA *Striga* thrust team. After solving the maize streak virus problems, in collaboration with scientists from CIMMYT and African national programmes, IITA scientists would like to approach *Striga* in a similar way. *Striga* has become a top research priority.

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PART IV

Sorghum

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Network Approach to Sorghum Improvement in West and Central Africa.

MELVILLE D. THOMAS

Coordinator, Sorghum Network, ICRISAT/SAFGRAD, Bamako, Mali.

Abstract

In attempts to meet set objectives, the West and Central Africa Sorghum Research Network, which has 17 participating member countries, places emphasis on activities that contribute towards strengthening sorghum programmes of National Agricultural Research Systems (NARS). Since 1987, the network has organized regional trials and nurseries with the participation of scientists from NARS through which promising early and medium-maturing genotypes and hybrids have been identified. Promising lines for tolerance to *Striga* and resistance to the three major sorghum leaf diseases in the region have also been identified. In addition to regional trials, five research projects were initiated in 1989 and their execution charged to Lead NARS Centres. For example, in Burkina Faso, Niger and Mali, scientists are working on, among other things, the identification of resistance to leaf anthracnose, long smut and head bugs, respectively. Studies on some aspects of the epidemiology and population dynamics of the causal agents of the three biotic stresses are also underway. In Nigeria, scientists have identified a suitable local sorghum variety (Farafara) for use in wheat/sorghum composite flour. The Cameroon lead Centre is to provide sorghum genotypes with good resistance to *Striga* for further testing in the region. Other activities undertaken by the Sorghum network include, monitoring tours, training and workshops.

Introduction

There appears to be a concensus on the inability of many countries in sub-Saharan Africa to grow sufficient food to feed their rapidly increasing human population (Youdeowei, 1987). Irrespective of the complexity of the factors which are responsible for this situation, long-run human capability, scientific and institutional, and social organizational issues-- the prime movers of agricultural development-- have been seriously neglected by both African policy makers and donors (Eicher, 1988). Youdeowei (1987) is of the view that although biological, social, economic and ill-defined agricultural policy issues contribute to the food crisis in Africa, drought-stress, poor soils and lack of efficient soil-water management techniques are the most severe constraints in semi-arid Africa.

Sorghum (*Sorghum bicolor* (L) Moench) is grown widely in many countries in semi-arid West Africa. Most of the sorghum is grown in the Sudanian zone (500-1000 mm annual rainfall) and the northern Guinean zone (1000-1200 mm annual rainfall). Sorghum is also grown in the southern fringes of the Sahel (400-500 mm annual rainfall). Along with pearl millet (*Pennisetum glaucum* (L.) R.Br.), sorghum provides the main energy source for the people of the Sudan and Northern Guinean

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zones (Curtis, 1965). But as it were, local varieties are low-yielding and are generally not responsive to high levels of fertilizer (Zummo, 1984). The need for improved cultivation of sorghum through research and extension cannot, therefore, be over-emphasized. The establishment of the Sorghum Network with regional responsibility is towards ultimately enhancing sorghum production in West and Central Africa.

Background and Objectives of the Sorghum Network

The West and Central Africa Sorghum Network became operational in 1985 under the auspices of SAFGRAD-OAU/STRC, with ICRISAT providing the technological support and backstopping. The Network is charged with addressing problems and constraints of sorghum production that are of regional significance and to resolve them by establishing necessary links with national, regional and international institutions and agencies. More specifically, the Sorghum Network is to work towards the following objectives:

a) Increasing the production of sorghum thereby contributing to the stabilization of food supplies and contributing to improved nutrition and income for farmers in the region.

b) Assisting and strengthening national sorghum improvement programmes and contributing to their research needs.

c) Developing improved varieties and hybrids and agronomic/management practices capable of giving increased and more stable economic yields.

d) organizing and promoting systematic regional testing of available and improved genetic material and technology.

e) Facilitating the development of agricultural research manpower among the 17 member countries.

f) Organizing training workshops, seminars and monitoring visits of network activities.

Set-up of Sorghum Network

Administrative and technical support are given by ICRISAT mainly through its Mali and Nigerian sub-stations. ICRISAT provides the Network Coordinator who operates from the Mali sub-station in Bamako. The Coordinator implements the decisions of the Steering Committee of the Network and serves as the driving force behind the Network. The Steering Committee comprises 6-7 NARS scientists elected every two years, but its meetings are also attended by the Network Coordinator (as member) and representatives of SAFGRAD Coordination Office, USAID, ICRISAT, INSAH, IRAT and Global 2000 (as observers). The Coordinator reports to the Executive Director of ICRISAT Sahelian Centre (ISC) in Niamey and works in close consultation with the Team Leader of WASIP-Mali. Direct links exist between the Coordinator and the SAFGRAD Coordination Office

in Ouagadougou. Yearly progress reports are prepared by the Coordinator and submitted to USAID, Ouagadougou, through the Executive Director of ISC. The Coordinator disburses funds for the activities of the Network and financial reports are prepared on a monthly basis by WASIP-Mali accounts section and sent directly to ICRISAT headquarters in Hyderabad, India, which has the responsibility to submit them to USAID, Ouagadougou.

Network Programmes and Implementation Strategy

The main activities of the Sorghum Network include regional trials and nurseries, assigned research, monitoring tours, training workshops and seminars. The Network places much emphasis on the regional trials to the extent that it can rightly be described as a "Trials" Network. However, since 1989 the Network has been pursuing specific technology-generating projects assigned to some NARS institutions that have proven abilities for their implementation.

a) ***Regional Trials and Nurseries.*** In 1986, the Sorghum Network organized three regional sorghum trials comprising 20 each of early and medium-duration varieties and 36 hybrid adaptation trials. A total of five countries each were sent packages for the early-duration and medium-duration variety trials and eight for the hybrid series.

From 1987 to 1991, the type of sorghum regional trials in West and Central Africa evolved from four to five. The number entries of the regional trials varied according to the type and purpose of the trial. The early and medium duration variety trials had 20 entries, whereas the hybrid and disease nursery trials varied from year to year as indicated in Table 1.

As shown in same Table, the top yielding cultivars are Nagawhite, from the early-maturity adaption trials; ICSV 1063 BF, which yielded highest in the medium-maturity cycles; and ICSH 567, from the hybrid trials:

Included in the entries for the regional trials were elite breeding lines and hybrids contributed by ICRISAT and the national programmes of Burkina Faso and Mali. The entries were mostly of recent origin and represented promising lines. The various member countries of the Network who served as cooperators for the regional trials were expected to select useful entries from these trials for their further testing and advancement as desired.

b) ***Research Projects with National Agricultural Research Systems***

Specific Research Projects: The Sorghum Network initiated four research projects at four NARS institutions in June 1989 which are partly funded by the Network. These include the anthracnose project whose main objective is to determine whether pathotypes of the pathogen occur in Burkina Faso and to identify genotypes resistant to the pathotypes. The long smut project in Niger is to develop a simple and effective inoculation method for use in screening techniques. The project on head bugs in Mali emphasizes, among other things, the biology of the insect, its economic importance, and identification of resistant sources. In Nigeria, the project

hopes to develop a technology for producing acceptable wheat-sorghum composite flour for bread and confectionery, aimed at increasing the sorghum component as high as possible. In 1990, a project was started by the Cameroon national programme on the identification of Striga resistant lines.

Table 1. Summary of regional trials of the West and Central Africa sorghum network.

Year		Type of trial	Number of entries	Sets of trials dispatched	Percentage of data recovery	Promising and top yielding cultivars tons/ha
1987	i)	Early maturing cycle adaptation trial (WASVAT-E)	20	10	90	Nagawhite - 2.8
	ii)	Medium maturing cycle adaptation trial (WASVAT-N)	20	13	92	ICSV1063 BF 2.6
	iii)	Sorghum hybrid trial (WASHAT)	25	15	100	ICSH4336 2.8
	iv)	Disease nursery trial (WASDN)	36	5	100	13 promising lines were identified
1988	i)	WASVAT-E	20	14	86	Nagawhite 3.6
	ii)	WASVAT-N	20	19	68	IVSV1063 3.3 ICSV1171 2.4
	iii)	WASHAT	20	12	100	ICSH507 3.6
	iv)	Striga trial (WASST)	11	6	50	ICSV1001 BF, ICSV1007 BF, ICSV 1164 BF and IC9830 were promising.
	v)	Disease nursery (WASLDN)	36	7	100	Three resistant genotypes were identified.
1989	i)	WASVAT-E	20	12	75	Nagawhite 2.8 ICSV1079 2.7
	ii)	WASVAT-N	20	19	68	ICSV1171 2.4
	iii)	WASHAT	20	9	89	ICSH 3.7
	iv)	WASLDN	25	10	20	Disease resistant lines include 84S82, 84-S-130.
	v)	WASST	11	9	67	ICSV1007 BF, ICSV1164 BF and IS2830.
1990	i)	WASVAT-E	20	15	87	CE-196-7-2-1 2.5
	ii)	WASVAT-N	20	19	68	CS85 2.1
	iii)	WASHAT	20	10	100	Best yielding hybrids were ICSN-9008 NG 3.7
	iv)	WASST	12	11	27	Framida and ICSV-1078
	v)	WASLDN	25	8	50	84-5109 and IS3443 were resistant to leaf diseases
1991	i)	WASVAT-E	14	15	80	Var 90w-186 2.5 Nagawhite 2.8
	ii)	WASVAT-N	20	18	77	Var. S219 2.3
	iii)	WASHAT	20	14	93	The hybrid ICSH8009 NG 3.7
	iv)	WASST	12	7	43	Seven *Striga* tolerant genotypes were identified.
	v)	WASLDN	14	9	55	New lines of sorghum F2-20 was found resistant to leaf anthracnose ; 84-S-82 was found resistant to leaf diseases.

WASVAT-E = West African Sorghum Variety Adaptation Trial, Early Maturing Cycle.
M = Medium Cycle
WASHAT = West African Sorghum Hybrid Adaptation Trial.
WASLDN = West African Sorghum Leaf Disease Nursery
WASST = West African Sorghum *Striga* Trial.
Source = SAFGRAD Phase II Report, 1987-1991.

Progress Made

Research Projects. Using the spreader row technique, the project in Burkina Faso screened a total of 80 sorghum lines of which 56 were local varieties and 24 were introduced genotypes. Out of the 80 lines tested, 74 were resistant to the foliar stage of the disease. Of the six susceptible lines, four were introduced genotypes. Only one introduced genotype was susceptible to stem infection. Grains of 30 out of the 80 lines were free of the fungus. The level of grain contamination by *C. graminicola* was higher in introduced genotypes. In addition to confirming these first year results, work on the variability of the pathogen will be undertaken during the second year.

Results from the project on head bugs in Mali indicated that the population of Eurystylus marginatus was more abundant towards the end of September and October. Early planting resulted in no attack by *E. marginatus*, whereas two generations of the insect developed in late planted sorghums. In a screening experiment, 25 out of 100 lines were resistant to *E. marginatus*. Further resistant lines were identified in an advance trial and in an international nursery. A limited survey in farmers' fields revealed that in certain localities, *E. marginatus* attack was higher in introduced lines than in local lines. However, the level of attack depended on the locality; some local varieties were severely attacked in some areas.

The project on long smut in Niger encountered problems with flooding in the field due to high rainfall. In addition, attempts at artificial inoculation were unsuccessful.

Results from the project in Nigeria indicate that the local variety "Farafara" is suitable for wheat-sorghum composite bread and confectionery. In the laboratory, acceptable bread can be produced with up to 50% level of wheat substitution by sorghum. Similarly, acceptable confectionery can be produced with up to 60% level of substitution with sorghum. Generally, composite bread is of lower volume and of shorter shelflife than 100% wheat bread. Future work will emphasize the area of pilot production. The technology developed at the laboratory level will be followed by pilot production. Two bakeries, one for bread and another for confectionery with pilot baking facilities will be involved. The economics of production will also be determined.

The significant results of the above mentioned projects are summarized in Table 2.

Table 2. Significant results on a yearly basis of research project activities of the West and Central Africa sorghum network.

Project	Country	Year project started	Significant results	
			Cropping season	Results
1. Anthracnose	Burkina Faso	1989	1989	1. Identified 74 out of 80 lines screened as resistant to foliar infection. 2. Grain of 30 lines were free of the fungus. Grain contamination was higher in introduced varieties.
			1990	1. The resistance to foliar infection observed in 1989 was confirmed in 70 lines. 2. A total of 44 lines, all local varieties, were resistant to leaf, stem and grain infection. 3. Disease progress more rapid in introduced varieties.
			1991	1. Identified 19 local varieties and three introduced varieties with rate reducing-like resistance to leaf infection.
2. Long-smut	Niger		1990	1. Eleven out of 75 varieties screened were highly resistant. 2. Late maturing varieties were more susceptible.
			1991	1. New sets of 24 varieties identified as resistant at two locations. 2. Longevity of teliospores of the long smut fungus was increased when stored dry. 3. Infection was higher when plants were inoculated with sporidia than with teliospores.
3. Head bugs	Mali	1989	1989	1. Population of the head bug insect was high at the and of September and October. 2. Early planting resulted in no attack, whereas two generations developed in late planted sorghums. 3. Twenty-five out of 100 lines were resistant.
4. *Striga*	Cameroun	1990	1990	1. Results obtained in 1989 were confirmed.
			1991	1. Identified 21 new sources of resistance out of 51 lines screened in a preliminary nursery. 2. The resistance of nine varieties identified in 1989 and 1990 were confirmed by artificial inoculation.
5. Wheat-sorghum flour[a]	Nigeria		1990	1. The project multiplied eight varieties and two germplasm 2. lines resistant to *Striga* for entries in regional *Striga* trials.
			1991	1. Fourteen lines with low *Striga* counts identified. 2. All 12 entries in the *Striga* regional trial came from the project.
			1989	1. Local Farafara variety identified as most suitable sorghum variety for the composite flour. 2. Up to 50 % substitution of sorghum for bread and up to 60% for confectionery. 3. Addition of 0.5 % cassava starch flour to the composite flour produced more spongy bread, closer textured and less crumbling, but shelf life was shortened. 4. Wheat-sorghum composite flour bread more popular among low income group because it was more filling than pure wheat bread.

a. Work was not carried out according to cropping season.

Synthesis of Primary Data Volume Two: The West and Central Africa Sorghum Research Network 1992. ICRISAT/SAFGRAD Collaborative Programme.

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Future Thrust of Sorghum Network

The following activities are proposed for the future activities of the Sorghum Network in West and Central Africa:

a) Expand the on-going specific and targetted research projects with NARS and initiate new ones.

b) Organize in-service training in various disciplines, but with emphasis on agronomy and food technology.

c) Supervise seed multiplication and dispersal of regional trials and nurseries both by ICRISAT and by strong NARS with the requisite capability.

d) Encourage degree training up to M.Sc. and Ph.D. levels according to the needs of the NARS.

e) Continued backstopping by ICRISAT especially relating to developing promising varieties and hybrids with high and stable yields.

f) Facilitate the exchange of germplasm between member states.

g) Organize annual research working groups on the research projects with active participation of NARS.

h) Organize germplasm collection and evaluation within agronomic packages for the NARS.

i) Organize (once every two years) scientific meetings and regional workshops as the forum for evaluating progress and planning for the future.

j) Organize monitoring tours in years when scientific meetings and regional workshops are not scheduled.

k) Set up agronomy-based regional trials to evaluate elite genotypes at different technological levels such as fertility level of N and P, land preparation methods, and plant populations. Also genotypes in sole versus intercropping trials. Information needed from research sites include rainfall and soil analysis. These trials should be conducted initially on-station but to be extended to on-farm sites later.

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Sorghum and Millet Improvement in Eastern Africa: Current Status of EARSAM Network Activities and Challenges in the 1990s.

V.Y. GUIRAGOSSIAN, and S.Z. MUKURU.

ICRISAT/SAFGRAD Nairobi, Kenya.

Abstract

Much has been achieved during Phase II of the SAFGRAD/ICRISAT programme. Production constraints have been identified, research priorities formulated, and Lead NARS Centres identified to carry out specific technology-generation research projects in addition to the backstopping provided by ICRISAT.

Members of the Eastern Africa Regional Sorghum And Millet (EARSAM) Network Steering Committee meet once or twice each year to monitor, review and evaluate Network activities and to discuss achievements and prepare future Network plans based on regional priorities. ICRISAT monitors recommendations made by the Steering Committee and facilitates the implementation of Network activities. ICRISAT's main objective is to facilitate the attainment of food sufficiency in the region. ICRISAT has tried to enhance the development of research leadership within NARS, giving their young scientists opportunities to look at problems, not only at local but also at regional levels. ICRISAT also tries to improve the research base of NARS through research support, training, and other activities.

During SAFGRAD Phase II, intensive exchange of germplasm and technologies took place among NARS in Eastern Africa. These exchanges substantially improved NARS research capabilities as reflected in the quality and standard of the scientific papers presented by NARS scientists during regional workshops. However, the challenges faced by the Network will not be over until the products of research reach the farmer and stabilize food supplies in the region. In the likelihood of the present trends of under-production and high population growth continuing, the net food shortfall in Eastern Africa will be quite substantial by the year 2000. Herein lies the challenge faced by EARSAM Network: to facilitate the attainment of food sufficiency in the region in the 1990s.

Introduction

The region herein referred to as Eastern Africa includes Burundi, Ethiopia, Kenya, Rwanda, Somalia, Sudan, Tanzania and Uganda. Almost all the major sorghum ecological zones found world-wide are represented in Eastern Africa, from sea level to 2,500 m above sea level (Gebrekidan, 1986). Well over 75% of the region has an average annual rainfall between 400 to 1,000 mm. The bimodal rainfall generally falls for about 3 to 5 months and is highly variable. Temperatures in the different ecological zones are variable and can range from 6°C (Highland) to 45°C (Lowland) (ICRISAT, 1989).

Although total sorghum and millet production in Eastern Africa has increased in both hectarage and, to some extent, yield per hectare, food production still does not keep pace with the more than 3% population growth (Table 1). There is, therefore, an urgent need to increase sorghum and millet production in order to help alleviate hunger and malnutrition (Guiragossian *et al.*, 1991).

Recognizing the need to improve productivity in this region, breeders have made efforts to increase yield through improved varieties. Despite the efforts by breeders to develop improved sorghum and millet varieties, their spread and rate of adoption is discouragingly low and slow.

Major Constraints to Production

a) ***Lack of Improved Cultivars.*** Low-yielding, traditional landraces are predominantly grown; there is thus potential to improve the yield and stability of the existing sorghum and millet varieties and landraces. Seed set, crop maturity and plant height are important traits to be considered.

b) ***Drought and Soil Management.*** Many of the soils in the region whether, heavy or light, are of low fertility. Increases in production on such soils are only possible when improved varieties are grown with improvement in soil management. Drought, stand establishment, temperature, and nutrient stresses all significantly affect production. Intercropping and sole cropping are both practised, but the relationships of interplanted crops still remain little understood.

Table 1. Statistics of sorghum, millet and total cereal production for eight countries in Eastern Africa.

Crop total	Burundi	Ethiopia	Kenya	Rwanda	Somalia	Sudan	Tanzania	Uganda	Africa
Sorghum									
Area (000 ha)	58	900	146	173	550	3682	514	180	16963
Production (000 ton)	88	964	143	164	291	1924	503	260	13995
Yield (kg/ha)	1514	1071	979	948	529	523	979	1444	825
Millet									
Area (000 ha)	13	200	96	2	0	1550	300	270	14263
Production (000 ton)	10	180	60	2	0	167	300	380	9302
Yield (kg/ha)	769	900	625	833	0	108	1000	1407	652
Total cereals									
Area (000 ha)	215	5017	1982	263	848	5448	3168	773	73957
Production (000 ton)	321	5925	3460	268	608	2369	4634	970	90845
Yield (kg/ha)	1489	1181	1746	1019	716	435	1463	1255	1228

Source: FAO Production Yearbook 1989, Food and Agriculture Organization of the United Nations, Rome. Italy: FAO.

c) **Diseases.** Priority diseases for regional research include pathogens that cause anthracnose, covered smut, grain mold and ergot of sorghum. For finger millet, head blast and pearl millet (and sorghum) ergot are the most wide-spread diseases in the region and sometimes cause heavy damage. Downy mildew, rust and smut are also common in the region; these diseases do not appear to do much damage to the local landraces but the situation could change with the introduction of improved cultivars.

d) **Insect Pests and Birds.** The predominant pests of sorghum are stem borers, shootfly, sorghum midge, and storage insects. Several of the insects found on sorghum also attack millets, but do not appear to significantly damage the crop. *Quelea* and other species of birds cause significant damage to both crops. The actual extent of such damage has not been critically evaluated.

e) ***Striga.*** Several species of this parasitic weed attack sorghum and finger millet crops resulting in significant production losses.

f) ***On-Farm Trials.*** To effectively translate research results for adoption, it is important to conduct verification trials on farmers' fields and with farmers' participation towards ensuring that the technology in question is backed with socio-economic considerations.

g) ***Marketing and Price Control.*** Most countries have no official market or pricing policies especially for food crops and, consequently, such crops do not enter into the official trading system. Proper and cost-effective distribution of grain with adequate price control is essential to absorb excess production.

h) ***Post-harvest Handling and Utilization.*** Eastern African countries are increasingly expressing concern about the post harvest-handling, storage insects, and utilization aspects of sorghum and millet. It is important that for rapid acceptance, improved cultivars be of good and high quality for food products, brewing and as livestock and poultry feeds.

i) ***Seed Production.*** One of the bottlenecks to rapid movement and adoption of improved crop varieties and hybrids in the region is the lack of effective seed industries. Kenya is the only country with a good and well established seed industries. It is, therefore, essential to strengthen the seed industry in each of the countries.

Historical Perspective of SAFGRAD-ICRISAT EARSAM Network

Since 1982, USAID has funded SAFGRAD for the implementation of sorghum and millet improvement in Eastern Africa through ICRISAT. As a project of the OAU, SAFGRAD mobilizes the efforts and strengths of national agricultural research systems through a networking approach in achieving the objective of improving sorghum and millet production in the region. While ICRISAT has provided improved technologies and supported NARS in their training and other needs, the OAU umbrella under which SAFGRAD functions has facilitated the mobility of scientists and research materials.

Between 1982-86 which period coincided with SAFGRAD phase I, ICRISAT/SAFGRAD made commendable progress in training NARS scientists and enhanced the interaction between scientists within and between participating countries and regions. As a result, there has been an increased sharing of research results and exchange of germplasm. Elite genotypes were evaluated on a regional basis. Thus, SAFGRAD Phase I activities established the groundwork for the second phase of the project.

In 1986, which formed the commencement of SAFGRAD phase II (1986-91), further efforts were needed to expand and strengthen sorghum and millet research in Eastern Africa. This was achieved by developing a strong and efficient networking model, the EARSAM Network. This model was designed to further strengthen the ties among the NARS of the region, not only in the interchange of scientific results, experiences and germplasm, but also in the sharing of responsibilities for common regional problems and, thus, avoid duplication of efforts.

In 1986, a Steering Committee comprising one elected NARS sorghum/millet scientist from each of the eight member-countries of EARSAM Network was formed to provide overall guidance for Network activities. Together with the Network Coordinator who is a member, representatives of SAFGRAD, ICRISAT and USAID attend Steering Committe meetings as observers.

In the context of providing overall technical direction to the Network and its activities, the EARSAM Steering Committee functions to:

a) Prepare short and long-term Network action plans based on prioritized problems of regional significance.

b) Monitor the implementation of workshop recommendations and Steering Committee decisions.

c) Facilitate the implementation of research Network activities in members' respective countries in particular, and in the region in general.

d) Determine themes for training workshops, seminars and regional short-course training programmes.

The day-to-day execution of Steering Committee decisions and Network activities rests with the Coordinator.

EARSAM Network Objectives and Programmes

In the overall context of SAFGRAD mandate to enhance food grain production in sub-Saharan Africa, the EARSAM Network has the following objectives relating to Eastern Africa:

a) To assist NARS in the development of improved sorghum and millet varieties and hybrids that, together with agronomic and soil management and conservation practices, will result in higher and more stable economic yields in the region.

b) To assist NARS to develop or adapt screening techniques to identify broad - based genetic resistances/tolerances to abiotic and biotic stresses, to incorporate them in elite breeding material and to identify materials adapted to the various ecological zones in Eastern Africa.

c) To organize and promote systematic regional cooperative testing of available elite cultivars.

d) To develop collaborative research projects on specific production constraints of major significance in the region with strong NARS institutions (Lead NARS Centres) and provide critical inputs to enable them carry out such assigned research adequately and satisfactorily.

e) To assist NARS in their training and manpower needs and development.

f) To organize regional workshops, monitoring tours and field days in order to report research findings, interchange ideas and breeding materials and foster closer national programme cooperation.

At the inception of the Network in 1986, the major and common constraints to sorghum and millet production were identified by the Steering Committee, research priorities were formulated and Lead NARS Centres identified to carry out specific and assigned technology-generation research projects of regional implications, in addition to the backstopping provided by ICRISAT. In this context, ICRISAT forged greater collaboration with NARS and transferred specific aspects of research to Lead Centres which assigned projects are partly supported by SAFGRAD through ICRISAT.

The concept of assigning research roles to Lead NARS Centres and their consequent close collaboration with ICRISAT is not only for the generation of needed technologies, but also towards developing research leadership of NARS scientists and strengthening their ability to carry out effective research.

EARSAM Network Achievements

a) ***Lead Centre Collaborative Projects.***

i. *Striga* resistance screening by the Institute of Agricultural Research, Ethiopia, has recorded commendable progress and achievements and especially relating to the screening of several hundred breeding and germplasm lines for resistance to *Striga* in field-sick plots out of which 27 resistant lines have been identified. In pot experiments at Holeta Research Station, five sorghum lines (SAR 24, Gambella 1107, N 13, ICSV 1006, and ICSV 1007) have been identified as resistant to both *S. hermonthica* and *S. asiatica.*

ii. Research on long smut at the Kenya Agricultural Research Institute has led to the selection of 18 sorghum lines that have shown resistance to long smut at Marimanti. A screening technique for long smut has also been developed in the greenhouse using artificial inoculation. Sporidia were found to be a more effective source of inoculum when inoculation occurred at the boot stage.

The resistance of IS 8595 may not be wholly attributed to its long glumes as presently believed, in light of recent findings at the Kenya Agricultural Research Institute (Lead Centre for long smut) to the effect that other long-glumed sorghum genotypes have been found highly susceptible. Also of note in terms of achievements at the Kenya Lead Centre is the confirmation that seed treatment with systemic fungicides available in Kenya (Rocol and Bayleton) are ineffective in the control of long smut.

iii. The Kenya Lead Centre has also developed a simple and reliable technique to screen sorghum germplasm and breeding lines for resistance to covered smut. By this technique that is now in wide use by NARS institutions, maximum infection results when 10 g of seed is mixed with 50 mg of dry teliospores.

iv. Out of over 300 sorghum lines screened for ergot resistance at the Ethiopia Lead Centre, about 48 have been identified that show less than 10% ergot-infected florets - of which six lines (ETS. 1446, 2448, 2465, 3155, 4457 and 4927) have been confirmed as having resistance to ergot following further screening. The same technique used at the Rwanda Lead Centre (l'Institut des Sciences Agronomiques) resulted in the identification of 8 resistant lines (IS. 25531, 25485, 25489, 25527, 255530, 25533, 25537 and 25542). Also identified are the common grasses *Panicum maximum* and *Cenchrus diliaris* which may serve as primary sources of ergot inoculum, having been confirmed as alternate/collateral hosts of the sorghum ergot pathogen in Rwanda. These grasses may serve as primary sources of ergot inoculum.

v. The Ethiopian Lead Centre has used the ICRISAT artificial screening technique for anthracnose to identify 67 anthracnose-resistant sorghum lines out of 111 screened.

vi. The Kenya Lead Centre has screened about 960 finger millet germplasm lines for resistance to finger millet head blast disease, out of which 201 selected lines are being screened again at "hot spot" locations in Eastern Africa to identify lines with stable resistance.

vii. Facilities for insect rearing on artificial diets have been established and successful rearing of sorghum stem borer *(Chilo partellus)* initiated at the Somalia Lead Centre. The growth, development and reproduction of *C. partellus* on the artificial diet were similar to those on its natural host, sorghum.

viii. The joint effort of Lead Centres on food crop utilisation in Ethiopia (Institute of Agricultural Research), Kenya (University of Nairobi) and Sudan (Food Research Centre) has shown a wide variation in the physico-chemical characteristics of sorghum cultivars commonly cultivated in each of the three countries; evaluated the organo-leptic qualities of such traditional foods as *injera* and nifro (Ethiopia), *ugali* (Kenya) and *kisra* (Sudan); observed comparatively high ratings for overall food quality in respect of sorghum cultivar SPV 475 (india), Dabar (Sudan) and IS 24129 (Tanzania); established significant associations between starch characteristics and *injera* quality, and protein content with *injera* and *kisra* quality; used the tangential abrasive dehulling device to dehull large numbers of sorghum samples

and to screen for grain hardness; and observed significantly improved *injera* dehulled sorghum grain used for its preparation.

b) ***Regional Germplasm Movement and Evaluation***

The model guiding the movement and evaluation of germplasm in EARSAM Network is depicted in Fig. 1. Adopted in July 1988, the model was used in the 1989/90 cropping season to organise the Network regional advanced elite yield trials. Resulting from such regional activities, several cultivars of sorghum and millet have been released by NARS as shown in Table 2.

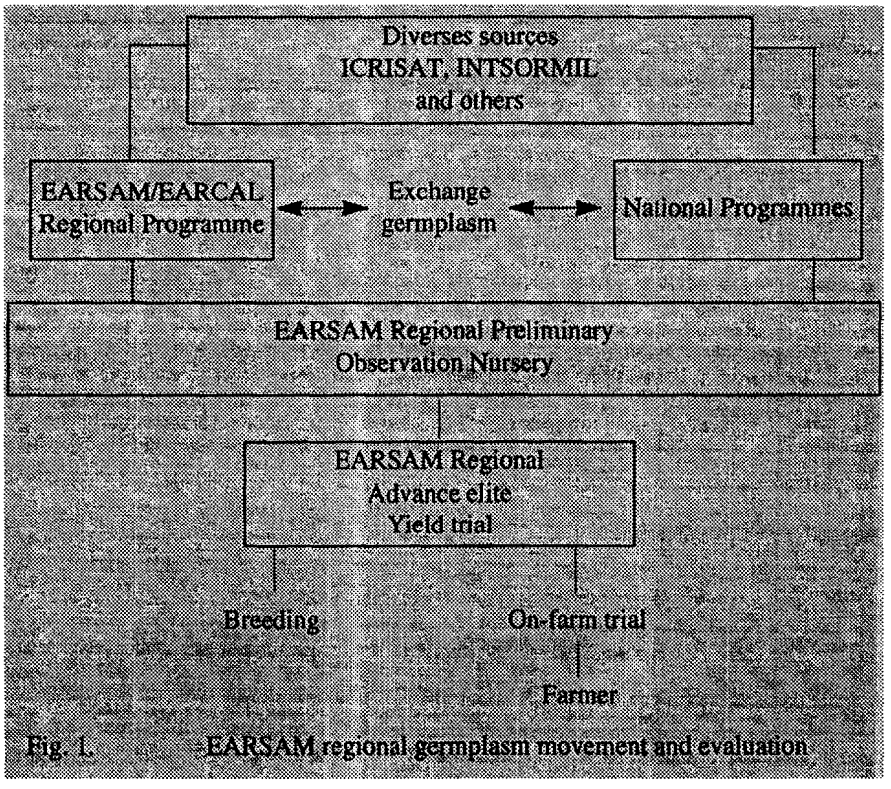

Fig. 1. EARSAM regional germplasm movement and evaluation

Between 1986 and 90, seed material of sorghum and millet germplasm and breeding lines, resistant or tolerant to *Striga*, stem borer, shootfly, downy mildew, midge, leaf diseases, ergot and to cold conditions have been provided to NARS institutions as follows:

Burundi	731	Somalia	583
Ethiopia	1052	Sudan	534
Kenya	3451	Tanzania	525
Rwanda	615	Uganda	825

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Most of the germplasm has been evaluated by the NARS, useful data generated and productive/adaptive cultivars selected for further testing as desired by each institution. EARSAM Network preliminary observation nurseries have been organised for evaluation to commence in the 1991 season in the different agro-ecological zones of Eastern Africa.

Table 2. Sorghum and millet cultivars released in eight Eastern African countries through SAFGRAD-ICRISAT EARSAM Network.

	Crop		
Country	Sorghum	Pearl millet	Finger millet
Burundi	5 Dx 160 Gambella 1107	-	-
Ethiopia	Melkamash Gambella 1107 Dinkmash Seredo	-	-
Kenya	Serena Seredo IS 76 2 Kx 17	-	-
Rwanda	Amasugi 5 Dx 160	-	-
Somalia	PP 290	-	-
Sudan	White Dwarf Milo Hageen Durra I Gadan Hamam	Ugandi	-
Tanzania	Serena Lulu Tegemeo	Serere 1 Serere composite	-
Uganda	Serena Seredo	Serere 1 Serere composite	Engeny P 224

c) ***Training***. During the period 1986-90, short-duration training courses were offered to NARS scientists and technicians covering seed production (43 participants, Nairobi, Kenya); cereal entomology (16 participants, India); cereal pathology (16 participants, India) and breeding (planned for Kenya in June 1991 for 16 participants).

d) ***Workshops.*** One facet of EARSAM Network activity that has grown markedly in size and quality has been the biennial regional workshops. The workshops are usually well attended by NARS scientists who present the results obtained from collaborative (Lead Centre) research projects and other studies. Scientists from ICRISAT, other international organizations as well as from Universities also attend towards sharing knowledge, expertise and experiences with NARS scientists and in the development of research plans and strategies for the following years. The regional workshops are organized jointly with the NARS institution hosting the event. Three regional workshops have been held since 1986: July 1986 in Burundi with 50 scientists participating, September 1988 in Somalia with 55 scientists; and June 1990 in Kenya with 67 scientists attending. Proceedings from all three regional workshops have been published and widely circulated.

e) ***Monitoring Tours and Field Days.*** The Network organises monitoring research tours and field days for NARS scientists to enable them visit and evaluate one another's research activities, to evaluate the various entries in the regional trials and nurseries, and to appreciate the interaction between genotypes and locations. Such visits also enable scientists to select or request genetic material of direct interest for utilization by their national programmes. Monitoring tours have so far been organized in Burundi (1986), Somalia (1988), Sudan (1989), Ethiopia (1990) and Kenya (1990).

In addition to tours and field days undertaken by NARS scientists, staff of ICRISAT in the regional programme also travel regularly in the region to observe Network activities, to interact with NARS scientists, and to offer on-the-spot suggestions towards strengthening the ability of NARS scientists to carry out effective research.

Challenges in the 1990s

Even though SAFGRAD/ICRISAT in general and EARSAM Network in particular have recorded commendabble achievements relating to sorghum and millet research, much remains to be done especially considering the widening food gap between demand and supply. Thus, in addition to continuing with and strengthening the activities pursued in the second phase of the SAFGRAD/ICRISAT programme and employing the networking approach, the EARSAM Network would pay particular attention to the following aspects:

a) ***Manpower development:*** Well-trained scientists and support staff are assets to a good national programme. The establishment of practical/applied training opportunities for technicians in the region in a well organized training centre with adequate facilities is needed to meet expanding manpower requirements. In addition, degree-level training at the Masters and Doctoral degree levels and covering all disciplines is of high NARS priority.

b) ***Research Station Improvement.*** One of the limitations to good quality research within NARS is the paucity of effective research station facilities and management. Every year a substantial percentage of the data collected is inaccurate because it has been collected in poor experimental fields that lack proper management. It will,

therefore, be necessary in the 1990s for NARS, in cooperation with other institutes involved in research station improvement and management, to train young scientists in station management in order to improve the research plots.

c) ***Resolving Constraints to Productivity***: More emphasis would need to be given to research towards resolving constraints relating to drought, *Striga,* insect pests and notably stem borers (Chilo), diseases and notably head blast (finger millet) and anthracnose (sorghum), grain molds (sorghum) and ergot (pearl millet), bird problems, post harvest handling and storage insect problems as well as sorghum and millet utilization.

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Besoins Agronomiques des Génotypes de Sorgho sous Condition de Culture Pluviale au Mali.

D. SOGODOGO et S.V.R. SHETTY.

ICRISAT - WASIP, Bamako - Mali

Résumé

Une étude sur les besoins agronomiques du sorgho sous condition de culture pluviale a été conduite au Mali de 1985 à 1989 dans la zone sahélienne et la zone soudano-Sahélienne, deux régions présentant des technologies de production différentes sur plusieurs points. Dans le sahel où la période de végétation est la plus courte, les variétés améliorées et précoces ont donné les meilleurs rendements pour des semis dans la seconde moitié de juillet, sur labour simple. L'apport d'engrais et le semis à 53333 plants/ha ont été favorables au sorgho.

Dans la zone Soudano-Sahélienne caractérisée par un cycle de culture relativement plus long, les variétés améliorées à cycle intermédiaire ont été les plus performantes sur un billonnage de début de saison. Le semis à 76.190 plants/ha vers la mi-juin et l'apport d'engrais ont considérablement amélioré le rendement du sorgho.

Introduction

La culture du sorgho s'étend au Mali, du Sud au Nord. Le sorgho cède progressivement le terrain au petit mil vers le Nord où il réapparait très localisé dans les lits de cours d'eau ou de mares comme culture de décrue. Sa culture s'est accrue ces dernières années dans le Sud à cause de la pluviométrie peu favorable à la culture du maïs. La culture pluviale est la forme de production du sorgho la plus dominante, et d'importants progrès ont été réalisés dans le domaine de la recherche sur l'amélioration du sorgho de ce type de culture.

Patel et Patel (1988) a trouvé que le décalage de date de semis entraînait une réduction de rendement du sorgho malgré le bon comportement de certains génotypes. Une augmentation de la distance entre les poquets sur la ligne s'était également traduite par une réduction de rendement (Chetram, 1970).

L'utilisation des engrais a fait remarquablement augmenter les rendements. L'apport de phosphore (Traoré, 1974) et d'azote a considérablement amélioré les rendements. Toutefois, Pieri (1973) avait trouvé que la réponse des céréales à l'apport d'azote variait en fonction de la pluviométrie et avait des effets notoires sur le rendement. Mais la variation dans la quantité et la distribution des pluies d'une année à l'autre (Sivakumar *et al,* 1983 et 1984) rendait difficile les prévisions dans ce domaine.

Les sols de culture de sorgho nécessitent des techniques de préparation du sol pour améliorer leur statut et le rendement des cultures (Vijayalakshmi, 1983), et une nécessaire collaboration doit s'établir entre chercheurs et climatologues pour mieux

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cerner les interactions entre le climat, le sol et la plante (Kanwar, 1982). Les efforts de la recherche doivent donc s'orienter vers une amélioration ou une transformation des systèmes de cultures existants (Rao, 1981).

De nos jours au Mali, la culture du sorgho est, dans la majorité des cas, caractérisée par des systèmes culturaux traditionnels. Le semis en poquets s'effectue sur sol non travaillé, à sec, et sur labour, houage, buttes ou billons, en humide. La densité varie de 25 000 à 30 000 plants ha. A côté du semis direct, existe le repiquage, mais à une moindre échelle. Le démariage est presque inexistant. Les écotypes locaux de haute taille produisent près de 800 kg de grain/ha. Malgré cette faiblesse de rendement, le sorgho demeure l'un des aliments de base des populations. Aussi admet-on, généralement, que les variétés améliorées issues des programmes de sélection diffèrent, par nature, des variétés locales. Elles ont une architecture moyenne ou petite et un cycle de végétation plus court que celui des variétés locales. Par conséquent, les besoins agronomiques des variétés améliorées et locales diffèreront. Aussi avons-nous entrepris cette étude.

Matériels et Méthode

Les essais étaient en factoriels pour l'étude de la réponse des génotypes à la densité, travail du sol et fumure minérale et en split-plot pour celle de la densité de semis et de la date de semis avec les génotypes comme sous-parcelles. Le dispositif était en blocs de Fisher à 4 répétitions. La parcelle élémentaire avait 4,5 m x 8 m de côté. Les semis ont été effectués à la daba et en poquet, le démariage à 2 plants/poquet. Le sorgho était semé à 0,75 m x 1,0 m (26666 plts/ha); 0,75 m x 0,5 m (53333 plts/ha); 0,75 m x 0,35 m (76190 plts/ha); 0,75 m x 0,25 m (106666 plts/ha) selon les cas. Les niveaux de fumure étaient : 0-0-0 (témoin absolu), 18-46-0 (100 kg de phosphate d'ammoniaque/ha au semis) et 41-46-0 (100 kg de phosphate d'ammoniaque/ha au semis et 50 kg d'urée/ha à la montaison).

Les variétés utilisées étaient : Malisor 84-1, Malisor 84-3, Malisor 84-4, Malisor 84-7, F4-286, CSM 388, S34, S35, CE 90, ICSV 1063 BF, ICSV 401 et les locales Lakahery et Sakoïka.

L'estimation de rendement à la récolte a porté sur les 4 lignes centrales diminuées d'1,5 m à chacune des extrémités. L'analyse de la variance a été utilisée pour la détermination des effets des différents facteurs et leur interaction sur le rendement du sorgho. La PPDS a été utilisée pour la séparation des moyennes.

Les essais ont été semés dans la deuxième moitié de Juin dans la zone soudanienne, à la Station de recherche agronomique de Sotuba et dans la deuxième moitié de Juillet dans la zone sahélienne, à la Station de recherche agronomique de Bema. Les parcelles ont reçu un minimum de deux sarclo-binages par campagne agricole.

Tableau 1. Influence d'une augmentation de densité de semis sur le rendement de grain (kg/ha) du sorgho à Béma, 1989.

Génotypes	Population à l'hectare				
	26666	53333	76190	106666	Moyenne
ICSV 401	1360	1280	1180	880	1175
Malisor 84-5	960	900	610	720	797
Lakahéry	290	310	100	180	220
Moyenne	870	830	630	593	731

Résultats et discussions.

Zone Sahélienne. Le rendement moyen des variétés améliorées a été meilleur à celui de la locale Lakahery. Les variétés ICSV 401, Malisor 84-5 et locale ont produit respectivement environ 1200 kg, 800 kg et 200 kg de grain/ha (Tableau 1). La variété locale a souffert de l'attaque des sautériaux. L'augmentation de densité a entraîné des réductions plus ou moins notoires de rendement. La réduction de rendement a été insignifiante en passant de 26666 à 53333 plants/ha mais les densités de 76190 et 106666 plants plants ont entraîné des réductions respectives de rendement de 27 % et 32 % (Tableau 1). Notons que les rendements du sorgho sont équivalents aux densités de semis 26666 plants et 53333 plants/ha, mais 26666 plants/ha ont favorisé le tallage du sorgho. Cependant, toutes les talles n'arrivent pas à maturité en cas d'arrêt précoce des pluies comme c'est souvent le cas.

La réaction des génotypes à l'apport de fumure minérale et à l'augmentation de densité a varié en fonction de la pluviométrie. En 1985, une mauvaise répartition des pluies en septembre a contribué à une réduction importante de rendement du sorgho, et nous n'avons pu noter de différence significative entre les rendements des génotypes. Cependant, les effets de la densité et de la fumure ont été significatifs (Tableau 2).

L'augmentation de densité a significativement amélioré le rendement du sorgho de 37 %. La F4-286 a été la moins performante à 26666 plants/ha avec 1280 kg de grain/ha. A 53333 plants/ha, la CE 90 et F4-286 ont été les moins performantes avec des rendements respectifs de 1908 kg et 1974 kg/ha (Fig. 1a1). Le meilleur rendement de sorgho a été obtenu avec un semis à 53333 plants/ha avec une application de la fumure 41-46-0 (Fig. 1a3).

La tendance des génotypes à bien répondre à l'apport de la fumure 41-46-0 a été nette (Fig. 1a2). Avec 1935 kg/ha, la F4-286 a été la moins performante des variétés. Cette variété s'est révélée très sensible aux maladies : anthracnose, tâches zonées et charbon.

Tableau 2. Influence du génotype, de la densité de semis et de la fumure sur le rendement du sorgho à Béma.

Traitements	Rendements de grain kg/ha			
	1985	1986	1988	1989
Génotypes	ns	*	**	ns
F4-286	1627	2344	1350	540a
Malisor 84-5	1804	3440	1330	550
Malisor 84-6	1874	3290	2420b	520b
CE 90	1818	3212	1920	620
ES±	181	147	130	46
Densité de semis/ha	*	*	*	*
26666 plts (75 x 100 cm)	1500	2820	1540	470
53333 plts (75x50 cm)	2061	3286	1980	520
ES±	116	122	90	32
Fumure minérale	*	ns	*	*
18-46-0 NPK	1465	2891	1610c	470c
41-45-0 NPK	2097	3252	1910	640
ES±	116	122	90	32
Interaction	G x D*	ns	ns	DxFM*
CV %	40	23	26	33

a- rendement de Malisor 8-4
b- rendement de la variété locale lakahery
c- rendement du niveau de fumure 0-0-0 NPK
18-46-0 : 100 kg de phosphate d'ammoniaque uniquement/ha
41-46-0 : 100 kg de phosphate d'ammoniaque et 50 kg d'urée/ha
NS : non significative
* : $P < 0,05$
** : $p < 0,01$

En 1986, la saison agricole a été moins pluvieuse avec des pluies relativement bien réparties. Les effets des génotypes et de la densité de semis ont été nets sur le rendement du sorgho. La F4-286 a donné le plus faible rendement (2344 kg/ha), tandis que Malisor 84-5, Malisor 84-6 et CE 90 (pris comme témoin de productivité) avaient des performances équivalentes de l'ordre de 3314 kg/ha. L'augmentation de densité a engendré un gain de production de 16 % (Tableau 2).

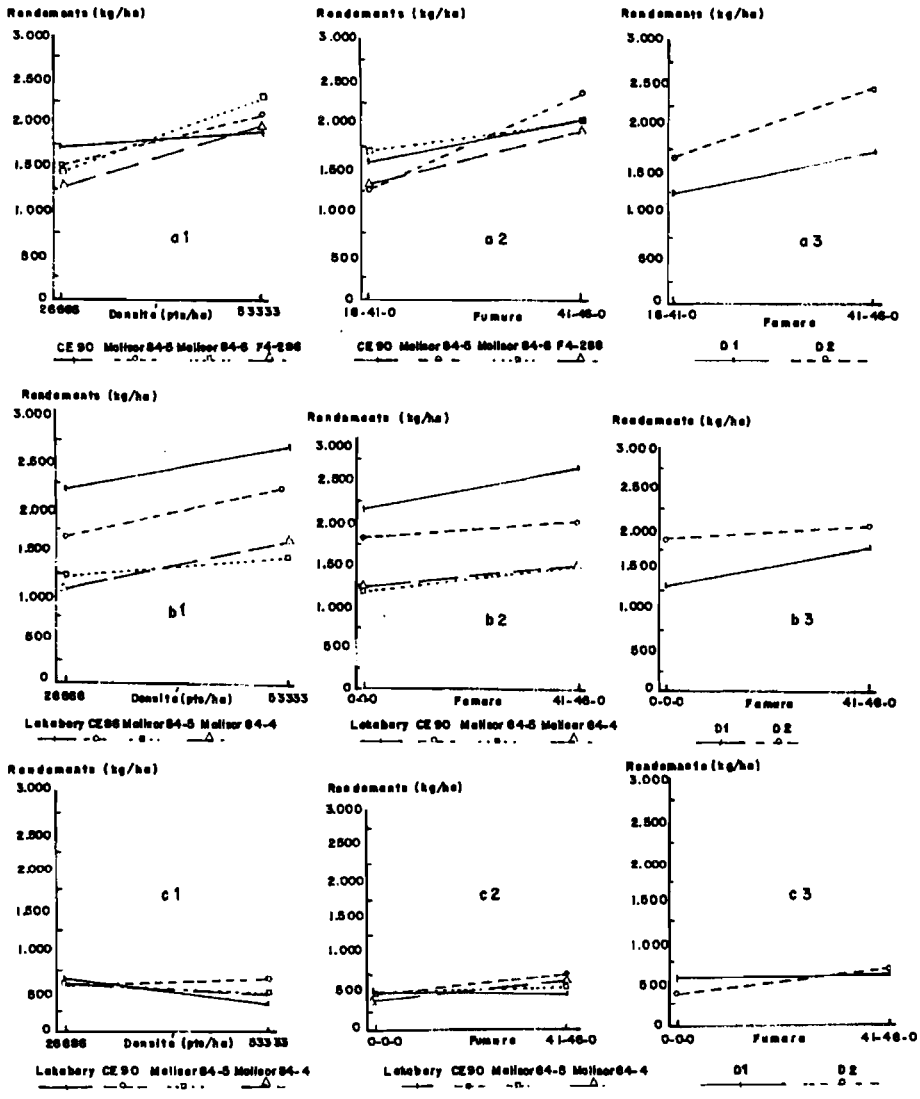

Fig. 1. Rendement du sorgho sous l'effet d'interaction en 1985 (a), 1988 (b) et 1989 (c) à Bema.

Les résultats de 1987 n'étaient pas interprétables à cause de l'absence de rendement dans plusieurs traitements. L'année 1988 a été la plus pluvieuse malgré un brusque arrêt des pluies. La mauvaise répartition des pluies en Août et en Septembre et surtout les attaques d'oiseaux ont été préjudiciables aux variétés améliorées qui ont été moins performantes que la locale Lakahery. Dans l'ensemble, les effets simples de génotypes, de densité et d'engrais ont été nets sur le rendement du sorgho. Le

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doublement de la densité de semis a entraîné 28 % d'accroissement de rendement et l'apport de doses de fumure vulgarisée un excédent de 19 % (Tableau 2). La tendance a été forte chez la locale Lakahery à surclasser en rendement les autres génotypes (Fig. 1b1 et 1b2). La densité de semis 53333 plants/ha a été la meilleure avec l'apport de la fumure vulgarisée (Fig. 1b3).

En 1989, les niveaux de rendement ont été faibles à cause de la faiblesse des pluies et surtout des dégâts de sautériaux. Mais les tendances observées restent les mêmes que celles des autres années. Les génotypes améliorés CE 90 Malisor 84-4 et Malisor 84-5 ont été plus performants que la locale Lakahery avec l'augmentation de densité et l'apport de fumure (Tableau 3, Fig. 1c1 et 1c2).

L'apport de fumure a significativement amélioré le rendement du sorgho de 36 %. Les variétés se sont mieux exprimées dans le cas d'un apport d'engrais à la densité de semis de 53333 plants/ha (Fig. C1c3).

Les génotypes améliorés comme Malisor 84-5 et Malisor 84-6 ont égalé en rendement, le témoin de productivité CE 90 (1985 et 1986). Ces génotypes ont produit en moyenne 2573 kg/ha contre 1985 kg/ha chez F4-286. La variété locale s'est révélée plus productive que les améliorées dans une situation de mauvaise répartition des pluies et souvent d'attaque des oiseaux. L'augmentation de la densité de semis et l'apport d'engrais sont apparus comme des facteurs agronomiques favorables àl'amélioration de rendement aussi bien des variétés locales que des variétés améliorées.

Cette étude dans le Sahel Nord-Ouest du Mali nous a permis de démontrer que le rendement du sorgho peut être considérablement amélioré grâce à : (i) l'utilisation des variétés améliorées (Malisor 84-4, Malisor 84-5, Malisor 84-6 et CE 90) semées dans la deuxième moitié de Juillet, (ii) l'apport de la dose de fumure minérale 41-46-0 (100 kg/ha de phosphate d'ammoniaque au semis à la volée puis enfouis et 50 kg d'urée/ha par localisation à 5 cm de la ligne de semis à la montaison du sorgho) sur labour simple de début de saison, et l'augmentation de la densité de semis de 26666 plants/ha (75 cm x 100 cm) à 53333 plants ha-1 (75 cm x 50 cm).

Tableau 3. Influence de la date de semis sur le rendement moyen (kg/ha du sorgho à Sotuba, 1988 et 1989).

Génotypes	Date de semis			
	15 juin	30 juin	15 juillet	30 juillet
Malisor 84-7	2649	1301	1046	226
Malisor 84-1	2906	2243	1418	521
S34	3268	1464	900	210
S35	2413	2438	1564	660
Sakoïka	2581	1271	626	91
Moyenne	2845	1744	1111	342

Zone Soudanienne. Les résultats sont dans le Tableau 3. Le rendement du sorgho a considérablement diminué au fur et à mesure du retard du semis. Le semis au 15 Juin a donné le meilleur rendement (2845 kg/ha). Les deuxième, troisième et quatrième dates de semis qui se suivent à 15 jours d'intervalles ont enregistré des réductions respectives de rendement de 39 %, 61 % et 88 %. La performance des génotypes a beaucoup varié selon la date de semis. Les génotypes les plus sensibles à la photopériode ont été les moins performants. Ainsi, la variété locale Sakoïka et Malisor 84-7 (issue de la population de base du programme de sélection du Mali) ont été les moins performantes avec des rendements de 1000 kg/ha tandis que Malisor 84-1 et les variétés du Nigéria (S34 et S35) toutes sélectionnées à partir de matériels indiens ont été les meilleures avec des rendements de près de 2000 kg/ha (Tableau 3).

L'influence de la densité de semis du sorgho s'est manifestée sur le rendement de grain et de matière sèche. L'augmentation de densité de semis a entraîné une tendance générale à un accroissement de rendement. Des taux d'accroissement de rendement de 34 %, 35 % et 53 % ont été enregistrés avec les augmentations respectives de densité de semis à l'ha : 53333, 76190 et 106666 (Tableau 4). A 76190 plants/ha, nous avons noté chez les variétés améliorées demi-tardives ICSV 1063 et S34, une tendance à la baisse de rendement dûe aux effets de compétition. A 106666 plants/ha, l'accroissement de rendement chez toutes les variétés serait dû à une augmentation du nombre de plants (Tableau 4).

Tableau 4. Influence d'une augmentation de densité de semis sur le rendement de grain (RG, kg/ha) et la production de matière sèche (MS, kg/ha) du sorgho à Sotuba, 1989.

Génotypes	Population/ha							
	26666		53333		76190		106666	
	RG	MS	RG	MS	RG	MS	RG	MS
ICSV 1063 BF	1650	8833	2080	8417	2080	6583	2150	4500
S 34	1370	8500	2000	8000	1780	5083	2150	4583
CSM 388	1230	7583	1620	7000	1870	6583	2200	6500
Moyenne	1417	8305	1900	7806	1910	6083	2167	5194

La production de matière sèche a évolué dans le sens contraire du rendement de grain. Nous avons enregistré des taux de réduction de 6 %, 27 % et 37 % avec des augmentations respectives de densité de semis de 53333, 76190 et 106666 plants/ ha (Tableau 4). L'augmentation de densité de semis accroît les besoins en éléments nutritifs des plants et la compétition quant à la lumière. Dans cette situation les plants photosynthétisent moins de matière sèche. Ainsi il apparaît que le sorgho

réagit favorablement à une augmentation de densité de semis jusqu'à 106666 plants/ha. Les variétés améliorées semi-tardives ont été plus sensibles aux effets de compétition dûe à l'augmentation de population avec l'application d'une dose unique de fumure minérale.

Tout comme dans la zone sahélienne, la réaction des génotypes n'a pas été la même en ce qui concerne la réponse à la densité et à la fumure minérale.

L'augmentation de densité s'est traduite en 1985 par une tendance à la baisse de rendement chez les variétés précoces et demi-tardives à cause d'une mauvaise répartition des pluies et à l'exception de Malisor 84-3, toutes les variétés ont favorablement réagi à l'apport de la dose vulgarisée de fumure minérale (Tableau 5, Fig. 2a1 et 2a2). En 1986, l'augmentation de densité s'est traduite par une tendance à la baisse de rendement de 6 %, la CSM 388 de long cycle ayant été la moins performante des variétés. L'application d'engrais (41-46-0), par contre, a favorisé un meilleur rendement du sorgho.

En 1988, les variétés Malisor 84-3 et Malisor 84-1 ont été retirées de l'essai, la première à cause de la petitesse de ses panicules et la seconde à cause de sa précocité. Elles ont été remplacées par respectivement Sakoïka et S34. L'augmentation de densité s'est traduite, chez les variétés à cycle long, par une baisse de rendement consécutive à une sécheresse de fin de saison (Tableau 5, Fig. 2b1). La densité de semis 53333 plants/ha a significativement mieux utilisé l'engrais que la forte densité de semis 106666 plants/ha (Fig. 2b3).

En 1989, Malisor 84-7 qui connaît quelquefois des problèmes d'excersion paniculaire a été remplacé par ICSV 1063 BF, un sorgho semi-tardif. Dans l'ensemble, comme pour obeïr à la tendance enregistrée les autres années, les variétés semi-tardives (S34 et ICSV 1063 BF) ont significativement surclassé les tardives (Sakoïka et CSM 388) (Tableau 5). L'augmentation de densité a entraîné un accroissement significatif de rendement des génotypes (Fig. 2c1). Les variétés de cycle intermédiaire ont mieux répondu à cette augmentation de population, et toutes les variétés ont réagi favorablement à l'apport d'engrais, particulièrement à la densité double de semis (106666 plants/ha) (Fig. 2c2 et 2c3).

Dans les conditions locales de labour et sans fumure (0-0-0), l'utilisation de la variété améliorée S34 a entraîné un surplus de revenu de 27300 F. L'application de la fumure minérale seule sur la variété locale (Sakoïka) et améliorée (S34) a entraîné des accroissements respectifs de revenu de 6.170 F et 40.950 F. Les effets synergiques de l'utilisation d'engrais et de variété améliorée ont rapporté 68250 F de bénéfice (Tableau 6).

Dans les conditions améliorées de travail du sol (billonnage de début de saison), sans apport d'engrais, l'utilisation de la variété améliorée seule a engendré un gain de 49.400 F. Des bénéfices de 26.000 F et 52.957 F ont été réalisés avec respectivement la variété locale et la variété améliorée rien qu'avec l'apport d'engrais. La combinaison des facteurs engrais et variété améliorée a eu des effets synergiques qui ont occasionné un bénéfice de 102.375 F (Tableau 6). Dans l'ensemble, la technologie améliorée de production a permis de réaliser un bénéfice de 72.150 F sur la technologie locale.

Tableau 5. Influence du génotype, de la densité et de la fumure minérale sur le rendement du sorgho à Sotuba.

a - Rendement de la variété locale Sakoïka

Traitements	Rendement grains kg/ha			
	1985	1986	1988	1989
Génotypes				
Malisor 84-3	1625	2069	1350a	1700a
Malisor 84-1	2331	2477	2000b	2000b
Malisor 84-7	2103	2370	1570	2240c
CSM388	812	1352	1280	1960
ES±	145	123	154	113
Densité de semis/ha	NS	NS	NS	*
53333 plts (75 x 50 cm)	1819	2116	1500	1740
106666 plts (75 x 25 cm)	1617	1978	1600	2010
ES±	144	116	109	80
Fumure minérale	NS	NS	**	**
18-46-0 NPK	1650	2019	1180d	1643d
41-46-0 NPK	1777	2115	1920	2105
ES±	144	116	109	80
Interaction	-	-	D x F. M**	NS
CV %	40	32	34	24

b - Rendement de S 34
c - Rendement de ICSV 1063 BF
d - Rendement du niveau de fumure 0-0-0
* $p < 0,05$
** $P < 0,01$
NS: Non significative.

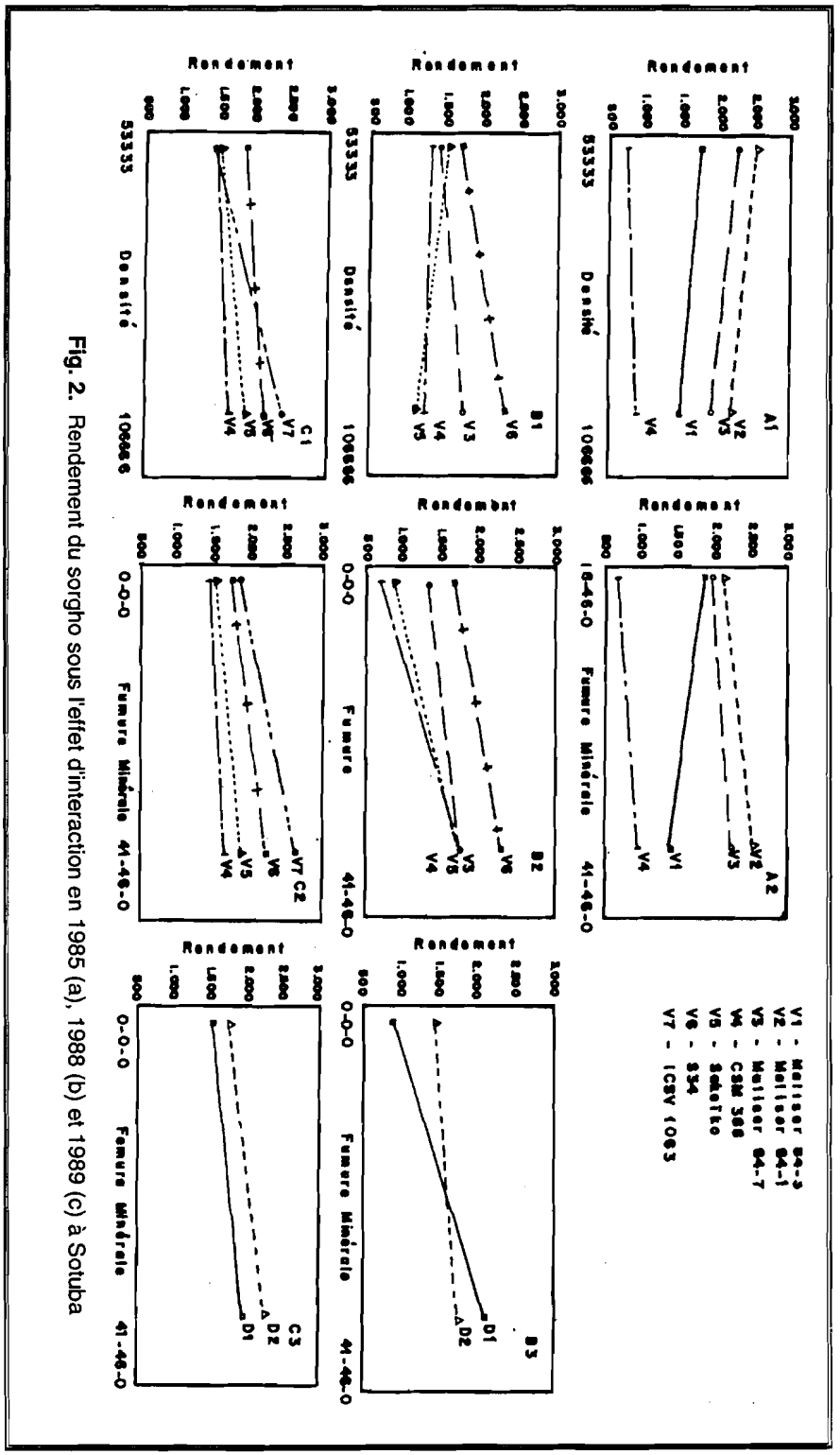

Fig. 2. Rendement du sorgho sous l'effet d'interaction en 1985 (a), 1988 (b) et 1989 (c) à Sotuba

Tableau 6. Influence du travail du sol, de la fumure minérale et de la densité de sorgho sur la productivité du sorgho de culture pure à Sotuba.

Traitements			Rendement de grain kg/ha			Revenu* brut CFA
			1988	1989	Moyenne	
TS	FM	V				
-	-	-	1990	2530	2260	146900
-	-	+	2610	2750	2680	174200
-	+	-	1830	2880	2355	153075
-	+	+	3500	3120	3310	215150
+	-	-	1170	2420	1795	116675
+	-	+	2580	2530	2555	166075
+	+	-	1720	2670	2195	142675
+	+	+	3110	3630	3370	219050

* 1 kg de grain de sorgho = 65 FCFA
T.S. = travail du sol. FM = fumure minérale. V = variété de sorgho
- pratique locale (labour simple sans engrais variété locale)
+ pratique améliorée (billonnage avec engrais variété améliorée).

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Estimation du Taux d'Allogamie chez les Sorghos de la Race *Guinea.*

J. CHANTEREAU et C. KONDOMBO.

CIRAD et INERA, Ouagadougou, Burkina Faso.

Résumé

Des travaux de mutagénèse et d'électrophorèse se rapportant à des écotypes locaux de sorgho de la race guinea prépondérante en Afrique de l'Ouest nous ont permis plusieurs estimations de leur taux d'allogamie. Celles-ci aboutissent le plus souvent àdes valeurs de 20 à 30 %. Elles sont supérieures à celles généralement admises pour les autres races de cette céréale. Pour mieux prendre en compte cette particularité, des recommandations sont faites pour la maintenance et l'amélioration des écotypes locaux guinea.

Introduction

Le sorgho est considéré comme une plante autogame. En effet, les taux d'allogamie généralement donnés pour cette plante sont faibles : de l'ordre de 5 à 7% (Doggett, 1988). La plupart du temps, ils ont été obtenus avec des variétés à panicule semi-compacte ou compacte du type dura (Fayed *et al.*, 1976).

A notre connaissance, il n'y a pas de publications d'études concernant l'allogamie des sorghos à panicule lâche appartenant à la race guinea prépondérante en Afrique de l'Ouest. Leur importance économique dans cette partie du monde, rend cette situation anormale. Pour remédier à cette ignorance, nous avons eu l'opportunité d'exploiter des travaux recourant à des techniques de mutagénèse et d'électrophorèse recemment utilisées sur des écotypes locaux traditionnels *Guinea.*

Apport de la Mutagenèse

Une variété locale guinea à grain rouge : Nafo-Natogue du Sénégal a subi en France, en 1984, un traitement mutagène de 100 jours aux rayons gamma à la dose de 28,5 Kr. La sélection des descendances des graines irradiées est en cours au Burkina Faso (Kondombo, 1988).

En M_2, l'apparition de plantules chlorotiques, de nature mutante, facilement identifiables, a rendu possible un calcul du taux de pollinisation croisée. Pour cela, nous avons exploité la différence de plantules chlorotiques, observée entre les descendances M_2 issues d'autofécondation et celles de M_2 issues de pollinisation libre.

Le détail des calculs, donné en annexe, amène à une estimation du taux d'allogamie de 29 %.

Apport de l'Electrophorèse

A l'occasion d'un travail d'analyse de la variabilité génétique des sorghos cultivés, 6 écotypes locaux guinea ont été prospectés autour de la station de Saria au Burkina Faso.

Une étude d'électrophorèse a montré que, sur 7 loci étudiés, 4 présentaient du polymorphisme. Les 6 populations étaient en moyenne polymorphes pour 2,7 d'entre eux. Par système enzymatique polymorphe, le taux observé d'hétérozygotie a été trouvé de 7,6 %.

Pour 4 de ces écotypes ayant des loci polymorphes, l'étude des descendances grain à grain d'un certain nombre de panicules a débouché sur des estimations de taux moyens d'allogamie respectivement de 7, 20, 21 et 28 % (Ollitrault, 1987).

Récemment, des études identiques avec 3 nouvelles variétés locales guinea, toujours prospectées autour de Saria, donne comme estimation de leur taux d'allogamie 21, 23 et 34 % (Degremont, résultats non publiés).

Discussion

Les différents taux d'allogamie établis ici pour les écotypes locaux guinea aboutissent, le plus souvent, à des valeurs comprises entre 20 et 30 %. Ils sont beaucoup plus forts que ceux habituellement admis pour le sorgho. Les seuls résultats trouvés proches des nôtres sont ceux de Garber et Atwood (1945) réalisés à partir de sudangrass, matériel bicolor à panicule lâche comme les guinea. Sans doute y a-t-il lieu de suspecter ce caractère dans l'explication des résultats observés. D'autres facteurs doivent jouer, qui sont vraisemblablement liés aux caractéristiques particulières de longueur et " mobilité " des glumes chez les guinea.

Le taux d'allogamie en liaison avec le polymorphisme observé contribuent à maintenir un taux d'hétérozygotie non négligeable chez les sorghos locaux guinea. Il y a lieu de penser que cette hétérozygotie profite aux écotypes par l'effet d'hétérosis qu'elle engendre et qui est, de façon quasi générale, positif. Avec nos méthodes habituelles de sélection qui recourent systématiquement à l'autofécondation, l'homozygotie devient générale, le polymorphisme diminue et l'hétérosis disparaît (Pernes, 1984).

Afin de vérifier l'effet dépressif attendu de cette situation, nous avons conduit un essai variétal à Saria en 1989 où nous comparions la variété locale " améliorée " en station : S 29 avec la population d'origine que les paysans maintiennent aux alentours en pollinisation ouverte : Blanc de Saria.

Les résultats vont dans le sens attendu :

Variété		Rendement en kg/ha
Blanc de Saria		2860
S 29		2469
	Moyenne	2665
	C.V.	8,6
	ETR (d.dl = 11)	230
	F variété	17,3 (HS)
	Pluviométrie utile	690 mm

La variété S 29 s'est révélée statistiquement inférieure au matériel traditionnel, entretenu sans autofécondation, qui lui est le plus apparenté.

Dans ces conditions, il convient de s'interroger si nos méthodes de maintenance et de sélection des variétés de type *guinea* sont appropriées. Calquées sur celles appliquées au matériel à panicule compacte, elles ne prendraient pas en compte la spécificité reproductive des principaux sorghos de l'Afrique de l'Ouest. Pour y parvenir, il est possible de faire quelques propositions :

Relativement à la **maintenance** des variétés guinea, la meilleure façon d'opérer paraît de les reproduire en parcelle isolée à partir de leur talon de prospection correctement échantillonné. Cela n'est pas toujours possible notamment si l'on doit entretenir de nombreux écotypes locaux. Dans ce cas là, il faut se limiter à la réjuvénation correcte des meilleurs d'entre eux à partir de leur talon de prospection.

S'il est nécessaire pour diverses raisons (comme celle de graines originelles en quantité insuffisante) de produire des semences par autofécondation, les effets liés à l'inbreeding peuvent être atténués en recourant à l'endogamie. Comparativement à l'autogamie stricte, celle-ci a une vitesse de fixation et de perte des allèles moins élevée.

Pour ce qui est de **l'amélioration** des mêmes variétés, l'usage des méthodes de sélection de nature récurrente peut être intensifié. Au sein d'un écotype, en alternant des phases de choix de géniteurs puis de brassage de ces derniers, on augmente progressivement la fréquence des gènes favorables. La sélection massale procède ainsi. Elle est surtout performante pour les caractères fortement héritables. Pour ceux qui le sont moins, il est possible d'améliorer son efficacité moyennant quelques aménagements (Gallais, 1990). D'autres méthodes de sélection récurrente sont envisageables (Marchand, 1975). Celle de " l'épi à la ligne " facilement mise en oeuvre, présente, entre autres, l'intérêt de mieux contrôler l'environnement que la sélection massale. Dans tous les cas, le taux d'allogamie suspecté de 20 à 30 % limite l'efficacité des phases de recombinaison qu'il est possible d'accroître par deux cultures successives de brassage.

ANNEXE

Calcul du taux d'allogamie à partir de graines irradiées de la variété Nafo-Natogue.

En hivernage 1987, les graines irradiées (semence M_1) ont été semées en une parcelle isolée à Saria. A raison d'une panicule par pied, tous les pieds M_1 ont été récoltés et ont donné 572 panicules-lignes M_2 semées en 1988 : 209 étaient issues d'autofécondations, 363 venaient de pieds en pollinisation libre.

Il y a eu apparition de plantules chlorotiques semblant de même nature :

- 11 des M_2 issues d'autofécondations avec apparition de 103 plantules chlorotiques sur un total de 1643 plantules observées soit un pourcentage de 6,26 %. (Pour un pied M_1 générant des plantules chlorotiques, 0,0626 représente la probabilité d'obtenir un zygote chlorotique suite à la fécondation d'une ovule par un pollen issu du même pied).

- 27 des M_2 issues de pollinisation libre (apparition de 301 plantules chlorotiques sur un total de 6600 plantules observées soit un pourcentage de 4,56 %). (Pour le même type de pied M_1 mais cette fois en pollinisation libre, 0,0456 représente la probabilité d'avoir une plantule chlorotique dans sa descendance).

La mise en oeuvre d'un test d'identité de pourcentage nous permet de conclure à une différence statistique entre des fréquences de plantules chlorotiques dans les 2 types de M_2 : valeur du test e = 2,86 pour une valeur seuil de 1,96 au risque a = 0,05. L'écart observé entre les pourcentages de plantules chlorotiques dans les 2 types de M_2 est mis sur le compte de la seule différence existant entre eux, à savoir le mode de pollinisation utilisé pour leur obtention.

A partir d'une panicule M1 en pollinisation libre générant des plantules chlorotiques en M_2, l'obtention d'une graine M_2 peut se faire soit par une pollinisation croisée soit par une autofécondation. Chacune de ces voies contribue de façon indépendante et exclusive à donner des plantules chlorotiques. Leur probabilité propre s'additionne pour donner la probabilité globale d'avoir une plantule chlorotique à partir d'une graine M_2 (probabilité trouvée égale à 0,0456). Pour chacune de ces voies, l'obtention d'une plantule chlorotique est le résultat d'événement élémentaires tous nécessaires dont les probabilités vont donc se multiplier.

Voie de l'Autofécondation :

Il faut que : la fleur M_1 soit autofécondée (probabilité a); qu'un zygote chlorotique soit produit suite à la fécondation d'un de ces ovules par un pollen du même pied (probabilité 0,0626).

Voie de la Pollinisation Croisée :

Il faut que : la fleur M_1 qui va donner une semence M_2 soit polliniée de façon croisée (probabilité 1-a); que le pollen fécondateur de cette fleur provienne d'un pied susceptible de générer des plantules chlorotiques : (probabilité estimée par le rapport 27/363 avec 363 = nombre de pieds pollinisateurs (c'est-à-dire non autofécondés) et 27 = nombre de pieds à descendances chlorotiques parmi les pieds pollinisateurs; qu'un zygote chlorotique soit produit suite à la fécondation d'un de ces ovules par un pollen du même type de pied pour l'aptitude à donner des descendances chlorotiques ce qui équivaut au cas de l'autofécondation (probabilité 0,0626).

Avec ces éléments, la probabilité observée d'apparition de plantules chlorotiques dans les M_2 issues de pollinisation libre se décompose ainsi :

$$0{,}0456 = (a * 0{,}0626) + ((1-a) * 27/363 * 0{,}0626)$$

Nous en tirons a (probabilité d'une autofécondation) = 0,707 et 1-a (probabilité d'une pollinisation croisée) = 0,293.

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Etude de la Qualité des Graines Récoltées des Sorghos de Types *Guinea* et *Caudatum*

C. LUCE et MOHAMED AG. HAMADA

IRAT/CIRAD/ICRISAT, Mali.

Résumé

Si l'influence dépressive des moisissures sur la faculté germinative et la vigueur des plantules est connue chez le sorgho, des relations nettes n'ont pas encore été établies entre certains caractères phénotypiques de la panicule ou du grain et l'incidence des moisissures. Des études conduites pendant les saisons pluvieuses 1989 et 1990 montrent une corrélation inverse significative entre la vitrosité du grain et l'indice de croissance d'une part et cet indice et la faculté germinative d'autre part. Quant à la couche brune, si elle semble n'avoir aucune influence sur l'indice de croissance, elle favorise par contre la germination chez les variétés à grain rouge. Enfin, on notera que c'est la pluviométrie entre les stades épiaison-récolte qui influence plus la pression de moisissures que la pluviométrie totale.

Introduction

Deux des principaux objectifs de sélection du sorgho du programme WASIP (West African Sorghum Improvement Program)-Mali sont la résistance aux moisissures du grain pour les sorghos de type *Caudatum* particulièrement, et l'amélioration de la productivité pour les sorghos de type *Guinea*. Par conséquent, afin de trouver des géniteurs intéressants, un certain nombre de cultivars *Caudatum* et *Guinea* de diverses provenances issues des collections mondiales de l'ICRISAT, d'introductions de différents pays de l'Afrique de l'Ouest, et de collection d'écotypes maliens, ont été testés en 1989 et en 1990, pendant la saison pluvieuse.

L'influence dépressive des moisissures du grain sur la faculté germinative des semences et la vigueur des jeunes plantules a été mise en évidence par Louvel (1983), Luce (1986, 1987) et Murty (1975). Par contre, en dehors de la corrélation négative avec la teneur en tannins ou la présence de la couche brune, des relations nettes entre certains caractères phénotypiques de la panicule ou du grain et l'incidence des moisissures n'ont pas encore été mises en évidence (Murty, 1975).

Nous avons, de ce fait, étudié, outre le comportement en végétation et le rendement, la qualité des récoltes relative à la faculté germinative, l'incidence des moisissures du grain en relation avec la précocité variétale, la vitrosité des graines et la présence ou non de couche brune au niveau du testa ont été étudiées. Le présent article résume les observations faites.

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Matériels et Méthodes

Les graines analysées ont été récoltées sur des panicules en pollinisation libre et en infestation naturelle. Les plantes se sont développées dans les conditions de pluviométrie des hivernages 1989 et 1990.

Pour l'étude de la faculté germinative, 200 graines sont mises à germer, en 4 répétions de 50 graines dans des boîtes de Pétri pendant 4 jours à 30°C . Les résultats sont exprimés en % de graines germées.

Quant à l'incidence des moisissures, on utilise le test "TGMR" de l'ICRISAT (Threshed Grain Mold Rating) avec des notations de 1 à 5 (1 = pas de moisissure et 5 = plus de 50% de la surface des graines moisie). L'observation se fait à sec sur l'aspect extérieur des graines en prenant en compte la couleur, la brillance, la présence d'un feutrage mycélien et de pycnides.

Pour la vitrosité, on utilise les normes de l'ICRISAT avec des notes de 1 à 5 (1 = texture de l'endosperme entièrement cornée, 5 textures de l'endosperme entièrement farineux).

Résultats et Discussions

Les données pluviométriques et les données du test de moisissures montrent que l'incidence moyenne des moisissures du grain dépend moins de la pluviométrie totale que de la pluviométrie utile ou celle après épiaison/floraison (Tableau 1). Le tableau 1 révèle aussi que les genres *Caudatum*, précoces ou intermédiaires sont plus infestés que les *Guinea* de même cycle.

Tableau 1. Influence de la pluviométrie sur la moisissure des grains en 1989 et 1990.

	1989	1990
Pluviométrie (mm)		
Totale	880	950
Utile	690	630
Après épiaison		
- des variétés précoces	200 - 170	180 - 120
- des variétés intermédiaires	170 - 90	120 - 30
- des variétés tardives	90 - 0	30 - 0
Moisissures (TGMR)		
Variétés précoces		
Caudatum	3.5	3.0
Guinea	2.6	2.6
Variétés intermédiaires		
Caudatum	3.3	2.6
Guinea	2.4	1.8

La faculté germinative des variétés *Guinea*, comme le montre le Tableau 2, est meilleure à celle des variétés *Caudatum*. Chez les *Guinea*, quelle que soit la précocité, la faculté germinative est toujours bonne, supérieure à 75%. Chez les *Caudatum*, ce sont les variétés qui épient au-delà de 80 jours qui présentent une faculté germinative supérieure à 75% (Tableau 2). Les écarts-types sont importants et c'est avec les variétés dont l'épiaison intervient au-delà de 80 jours qu'ils sont les plus faibles (Tableau 2).

Quant à l'incidence des moisissures, elle est moindre chez les *Guinea* que chez les *Caudatum* (entre 10% et 30% selon les cycles des variétés et l'année). Toutefois, on notera que cette incidence n'est pas négligeable chez les *Guinea* au moins pour les variétés épiant à 70 jours environ. Les moisissures diminuent avec la tardiveté des variétés (Tableau 2).

Les variétés *Caudatum* ont une vitrosité moyenne variant entre 4 et 4,5 alors qu'elle est de 1,5 à 2,5 chez les *Guinea*. Les écarts-types montrent que dans l'ensemble, la vitrosité fluctue moins chez les *Caudatum* que chez les *Guinea*, surtout avec les variétés testées en hivernage 1989 (Tableau 2).

Notons que l'incidence des moisissures et la faculté germinative évoluent en sens inverse: c'est aux scores d'incidence les plus faibles que les facultés germinatives sont les plus fortes. Il apparaît d'autre part que, plus les variétés sont tardives, plus faible est l'incidence des moisissures (Tableau 2).

Tableau 2. Comparaison entre *Caudatum* et *Guinea* pour la faculté germinative, les moisissures et la vitrosité.

Caractère évalué	Catégories de précocité (jours à 50 % épiaison)							
	< 60		60 - 69		70 - 79		> 80	
	Caud.	*Guin.*	*Caud.*	*Guin.*	*Caud.*	*Guin.*	*Caud.*	*Guin.*
Faculté germinative (%)								
1989	61,5 ± 13,7	82,4 ± 14,6	49,0 ± 18,1	77,0 ± 19,4	51,6 ± 19,8	84,8 ± 17,3	78,8 ± 15,9	88,4 ± 11,6
1990	33,4 ± 17,6	81,3 ± 12,4	51,3 ± 20,2	73,4 ± 16,4	56,7 ± 14,9	81,1 ± 12,4	77,8 ± 15,2	88,2 ± 8,8
Moisissures (test TGMR)								
1989	3,3 ± 0,75	2,8 ± 0,76	3,7 ± 0,66	2,5 ± 0,68	3,3 ± 0,71	2,4 ± 0,66	2,2 ± 0,42	2,1 ± 0,25
1990	3,1 ± 0,93	2,8 ± 0,75	2,9 ± 0,97	2,5 ± 0,71	2,6 ± 0,72	1,8 ± 0,41	2,1 ± 0,85	1,3 ± 0,50
Virtuosité (norme de 1 à 5)								
1989	4,1 ± 0,61	2,6 ± 0,96	4,3 ± 0,57	2,4 ± 1,21	4,2 ± 0,47	2,5 ± 1,14	4,0 ± 0,52	1,6 ± 1,06
1990	4,4 ± 0,74	1,7 ± 0,80	4,5 ± 0,65	2,1 ± 0,80	4,4 ± 0,64	1,9 ± 0,45	4,2 ± 0,77	1,6 ± 0,45

On note qu'en 1989, chez les *Caudatum*, les indices de vitrosité et des moisissures évoluent en sens contraire, tandis que chez les *Guinea*, les indices de vitrosité et des moisissures évoluent dans le même sens. En 1990, aucune relation n'apparaît entre les deux facteurs (Tableau 2).

En fait, l'étude statistique (Tableau 3) révèle, que pour l'hivernage 1989, ce sont les *Guinea* qui présentent entre les trois facteurs faculté germinative/moisissure/vitrosité le plus de corrélations significatives : avec une corrélation inverse entre faculté germinative et moisissure d'une part et une corrélation inverse entre indice de vitrosité et faculté germinative d'autre part. Chez les *Caudatum* les corrélations sont pour la plupart non significatives sauf entre faculté germinative et moisissures pour les variétés avec des cycles "épiaison" inférieurs à 70 jours. En 1990, chez les *Caudatum* comme chez les *Guinea*, on trouve peu de corrélations significatives.

L'absence/manque de corrélations chez les *Caudatum* impliquant la vitrosité peut s'expliquer par la faible variabilité de ce facteur : la moyenne des écarts-types est de 0,54 pour les *Caudatum* et 1,12 pour les *Guinea* en 1989; en 1990, ces valeurs sont de 0,70 pour les *Caudatum* et de 0,62 pour les *Guinea*. Une autre explication de cette situation réside dans le fait qu'en moyenne, les variétés *Caudatum* à grain rouge soient plus farineuses mais présentent une meilleure faculté germinative et moins de moisissures que les variétés à grain clair (Tableau 4).

Tableau 3. Corrélations entre faculté germinative (FG), moisissures (MOIS) et vitrosité (VITR).

Précocité (j)	Type	FG - Mois		FG - Vitre		FG - Vitre	
		1989	1990	1989	1990	1989	1990
< 60	*Caudatum*	-0,64**	-0,181	-0,005	-0,08	-0,208	0,459
	Guinea	-0,323*	-0,44	-0,569**	-0,669	0,311	0,378
60 - 79	*Caudatum*	-0,46**	-0,442*	0,205	0,207	-0,191	-0,303
	Guinea	-0,441**	-0,415	-0,798**	-0,022	0,298*	-
79 - 79	*Caudatum*	-0,101	-0,488**	-0,331*	-0,051	0,114	-0,028
	Guinea	-0,754**	-0,509	-0,683**	-0,527	-0,596**	-0,177
> 80	*Caudatum*	-0,131	-0,317	-0,256	-0,394	-0,122	-0,369
	Guinea	-0,349**	-0,025	-0,77**	-0,412**	-0,377**	-0,290

* = coefficient de corrélation significatif au seuil de 5%.
** = Coefficient de corrélation significatif au seuil de 1%.

Tableau 4. Influence de la coloration du grain sur la faculté germinative, l'incidence des moisissures et la vitrosité du grain chez les variétés *Caudatum*.

Précocité	Couleur	Faculté germinative		Moisissures		Vitrosité	
		1989	1990	1989	1990	1989	1990
< 60 j	Rouge	72,3	33,2	2,4	3,2	4,5	4,6
	Claire	56,5	34,0	3,7	3,5	4,2	3,6
60 - 69 j	Rouge	53,7	55,7	3,0	2,2	4,6	4,8
	Claire	47,7	47,7	3,8	3,2	4,2	4,3
70 - 79 j	Rouge	50,6	63,6	2,7	2,0	4,2	4,3
	Claire	51,7	55,3	3,8	2,7	4,1	4,3

La faculté germinative est donnée en % ; l'incidence des moisissures est notée de 1 (grain sain) à 5 (grain moisi); la vitrosité est notée de 1 (grain vitreux) à 5 (grain farineux).

En 1989, la recherche de la présence ou non de la couche brune des graines n'a pas été systématiquement conduite sur les 107 variétés *Caudatum* mais elle l'a été en 1990 sur les 82 variétés *Caudatum*. Il ressort du Tableau 5 que l'influence de la couche brune sur les moisissures paraît nulle. Par contre, la présence de la couche brune semble accroître la faculté germinative chez les variétés à grain clair.

Tableau 5. Influence de la couche brune du grain sur la faculté germinative et l'incidence des moisissures chez les variétés *Caudatum* (hivernage 1990).

Précocité	Couleur du grain	Faculté germinative		Vitrosité	
		Avec couche brune	Sans couche brune	Avec couche brune	Sans couche brune
60 - 69 j	Rouge	48,1	45,5	2,6	2,6
	Claire	65,0	39,7	3,7	3,6
70 - 79 j	Rouge	57,5	62,4	2,2	2,5
	Claire	63,3	51,9	2,5	2,7

La faculté germinative est donnée en % ; l'incidence des moisissures est notée de 1 (grain sain) à 5 (grain moisi).

Conclusion

Le problème de la qualité des grains du sorgho quant à leur infestation par les moisissures du grain et à leur la faculté germinative, dans les zones à pluviométrie voisine de 800 mm, se retrouve aussi bien dans les variétés de type *Caudatum* que

dans celles de type *Guinea*. A l'intérieur des deux genres les variétés à cycles courts et celles à cycles intermédiaires (50% épiaison jusqu'à environ 80 jours après le semis) sont toutes deux concernées.

L'étude de ces paramètres pendant les hivernages 1989 et 1990 montre que ce n'est pas la pluviométrie totale qui influe sur le niveau de pression des moisissures mais plutôt la pluviométrie entre les stades épiaison/floraison et la récolte.

D'une manière générale, les variétés du type *Guinea* se comportent mieux que les variétés *Caudatum* ne serait-ce qu'à cause de la plus grande vitrosité de leur grain. En effet, si les variétés testées présentent une variabilité phénotypique importante comme les *Guinea* utilisées en hivernage 1989, on constate : (i) une corrélation inverse significative entre vitrosité du grain et moisissures, (ii) une corrélation inverse significative entre moisissures et faculté germinative.

Parmi les variétés *Caudatum* testées, celles avec les moindres niveaux de moisissures sont à grain rouge, d'où un problème de sélection pour l'obtention de variétés *Caudatum* àgrain clair résistantes aux moisissures. Par ailleurs, on constate que toutes les variétés à grain rouge ne sont pas forcément résistantes à la moisissure.

La présence ou non de couche brune au niveau du testa semble n'avoir aucune influence sur l'incidence des moisissures. Par contre, chez les variétés à grain clair, on constate une meilleure faculté germinative lorsque la couche brune est présente.

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Distribution, Dégâts et Dynamiques des Populations d'*Eurystylus marginatus* Odhiambo (*Heteroptera, Miridae*), Ravageurs du Sorgho au Mali.

Y.O. DOUMBIA et G.L. TEETES.

IER Mali et Texas A&M University, USA.

Résumé

Eurystylus marginatus est la plus importante des espèces de punaise se nourrisant des grains de sorgho au Mali. L'étude de la distribution de l'insecte a permis d'identifier les principaux foyers d'infestation dans les différentes zones agricoles du pays. A la Station de Sotuba, la fluctuation des populations larvaires et imaginales est caractérisée par deux pics d'abondance, le premier en fin septembre et le second à la fin du mois d'octobre. Les résultats des enquêtes effectuées dans les champs paysans et les stations de recherche, revèlent des dégâts plus importants sur les variétés de sorgho améliorées que sur les variétés traditionnelles. Les taux d'infestation sont les plus élevés dans les stations.

Introduction

E. marginatus est considéré , ces dernières années, comme un ravageur important du sorgho au Mali et dans les autres régions soudano-sahéliennes d'Afrique de l'Ouest. Les dégâts de l'insecte avaient déjà été signalés au Mali (Doumbia et Bonzi, 1985 et 1989). l'importance économique d'*E. marginatus*, bien que réelle, n'a pas encore été étudiée dans ses détails en Afrique de l'Ouest. L'on sait cependant que les attaques du ravageur sur les grains entrainent une dépréciation de leur valeur monétaire sur le marché, que les variétés à panicule compacte sont plus infestées que les variétés à panicule lâche, et que, les variétés à glume longue sont moins affectées par les dégâts de la punaise que les variétés à glume courte (Doumbia, 1990).

La présente étude, réalisée dans le cadre des programmes collaboratifs IER/ICRISAT, IER/ROCARS et IER/INTSORMIL, fournit des informations sur la distribution, les dégâts et la dynamique des populations du ravageur en relation avec la pluviométrie, la température et l'hygrométrie.

Matériel et Méthode

Distribution et Dégâts de la Punaise en Milieu Paysan. Concernant la distribution, la technique d'étude était la même que celle utilisée par Doumbia et Bonzi (1989). Des enquêtes et des prospections ont été effectuées. Elles ont consisté en des prélèvements d'échantillons de cinq panicules de sorgho à la maturité dans des champs situés dans différentes localités du pays. Avant les prélèvements, chaque panicule était enveloppée dans un sac en polystyrène (45 x

30 cm), de manière àemprisonner les punaises, qui étaient ensuite dénombrées ; les dégâts sur les panicules étaient appréciés visuellement par l'attribution d'une note suivant une échelle en cinq points : 1) infestation des grains inférieure à 10 % ; 2) 10 à 20 % des grains infestés ; 3) 20 à 40 % des grains infestés ; 4) 40 à 60 % des grains infestés ; 5) plus de 60 % des grains infestés.

Dynamique des Populations. La fluctuation des populations larvaires et imaginales a été étudiée de 1989 à 1990 à la station de Recherche Agronomique de Sotuba. La technique consiste àprélever au hasard dix échantillons de cinq panicules chacun, sur différentes variétés de sorgho au stade grain laiteux. Comme précédemment les panicules sont d'abord enfermées dans des sacs en polystyrène puis coupées et transportées au laboratoire pour en dénombrer les punaises.

Les fréquence d'échantillonage sont de dix jours. Après la récolte du sorgho de saison, les prélèvements se poursuivent sur les rejets d'une part et la culture de contre saison mise en place à la station d'autre part.

Importance de l'espèce Eurystylus marginatus. Pour cette étude des observations ont été faites dans les parcelles de l'essai " étude du comportement de 16 génotypes de sorgho pour leur résistance à *E. marginatus* ", mis en place à Sotuba. Le dispositif expérimental est un split bloc à 3 répétitions. Quatorze jours après l'anthèse, cinq panicules par variété et par parcelle élémentaire sont prélevées dans les blocs de l'essai pour le comptage et l'identification des espèces.

Résultats et Discussions

Importance Numérique de l'Espèce. Les résultats obtenus en 1989 et 1990 sont donnés au Tableau 1. Au total 16 espèces de punaise ont été recensées sur les variétés au stade grain laiteux. Parmi ces espèces, *E. marginatus* était la plus fréquente. Les dégâts de ce ravageur avaient déjà été signalés sur le sorgho au Mali (Doumbia et Bonzi, 1985, puis 1989), au Niger (Steck *et al*, 1989) et dans le reste du Sahel (Gahukar *et al*, 1989).

Distribution Géographique. Au Mali, *E. marginatus* est très répandue dans les zones de culture du sorgho. Les principaux foyers se trouvent dans les localites de Bamako, Bankoumana, Siby et Koutiala pour la zone Sud, à Sirakorola, Kolokani, Bananba pour la zone Nord/Ouest et Ségou, Cinzana pour le Nord/Est. Dans les localités de Kogoni et Bema, les foyers sont moyennement importants. (Fig. 1).

Abondance Relative des Populations. L'abondance des populations varie selon les génotypes de sorgho, l'année et le milieu. Dans l'essai : " étude du comportement des génotyques de sorgho pour leur résistance à la punaise à Sotuba ", nous avons noté 730 individus par 5 panicules pour la variété la plus infestée (Elmota Galmi) contre 20 individus pour la moins infestée (Malisor 84-1) en 1989. En 1990 il y eu une baisse du niveau de la population avec 343 individus pour la variété la plus infestée et 19 pour la moins infestée (Tableau 2).

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Tableau 1. Principales familles et espèces d'hemiptères rencontrées dans les panicules de sorgho à Sotuba (nombre moyen d'insectes/5 panicules).

Ordre/Familles/Espèces	Nombre	d'insectes/5 panicules
	1989	1990
Alydidae		
Myrperus jaculus (Thumber)	*	*
Coreidae		
Cletus sp	*	*
Lygaeidae		
Nysus sp	*	*
Spilostetus mimus (Stäl)	*	*
Spilotostus pandurus (Scopoli)	0,9	*
Spilotostus rivularis (Germar)	-	*
Miridae		
Campilamma sp	11	3,2
Creontiades pallidus (Rambour)	2	0,3
Eurystylus marginatus (Odhiambo)	154	81
Pentatomidae		
Aethemenes cloris (Westwood)	*	0,1
Aganoscelis haroldi (Bergroth)	*	-
As pavia armigera	-	*
Calidea sp	0,1	-
Diploxis floweri (Distant)	0,3	*
Pyrrhocoridae		
Disdercus supersititiosus (Fabricius)	1	2
Rhopalidae		
Lyorhyssus hualinus (Fabricius)	-	0,16

* espèces dont le nombre est inférieur à 0,1
\- espèces absentes dans les prélèvements.

Fig. 1 : Distribution d'*E. Marginatus* Odh. au Mali

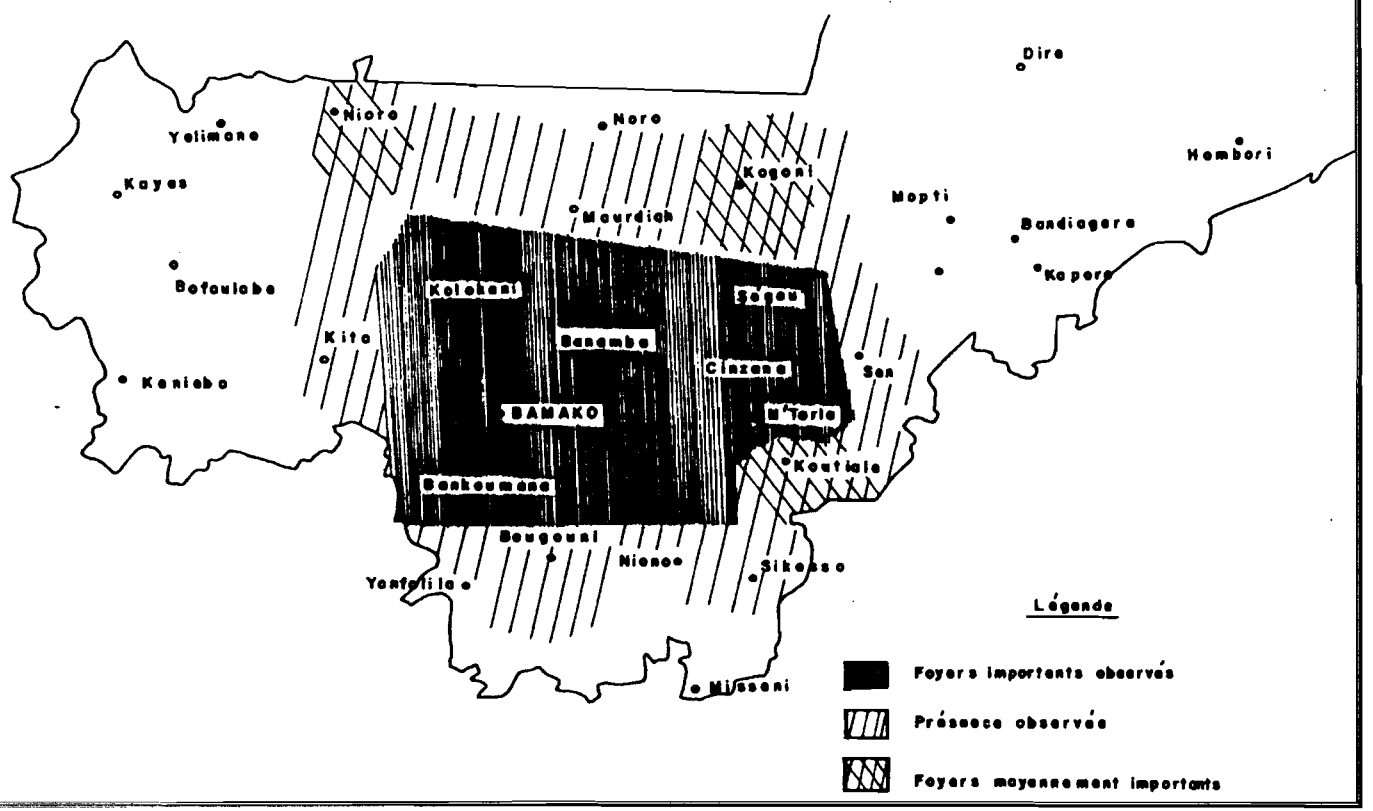


Tableau 2. Variation des populations et dégâts d'*E. marginatus* sur les variétés de sorgho à la Station de Sotuba en 1989 et 1990.

Génotypes	Nombre d'*Eurystylus* par 5 panicules						Note visuelle (2) (dégâts)		Cycle moyen semis 50 % floraison
	Larves		Adultes		Larves et adultes				
	1989	1990	1989	1990	1989	1990	1989	1990	
Malisor 84-7	21,00B	23C	43,33CDE	4B	69,33B	27B	2+0,81	1,3+0,32	68
Sureno	92,67B	40,66BC	210,00A	25B	302,67B	65,66B	4+0,00	2,4+0,00	66
ICSV-16-5	30,00B	96,33BC	12,67DE	37,33AB	42,67B	133,66B	4+0,00	2,4+0,00	61
ICSV 1063	31,67B	10C	76,00CDE	19B	107,67B	29B	4,66+0,47	2,6+0,16	68
SC 283	24,33B	16C	0,33E	5,33B	24,67B	21,33B	5+0,00	3,06+0,52	52
R 8505	38,00B	39,33BC	11,00DE	1,66B	49,00B	40,0B	3+0,00	2,46+0,09	58
Elmota galmi	704,00B	330A	26,00DE	30B	730,00A	343,33A	2+0,81	2,4+0,16	48
S 34	46,00B	124,33B	119,67	11,66B	165,67B	136B	5+0,00	2,73+0,61	69
CSM 388	27,33B	25,66BC	81,00CD	77,33A	108,33B	103B	4,33+0,47	(1)	72
SC 279	90,67B	8C	9,67DE	0,33B	100,33B	8,33B	2,33+0,47	2+0,00	47
Malisr 84-5	93,00B	35,66BC	33,33	12,66B	126,33B	48,33B	4,33+0,47	2,06+0,49	59
Malisor 84-1	92,33B	90,66BC	76,00CDE	10,00B	128,33B	100,66B	5+0,00	2,26+0,18	69
Kendé	19,67B	8,33C	0,33E	5,33B	20,00B	13,66B	2+0,00	2,2+0,16	55
Gadiaba	20,00	43,33BC	161,33AB	21,66B	181,33B	65,00B	5+0,00	3+0,43	72
	HS*	HS**	HS*	S	HS*	HS**			
	136,49 %	81,12	47,31 %	137,01	85,23 %	80,40 %			

* et ** significatifs aux seuils respectifs de P = 0,01 et P = 0,005.
(1) variété n'ayant pas pu boucler son cycle à cause de la sécheresse.
(2) Les valeurs des notes visuelles sont suivies de la déviation standard (+ SD).

Dans d'autres essais, et sur d'autres variétés des effectifs plus importants avec un maximum de 1100 individus/5 panicules ont été enregistrés à Sotuba.

Dans les champs paysans, les infestations sont plus élevées sur les variétés améliorées telles CE 151, S34, Malisor 5, comparativement aux variétés locales Gadiaba, Sakoïta et Kitaka; les taux dépassent généralement 100 individus par 5 panicules.

Le niveau d'infestation a été plus faible en 1990 qu'en 1989 (Tableau 3 et 4). Les prospections réalisées dans 7 villages situés dans le Sud de Bamako, sur des variétés locales indiquent un faible niveau des populations. Cependant, à Cinzana, des populations dont l'effectif est supérieur à 60 individus par 5 panicules ont été recensées sur les variétés locales Nguègnèblé et Nguègnèfing (Tableau 5).

Dégâts. Les dégâts de la punaise sur le sorgho sont aussi importants dans les stations que dans les champs paysans. Les notes visuelles attribuées aux différentes variétés sous infestation naturelle, se situent entre 1 à 4 à la station (Tableau 2) et entre 1 et 3 dans les champs paysans prospectés (Tableau 3).

Dynamique des Populations. En 1989, les premiers adultes d'*E. marginatus* ont été observés à Sotuba sur les panicules des sorghos vers le 15 Septembre. En 1990, il sont apparus une semaine plus tôt. La fluctuation des populations larvaires et imaginales est caractérisée par 2 pics d'abondance. Pour les deux années, le 1er pic se manifeste en fin septembre et le second à la fin du mois d'octobre (Fig. 2 et 3). Ces pics coïncident avec les stades grain laiteux et maturation des variétés à cycles moyen et tardif.

L'abondance relative des populations larvaires varie d'une année à l'autre. En 1990 nous avons noté une forte diminution des populations de la seconde génération par rapport à celle de 1989. Cela peut s'expliquer par la faible pluviométrie enregistrée dans les 2 dernières décades de septembre et par l'arrêt précoce des pluies à partir du 5 octobre. Ce déficit hydrique a eu pour conséquence une baisse de l'hygrométrie entraînant la chute du niveau de populations.

Après la récolte des sorghos de saison au mois de novembre, *E. marginatus* disparaît normalement de la station. Cependant, en 1989 et 1990, nous avons capturé quelques adultes respectivement en fin janvier et février sur des sorghos de contre saison à Sotuba.

Tableau 3. Résultats de l'enquête sur l'importance des dégâts de la punaise *Eurystylys marginatus* sur les sorgho dans quelques localités au Mali (1989).

Village Date de prélèvement	Variétés	Forme/ panicules	Nbre d'*Eurystylus*/ 5 panicules		Inci-dence	Stade phénnologique
			Adultes	Larves		
Sirado (Djidjèni) 13/10/89	Gadiaba locale	Compacte	625	132,5	2	Maturité complète
Sirakolola 17/10/89	Gadiaba	Compacte	25	12,5	2	Grain laiteux
Sikouna 22/10/89	Malisor 84-5		52,5	142,5	3	Maturité complète
	CE-151	Compacte	150	105	3	Maturité complète
Kalé 21/10/89	Malisor 84-5		7,5	25	1	Maturité complète
	CE-151	Compacte	10	25	1	Maturité complète
Njibougou 22/10/89	CE-151	Compacte	0	0	0	Maturité complète
Banamba 17/10/89	Gadiaba locale	Compacte	2,5	7,5	1	Grain laiteux
Touba 23/10/89	CE-151 locale	Compacte	100	80	3	Maturité complète
Tomba 17/10/89	Gadiaba locale	Compacte	7,5	20	1	Grain laiteux
Bouala 24/10/89	CE-151	Compacte	0	0	0	Grain laiteux
Kayo 21/10/89	CE-151	Compacte	35	77,5	2	Maturité complète
	Malisor 84-1	Compacte	5	20	1	Maturité complète
	Sakoïla locale		0	0	0	Grain laiteux
Kongola 24/10/89	S 34	Compacte	17,5	40	3	Maturité complète
	Malisor 84-8	Compacte	5	12,5	1	Maturité complète
	(1 pan.82-500)	Compacte	10	10	2	Maturité complète
	Kitala(locale)	Lâche	0	0	0	Maturité complète

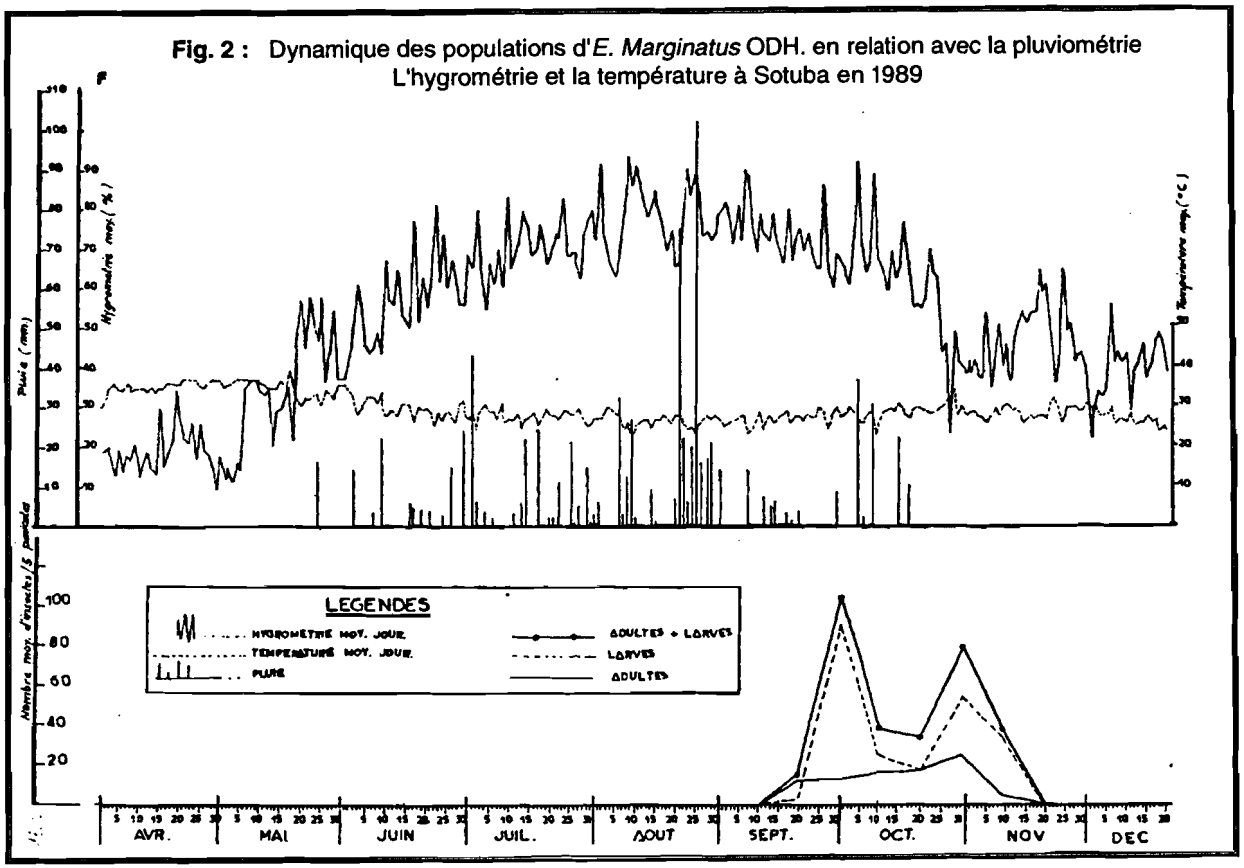
Tableau 4. Nombre d'*E. marginatus*/5 panicules et dégâts sur quelques variétés de sorgho au Mali en 1990.

Localités	Variétés	Adultes	Larves	Total	Note
Bema					
24/10/90	90 BE-SP F2-5	15	2	17	1
	90 BE-SP F2-4	6	0	6	1
	90 BE-SP F2-6	7	1	8	1
Cinzana					
25/10/90	90 BE-SP F2-5				
	Composite compacte	6	71	77	3
	VI composite compacte	27	133	160	3
Koula					
28/09/90	CE 151	22	34	56	2
Tomba					
20/10/90	Gadiaba	23	44	67	2
Galo					
20/10/90	Gadiaba	14	28	42	2

Tableau 5. Résultats de l'importance et l'incidence de la punaise *Eurystylus marginatus* sur quelques variétés dans la localité de Cinzana.

Provenance Date de prélèvement	Variétés	Forme panicule	Longueur glume	Nombre d'E./ 2 panicules		Incidence	Stade phénologique
				Adultes	Larves		
Cinzana Champs Mamadou Diallo 25/10/90	N'guegneble	Lâche	Longue	15	52,5	2	Maturité
Cinzana Test multilocal 25/10/90	N'guegneble	Lâche	Longue	15	60	1	Maturité
Windia	CSM-219	Lâche	Longue	15	97,5	3	Maturité
Champ paysan	N'guegneble	Lâche	Longue	22,5	37,5	2	Maturité

Fig. 2 : Dynamique des populations d'*E. Marginatus* ODH. en relation avec la pluviométrie
L'hygrométrie et la température à Sotuba en 1989



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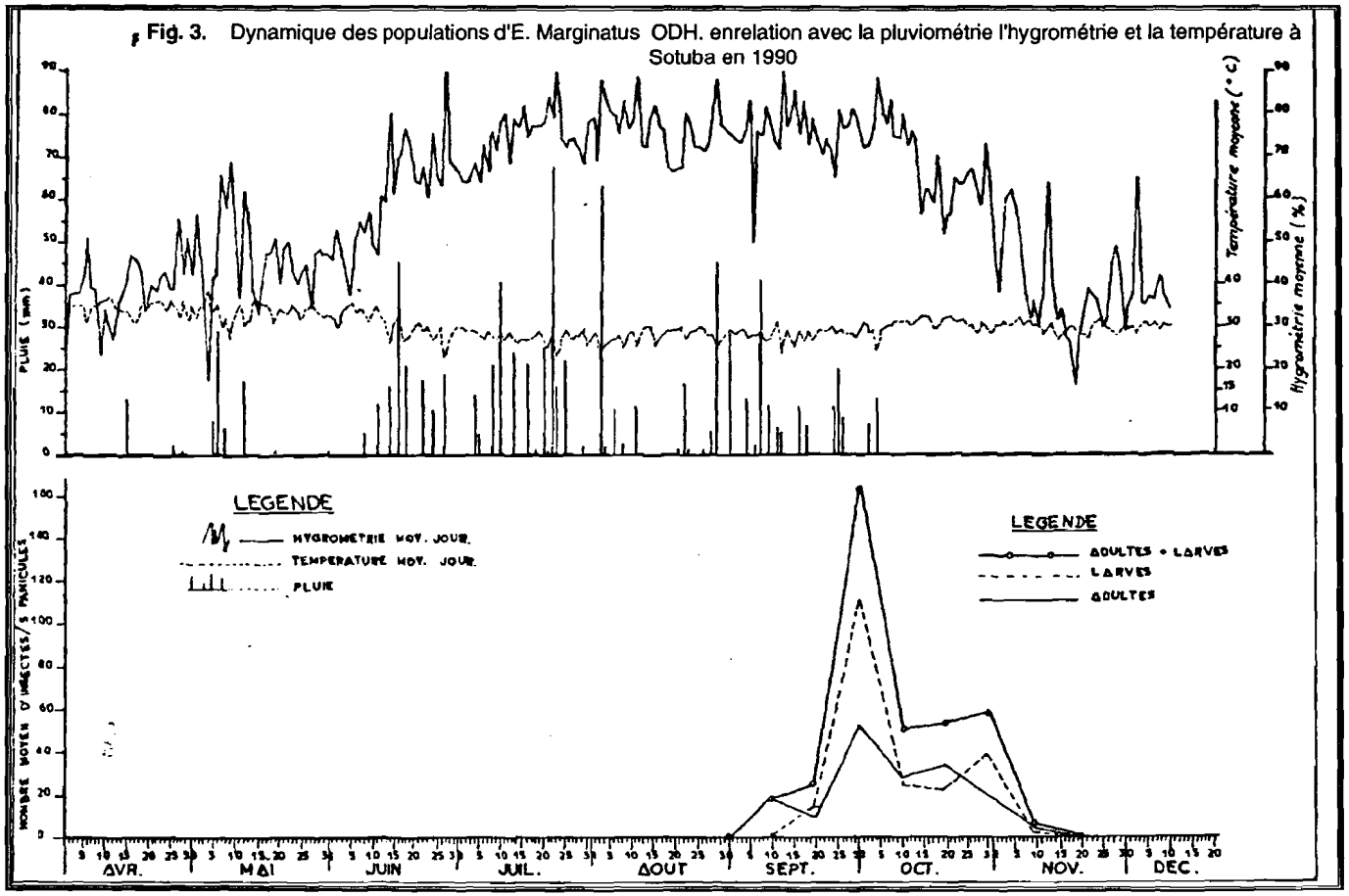

Fig. 3. Dynamique des populations d'E. Marginatus ODH. enrelation avec la pluviométrie l'hygrométrie et la température à Sotuba en 1990

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Réaction de Variétés de Sorgho aux Attaques de la Punaise des Panicules *Eurystylus immaculatus* Odhiambo (Heteroptera, Miridae) en Afrique de l'Ouest

A. RATNADASS, K.V. RAMAIAH, H.C. SHARMA, B. CISSE

ICRISAT - WASIP, Bamako, Mali.

Résumé

Les punaises du genre *Eurystylus* sont devenues les ravageurs principaux du sorgho en Afrique de l'Ouest. La gravité de l'infestation du sorgho et l'analyse de la sensibilité de différentes variétés au Mali et au Burkina Faso ont fait l'objet de la présente étude. On a montré que les panicules peuvent héberger une cinquantaine de punaises chez les variétés résistantes Malisor 84-7 et CSM 388 alors que ce nombre excède 300 chez les variétés sensibles. L'infestation cause une perte quantitative et qualitative pour les variétés sensibles, se traduisant par une réduction de 50% du poids de 100 grains chez S34, une baisse de vitroisité 3 fois supérieure chez S34 que chez Malisor 84-7. La baisse de rendement au décorticage est 30% chez S34 et seulement 5% chez Malisor 84-7. La stabilité de la résistance de Malisor 84-7 a été confirmée et mérite que l'on en détermine le mécanisme.

Introduction.

Les punaises du genre *Eurystylus* sont devenues depuis quelques années les ravageurs principaux du sorgho en Afrique de l'Ouest (Mac Farlane, 1984; Doumbia et Bonzi, 1985 et 1989, Gahukar *et al*, 1989; Nwanze, 1985; Sharma, 1985, 1986 et 1989; Steck *et al*, 1989). Au Mali et au Burkina Faso, *E. immaculatus* semble être l'espèce dominante. Les adultes pondent leurs oeufs à l'intérieur de la graine laiteuse et les larves qui en naissent, en suçant ces graines, causent un important dommage tant quantitatif que qualitatif sur les sorghos. Aussi paraît-il urgent, étant donné la place de la céréale dans l'alimentation des populations des pays concernés, de pouvoir mesurer d'une part la sensibilité de l'éventail de sorgho aux ravageurs et d'identifier les sources de résistance et d'autre part de mesurer les dégâts quantitatifs et qualitatifs occasionnés par les punaises. Ainsi l'étude dont les résultats sont présentés ici met en évidence la gravité de l'infestation du sorgho par la punaise des panicules au Mali et au Burkina Faso. Elle met aussi en évidence d'importantes différences de sensibilité entre les variétés testées.

Matériels et Méthodes

Le matériel végétal consiste en 12 variétés sélectionnées notamment à partir des essais d'amélioration conduits par le programme régional de l'ICRISAT depuis 1985 au Mali et au Burkina Faso, à savoir : ICSV 16-5 BF, ICSV 1001 BF (Framida), ICSV 1143 BF, ICSV 1063 BF, ICSV 1166 BF, ICSV 1122 BF, du programme bilatéral ICRISAT-Mali : CSM 63, CSM 388, Malisor 84-7 (ICRISAT Sahelian

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Centre, 1986, 1987, 1988, 1989 et 1990), d'une variété du Centre de l'ICRISAT en Inde : ICSV 2 IN (SPV 35), d'une variété locale malienne de type Durra à panicule crossée (Gadiaba), et d'une variété productive servant de témoin sensible (S 34). Malisor 84-7 (à panicule très compacte) et CSM 388 (Guinea à panicule lâche) tiennent respectivement lieu de témoin résistant et de témoin local. Ces variétés constituent une pépinière avancée de criblage pour la résistance à *E. immaculatus*.

L'essai a été conduit dans trois localités (Samanko et Cinzana au Mali, Farako-Bâ au Burkina Faso) et pendant deux hivernages consécutifs, avec deux dates de semis (DS) dans chaque localité : des DS normales (comprises entre le 5 et le 15 Juillet 1989, et le 23 Juin et le 7 Juillet 1990) et des DS différées de deux à trois semaines (21 au 26 Juillet 1989, 13 au 28 Juillet 1990). L'objectif était d'obtenir une infestation naturelle maximale au moins à l'une des deux dates.

Le dispositif était un Bloc de Fisher avec trois répétitions (parcelles de trois lignes de 5,00 m à Samanko, deux à Cinzana et Farako-Bâ en 1989, de quatre lignes dans les trois localités en 1990; écartement de 0,75 m).

Le nombre de punaises a été déterminé par échantillonnage de cinq panicules exposées à l'infestation naturelle par parcelle au stade grain laiteux/pâteux (soit 20 jours après floraison). Ces panicules étaient enfermées dans un sac de polyéthylène et secouées afin d'en déloger tous les insectes, qui étaient ensuite comptés au laboratoire.

Pour le criblage, deux panicules par parcelle ont été encagées au début de la floraison, et infestées à la fin de celle-ci avec 40 adultes par panicule (Sharma, 1985). Les adultes sont récoltés avec un aspirateur à bouche dans les champs de sorgho environnants. Vingt (20) jours après, un coton imbibé d'acétate d'éthyle était introduit dans la cage et, celle-ci retirée, la panicule est secouée dans un sac de polyéthylène et les insectes morts comptés au laboratoire.

Deux autres panicules par parcelle étaient protégées, en 1989, avec des sachets d'autofécondation en papier sulfurisé, et en 1990, avec les mêmes cages que celles servant à l'infestation, pour servir de témoins protégés à celles soumises à l'infestation naturelle et artificielle.

Les dégâts de punaises ont également fait l'objet d'une notation visuelle à maturité sur une échelle de 1 à 9 où 1 correspondait à tous les grains bien développés, avec seulement quelques piqûres d'alimentation, et 9 à la plupart des grains non développés et invisibles en dehors des glumes du fait des attaques de punaises.

Les autres paramètres mesurés ont été : le poids de 1000 grains, la proportion de grains à faible densité déterminée par flottaison des grains sur une solution de nitrate de sodium de densité spécifique 1,205, le pourcentage de germination et enfin la vitrosité du grain sur une échelle de 1 à 5 où 1 représente le grain dur et vitreux et 5, le grain tendre et farineux.

Sur certains échantillons, les mesures suivantes aussi ont été réalisées par le Laboratoire de Technologie Céréalière de Sotuba : rendement au décorticage

(Reichert *et al.*, 1982) et qualité du tô (Da *et al.*, 1982) apprécié par sa consistance et sa couleur, sur une échelle de 1 à 5 où 1 est le bon tô d'aspect clair et granuleux et 5, le tô brun foncé et collant, à rejeter.

Résultats et Discussions.

Les nombres de punaises relevés sur les différents essais, en infestation naturelle indiquent que Malisor 84-7 et CSM 388 étaient les variétés les moins infestées avec respectivement 51 et 62 punaises par cinq panicules alors que les autres variétés hébergaient plus de 300 punaises (Tableau 1). Ce résultat est partiellement confirmé par les chiffres obtenus sous infestation artificielle qui montrent que la résistance de Malisor 84-7 n'est pas le seul fait d'un mécanisme de non-préférence ou d'évasion.

Les notes visuelles relevées sous infestation naturelle sur les 12 essais identifient CSM 388 et Malisor 84-7 comme les seules variétés résistantes en référence à ce critère dont les valeurs n'excèdent jamais respectivement 3,3 et 4,0 alors qu'elles atteignent 7,7 pour Framida et 7,3 pour S 34 (Tableau 2), résultat confirmé par les données obtenues sous infestation artificielle.

L'infestation des punaises cause une perte à la fois quantitative et qualitative pour les variétés sensibles, alors que les variétés résistantes sont beaucoup moins affectées (Tableaux 3-6). Ainsi, la réduction du poids de 1000 grains est de l'ordre de 50 % pour S 34 alors qu'elle n'est pas significative pour Malisor 84-7 ; la baisse de rendement au décorticage est respectivement supérieure à 30 et de 5 % seulement. La diminution de la vitrosité est trois fois plus importante chez S 34 que chez Malisor 84-7. En revanche, l'attaque par les punaises ne se traduit pas toujours par une réduction de la qualité du tô préparé avec la fraction récupérée après décorticage.

Dans le cas de la variété S 34, les coefficients de corrélation entre la note visuelle et le poids de 1000 grains, la vitrosité, le pourcentage de germination et le pourcentage de flottaison sont respectivement de -0,558, 0,616, -0,725 et 0,743, tous significatifs au seuil de 0,1 %. En revanche, dans le cas de Malisor 84-7, il n'y a pas de corrélation significative entre note visuelle et les autres paramètres mesurés.

Tableau 1. Populations de punaises observées sous infestation naturelle sur les 12 variétés de sorgho de la pépinière avancée de criblage pour la résistance à la punaise des panicules à Samanko (SA), Cinzana (CZ) et Farako-Bâ (BF), en hivernages 1989 et 1990 (1)

Variété	Nombre de punaises par 5 panicules (2)									
	Hivernage 1989				Hivernage 1990					
	SA (DS1)	SA (DS2)	CZ (DS1)	FB (DS1)	SA (DS1)	SA (DS2)	CZ (DS1)	CZ (DS2)	FB (DS1)	FB (DS2)
ICSV 16-5 BF	846(28,6)	54(6,3)	42(6,4)	314(17,5)	174(13,1)	187(13,4)	103(10,2)	28(4,9)	0(0,3)	17(3,8)
Franida	418(20,3)	43(6,5)	132(10,7)	287(16,9)	145(11,7)	98(9,2)	50(7,1)	50(6,9)	1(0,8)	53(7,0)
ICSV 1143 BF	826(28,6)	59(7,7)	52(6,7)	391(19,7)	324(17,9)	163(16,7)	142(11,4)	71(7,9)	1(0,7)	9(2,8)
ICSV 1063 BF	786(26,3)	42(6,3)	34(5,7)	255(15,5)	361(18,6)	178(12,3)	67(8,0)	67(6,8)	1(0,7)	55(7,2)
ICSV 2 IN	297(17,1)	29(5,3)	132(11,4)	139(11,4)	26(5,1)	283(16,7)	117(10,5)	58(6,6)	0(0,3)	79(8,6)
ICSV 1166 BF	664(25,7)	22(4,5)	50(6,6)	318(17,7)	226(14,8)	150(12,3)	248(15,0)	14(3,0)	7(2,1)	16(3,9)
ICSV 1122 BF	358(17,3)	31(5,3)	152(11,0)	93(9,2)	67(8,0)	143(11,9)	167(12,4)	19(4,2)	0(0,3)	41(6,2)
Gadiaba	48(6,2)	30(5,2)	24(4,5)	34(5,7)	155(12,4)	385(19,4)	89(9,0)	23(4,8)	1(0,6)	14(3,7)
CSM 63	406(20,1)	14(3,1)	74(8,2)	73(8,1)	9(2,9)	43(6,1)	35(5,9)	44(6,6)	2(1,3)	3(1,8)
Temoins										
S34 (sensible)	369(18,9)	35(5,8)	26(4,4)	237(14,3)	95(9,7)	77(8,7)	95(9,3)	32(5,6)	3(1,8)	71(8,2)
Malisor 84-7 (resistant)	51(6,5)	13(3,5)	3(1,8)	40(5,7)	26(4,9)	47(6,5)	24(4,9)	4(1,8)	0(0,3)	19(4,2)
CSM 288 (local)	45(6,5)	15(3,8)	10(2,9	24(4,8)	62(7,4)	55(7,1)	0(0,3)	3(1,3)	4(2,1)	9(2,5)
Test F (3)	(***)	N.S.	(**)	(***)	(***)	(***)	(***)	n.s.	n.s.	(**)
Moyenne	(18,5)	(5,3)	(6,7)	(12,3)	(10,5)	(11,3)	(8,7)	(5,0)	(0,9)	(5,0)
CV (%)	(27,4)	(39,7)	(42,0)	(27,4)	(23,5)	(27,5)	(30,7)	(52,5)	(86,8)	(37,6)
ETM	(±2,88)	(±0,68)	(±1,62)	(±1,92)	(±1,43	(±1,81)	(±1,54)	(±1,52)	(±0,47	(±1,08)

(1) Dispositifs en blocs complets à trois répétitions pour les trois localités, deux dates de semis (DS1 et DS2) et deux années.

(2) La variabilité a été analysée après transformation $\sqrt{X}$. Les valeurs entre parenthèses sont les valeurs transformées. Les valeurs maximales observées sur les 10 essais pour chaque variété sont indiquées en caractère gras.

(3) Test F : n.s. non significatif au seuil de 5% ; ** significatif au seuil de 1% ; *** significatif au seuil de 0,1%.

Tableau 2. Notation visuelle de l'attaque par les punaises sous infestation naturelle des 12 variétés de la pépinière avancée de criblage pour la résistance à la punaise des panicules à Samanko (SA), Cinzana (CZ) et Farako-Bâ (BF) en hivernage 1990 (1).

	Note visuelle (2)											
Variété	SA (DS1)	SA2	CZ1	CZ2	FB1	FB2	SA1	SA2	CZ (DS1)	CZ (DS2)	FB (DS1)	FB (DS2)
ICSV 16-5 BF	4,0	5,7	6,3	4,7	4,7	4,3	2,8	2,8	3,0	2,0	2,3	2,7
Framida	4,0	7,7	7,0	5,7	5,0	5,3	3,8	4,0	3,7	4,0	4,3	4,0
ICSV 1143	4,0	6,0	6,0	4,3	4,7	4,3	3,2	3,7	3,0	3,0	2,3	3,3
ICSV 1063	4,7	5,3	6,3	4,3	4,3	5,0	3,3	3,5	3,0	3,3	3,7	4,0
ICSV 2 IN	4,0	6,0	7,0	4,7	6,0	4,7	3,7	3,2	3,0	3,0	3,0	4,3
ICSV 116	3,7	6,0	6,3	3,7	5,0	4,0	3,0	3,2	2,0	3,3	1,3	3,3
ICSV 1122	5,3	6,0	7,0	5,0	7,0	6,7	3,5	3,7	2,0	4,0	3,7	5,0
Gadiaba	6,7	6,0	5,7	6,0	5,0	4,3	3,2	2,8	3,0	2,7	3,0	4,0
CSM 63	2,7	4,7	4,3	2,7	3,0	3,0	2,5	2,5	3,0	2,3	2,0	2,3
Témoins												
S34 sensible	5,3	7,0	6,7	7,3	5,3	7,3	3,8	6,3	2,7	4,7	2,3	4,0
Malisor 84-7 (résistant)	3,3	2,0	4,0	2,3	3,7	3,3	2,7	2,0	1,7	1,7	1,7	2,7
CSM 388(local)	2,7	2,7	3,3	3,0	2,3	2,0	1,8	1,8	1,0	1,0	1,7	1,7
Test F(3)	***	***	***	***	***	***	***	***	***	***	***	***
Moyenne	4,2	5,4	5,8	5,8	4,5	4,7	4,5	3,1	2,6	2,6	2,6	3,4
CV (%)	15,8	21,8	14,8	14,8	18,9	18,2	15,4	12,6	18,9	18,1	25,3	23,0
ETM	±0,38	±0,68	±0,50	±0,50	±0,49	±0,49	±0,40	±0,23	±0,35	+0,35	±0,38	±0,46

(1) Dispositifs en blocs complets à trois répétitions pour les trois localités, deux dates de semis (DS1) et (DS2) et deux années.

(2) Notation visuelle sur une échelle de 1 à 9 ou 1 = grains avec seules quelques piqûres d'alimentation et 9 = plus de 75% des grains fletris. Les valeurs maximales observées sur les 10 essais pour chaque variété sont indiquées en caractères gras.

(3) Test F : ** significatif au seuil de 1% ; *** significatif au seuil de 0,1%.

Tableau 3. Effet de l'infestation par les punaises sur le poids de 1000 grains, la vitrosité, les pourcentages de germination et de flottaison (proportion des grains à faible densité de quatre variétés de la pépinière avancée de criblage pour la résistance à la punaise des panicules à Cinzana en hivernage 1989 (1)

Variété essai	Gadiaba		S34		Malisor 84-7	CSM 388	
	DS1	DS2	DS1	DS2	DS1	DS1	DS2
Poids (1000 gr. p(2)	43,7 + 4,8(6)	43,1 ± 2,8(6)	24,6 ± 2,1(6)	22,4 ± 2,9(4)	14,7 ± 1,9(6)	21,6 ± 0,7(5)	24,9 ± 2,6(6)
A(2)	31,1 ± 1,7(9)	26,7 ± 0,3(6)	18,1 ± 31,2(9)	8,8 ± 3,8(6)	13,9 ± 0,5(6)	21,2 ± 1,0(9)	18,9 ± 2,9(6)
Signification (3)	***	***	***	***	n.s.	n.s.	*
Vitrosité 4 p(2)	3,1 ± 0,3(6)	3,0 ± 2,9(6)	2,9 ± 0,1(4)	2,9 ± 0,2(6)	1,9 ± 0,4(6)	1,5 ± 0,3(5)	1,3 ± 2,9(6)
A(2)	4,7 ± 0,2(9)	4,8 ± 0,3(6)	4,7 ± 0,1(9)	4,6 ± 0,2(6)	2,4 + 0,3(6)	1,4 ± 0,1(9)	2,0 ± 2,9(6)
Signification (3)	***	***	***	***	*	n.s.	***
% germination p(2)	93,3 ± 3,1(3)	90,3 ± 2,9(2,9(6)	98,7 ± 1,2(3)	96,0 ± 1,2(6)	94,7 ± 2,4(6)	99,3 ± 1,2(3)	97,7 ± 1,9(6)
A(2)	60,0 ± 22,5(3)	13,3 ± 23,1(3)	71,3 ± 12,1(3)	45,3 ± 23,8(3)	66,7 ± 23,9(3)	84,7 ± 16,3(3)	58,0 ± 43,9(3)
Signification (3)	*	***	***	***	*	n.s.	n.s.
% flottaison(5) p(2)	15,9 ± 9,2(6)	23,9 ± 11,7(6)	11,3 ± 4,9(6)	9,5 ± 2,2(4)	6,6 ± 3,3(6)	2,8 ± 3,3(5)	1,1 ± 1,0(6)
A(2)	80,4 ± 26,5(9)	84,7 ± 18,0(6)	73,5 ± 17,0(9)	98,5 ± 2,3(6)	25,1 ± 6,5(6)	3,9 ± 3,1(9)	4,7 ± 5,3(6)
Signification (3)	***	***	***	***	***	n.s.	n.s.

(1) Valeurs exprimées sous la forme : Moyenne ± écart-type (nombre d'observations entre parenthèses)

(2) P : grains provenant de panicules protégées ; A : grains provenant de panicules soumises à l'infestation artificielle sous cage avec 40 adultes pendant 20 jours.

(3) Signification du test unilatéral de comparaison des moyennes (valeurs non transformées) par la méthode des échantillons indépendants : n.s. non significatif au seuil de 5% ;
* significatif au seuil de 5% ; ** significatif au seuil de 1% ; *** significatif au seuil de 0,1%.

(4) Sur une échelle de 1 à 5 où 1 = grain dur et vitreux et 5 = grain tendre et farineux.

(5) Dans une solution de NaNo3 de densité spécifique 1,205.

Tableau 4. Effet de l'infestation par les punaises sur le rendement au décorticage et la qualité du tô (consistance et couleur) de quatre variétés de la pépinière avancée de criblage pour la résistance à la punaise des panicules à Cinzana en hivernage 1989 (deux date de remise : DS1 et DS2)

Variété		Gadiaba		S 34		Malisor 84-7	CSM 388	
Essai		(DS1)	(DS2)	(DS1)	(DS2)	(DS2)	(DS1)	(DS2)
Rendement au	p(2)	79,4 ± 1,4	75,9 ± 1,0	76,7 ± 0,7	81,7 ± 0,8	78,1 ± 0,1	88,7 ± 0,6	89,5 ± 0,1
décorticage (%)	N(2)	43,7 ± 0,3***	44,4 ± 1,1***	42,1 ± 2,6	51,6 ± 1,2	73,0 ± 1,6**	85,7 ± 0,3**	85,2 ± 0,4***
	A(2)	44,5 ± 1,1***	35,7 ± 5,4**	43,7 ± 0,2	-	72,7 ± 0,5***	86,1 ± ,1**	84,5 ± 0,2***
Consistance du	p(2)	1,2 ± 0,3	1,2 ± 0,3	1,2 ± 0,3	1,5 ± 0,5	1,2 ± 0,3	1,2 ± 0,3	1,3 ± 0,3
tô (manuelle)4	N(2)	3,3 ± 0,6***	2,3 ± 0,3**	2,8 ± 0,3	2,0 ± 0,0 n.s	1,3 ± 0,3 n.s.	1,3 ± 0,3 n.s	1,5 ± 0,0 n.s.
	A(2)	-	1,0	1,0	-	1,2 ± 0,3 n.s.	1,7 ± 0,3 n.s	1,7 ± 0,3 n.s.
Couleur du tô	p(2)	0,3	1,0	1,0	1,0	1,0	1,0	-
	N(2)	5,0	1,0	1,,0	1,0	1,0	1,0	1,0
	A((2)	5,0	1,0	1,0	-	1,0	2,0	2,0

(1) Valeurs exprimées sous la forme : Moyenne ± écart-type (trois répétitions); - : donnée manquante

(2) P : Grains provenant de panicules protégées ; N : grains provenant de panicules soumises à l'infestation naturelle ; A : grains provenant de panicules soumises à l'infestation artificielle sous cage avec 40 adultes pendant 20 jours.
Signification au test unilatéral de comparaison des moyennes observées sur panicules infestées/témoins protegé par la méthode des échantillons indépendants : n.s. non significatif au seuil de 5% ; ** significatif au seuil de 1% ; *** significatif au seuil de 0,1%.

(3) Pourcentage de récupération au TADD.

(4) Sur une échelle de 1 à 5 où 1 = tô de bonne qualité et 5 = tô à rejeter.

Tableau 5. Effet de l'infestation par les punaises sur le poids de 1000 grains et la vitrosité des 12 variétés de sorgho de la pépinière avancée de criblage pour la résistance à la punaise des panicules en hivernage 1990 (2ème DS)(1).

Variété	Poids de 1000 grains (g) (2)			Vitrosité (2)		
	P	N	A	P	N	A
ICVS 16-5 BF	21,5	21,4 n.s.	20,2 n.s.	2,0	3,2 n.s.	2,8n.s.
Framida	27,7	18,0*	22,4**	2,4	3,6***	3,3*
ICSV 1143 BF	28,5	22,6 n.s.	23,1**	1,7	2,6n.s.	3,1*
ICSV 1063 BF	23,6	20,4 n.s	22,8 n.s.	1,7	3,1**	2,7***
ICSV 2 IN	19,5	19,5 n.s.	16,8 n.s.	1,9	3,1*	3,3***
ICSV 1166 BF	24,1	19,6*	19,4 n.s.	1,4	3,0**	2,9***
ICSV 1122 BF	11,3	13,9 n.s.	9,3 n.s.	2,4	3,2n.s.	3,5n.s.
Gadiaba	44,9	38,0 n.s.	32,1 n.s.	2,0	3,0**	3,5 n.s.
CSM 63	18,3	19,9 n.s.	14,5*	1,7	2,6*	2,9 n.s.
Témoins						
S 34 (sensible)	24,5	12,3***	13,8*	2,0	3,7*	3,6 n.s.
Malisor 84-7 (résistant)	15,6	16,8 n.s.	38,0 n.s.	1,5	1,7**	2,1*
CSM 388 (local)	16,5	20,9	19,9 n.s.	1,1	1,5n.s.	2,0 n.s.
Test F(3)	***	***	***	*	***	**
Moyenne	23,0	20,3	19,1	1,8	2,9	3,0
CV %	11,9	9,1	16,1	22,4	12,0	16,5
ETM	±1,58	± 1,07	±1,78	± 0,23	± 0,20	± 0,28

(1) Dispositif en blocs complets à trois répétitions

(2) P : grains provenant de panicules protégées ; N : grains provenant de panicules soumises à l'infestation naturelle ;
A : grains provenant de panicules soumises à l'infestation artificielle sous cage avec 40 adultes pendant 20 jours ;
Signification du test unilateral de comparaison des moyennes par la méthode des couples : n.s. Non significatif au seuil de 5% ; * significatif au seuil de 5% ; ** significatif au seuil de 1% ; *** significatif au seuil de 0,1%.

(3) Signification du test F : cf (2).

Tableau 6. Effet de l'infestation par les punaises sur les pourcentages de germination et de flottaison (proportion de grains à faible densité) des 12 variétés de sorgho de la pépinière avancée de criblage pour la résistance à la punaise des panicules à Samanko en hivernage 1990 (2ème DS)(1).

Variété	Germination (%)(2)			Flottaison (%)(2)		
	P	N	A	P	N	A
ICSV 16-5 BF	95,0(77,1)	86,3(68,5)*	82,0(65,7) n.s.	5,3(13,3)	46,7(43,9) n.s.	28,7(31,2) n.s.
Framida	91,0(73,0)	59,7(51,0)*	78,0(62,0)*	46,0(42,6)	99,6(87,8)*	80,0(65,6)*
ICSV 1143 BF	95,7(78,1)	91,0(72,7)n.s.	86,3(68,5)*	7,3(14,9)	65,6(54,1)**	48,2(43,9)*
ICSV 1063 BF	91,7(73,8)	79,3(63,4)*	73,7(59,2) n.s.	13,8(21,1)	76,0(60,7)**	42,1(40,4) n.s.
ICSV 2 IN	91,3(73,2)	80,7(64,0)**	67,0(56,0) n.s.	13,8(20,9)	34,4(35,8) n.s.	51,3(46,1)*
ICSV 1166 BF	94,7(76,7)	81,0(64,2)***	78,3(62,8)*	4,9(12,6)	71,6(57,1)**	60,0(50,9)**
ICSV 1122 BF	84,5(68,0)	68,0(56,0)*	56,7(48,9) n.s.	30,2(42,0)	62,9(52,6) n.s.	68,0(55,8) n.s.
Gadiaba	77,7(62,4)	67,3(55,4) n.s.	44,3(41,7) n.s.	25,8(29,5)	84,9(67,3)*	70,0(59,1) n.s.
CSM 63	92,0(79,7)	90,0(71,6) n.s.	60,0(51,2) n.s.	13,8(21,7)	26,7(30,9) n.s.	65,3(56,0) n.s.
Témoins						
S 34 (sensible)	82,7(65,5)	44,3(41,3)*	48,0(33,9)*	31,1(33,9)	99,1(85,7)***	80,2(64,8)*
Malisor 84-7 (résistant)	91,7(73,6)	79,7(63,5) n.s.	90,7(72,2) n.s.	8,9(15,6)	15,3(22,6) n.s.	10,2(18,6) n.s.
CSM 388	99(5(87,7)	97,7(81,9) n.s.	92,0(73,2) n.s.	0,4(1,3)	2,9(7,7) n.s.	6,9(13,8) n.s.
Test F	(***)	(***)	(**)	(***)	(***)	(**)
Moyenne	(73,6)	(62,8)	(58,0)	(22,5)	(50,6)	(45,5)
CV %	(5,9)	(9,9)	(18,2)	(38,4)	(17,7)	(31,3)
ETM	(± 2,51)	(± 3,60)	(± 6,10)	(± 4,98)	(± 5,18)	(± 8,23)

(1) Dispositifs en blocs complets à trois répétitions

(2) P : grains provenant de panicules protégées ; N : grains provenant de panicules soumises à l'infestation naturelle ; A : grains provenant de panicules soumises à l'infestation artificielle sous cage avec 40 adultes pendant 20 jours.
Signification du test unilatéral de comparaison des moyennes par la méthode des couples : n.s. non significatif au seuil de 5% ; * significatif au seuil de 5% ; ** significatif au seuil de 1% ; *** significatif au seuil de 0,1%.

(3) Signification du test F : cf (2)

Ces résultats mettent nettement en évidence la gravité du problème lié à l'infestation du sorgho par la punaise des panicules dans les régions étudiées et son incidence économique. Les hivernages 1989 et 1990 ont été caractérisés par des populations très importantes de ce ravageur à Samanko, ce qui en fait alors un site idéal pour le criblage du sorgho pour la résistance à cet insecte, en infestation naturelle comme artificielle. Une meilleure connaissance de la dynamique des populations d'*E. immaculatus* sur les différentes stations constituerait cependant un facteur essentiel d'efficacité du criblage en conditions d'infestation naturelle, qui reste le seul moyen d'évaluation à grande échelle, la technique d'infestation artificielle en cage présentant des contraintes évidentes. La vérification en conditions de non-choix étant cependant indispensable pour confirmer la résistance, cette technique doit être améliorée pour en accroître l'efficacité et le rendement. De nouveaux sacs et de nouvelles cages qui n'affectent ni le développement des grains ni celui des insectes devraient être conçus. Une bonne connaissance de la biologie du ravageur permettrait d'en envisager l'élevage, et réduire ainsi considérablement la pénibilité du travail d'infestation artificielle. L'échelle de notation utilisée s'est révélée satisfaisante. C'est un critère à la fois plus simple d'utilisation et plus fiable que l'échantillonnage des populations.

Si cette étude a mis clairement en évidence d'importantes différences dans la sensibilité des différentes variétés aux attaques d'*E. immaculatus*, elle a surtout permis de confirmer la résistance de Malisor 84.7, CSM 388 ou la sensibilité de S34 utilisées comme des témoins dans l'infestation de la punaise. La résistance de Malisor 84-7 s'est révélée stable à travers les localités, années et dates de semis.

L'identification de sources de résistance doit donc rester une priorité des programmes d'amélioration du sorgho. En effet, mis à part les sorghos Guinea dont les caractéristiques de la panicule et des glumes peuvent expliquer dans une large mesure la résistance, parmi les variétés à panicules compactes, Malisor 84-7 est la seule source prometteuse. Du fait de son haut niveau de résistance, elle est d'ailleurs à l'origine de plusieurs croisements avec des variétés productives, dont les descendances sont en cours d'évaluation.

D'importants efforts de recherches doivent également être consacrés à l'étude du mécanisme de résistance de la variété Malisor 84-7, pour bien orienter le criblage. Une fois identifiées d'autres variétés présentant le même type et niveau de résistance, pourront être envisagées des études sur la génétique de sa transmission, dont la compréhension constitue le préalable indispensable à la mise en oeuvre des stratégies de sélection les plus adaptées.

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Chemical Control of Sorghum Stem Borers in the Nigerian Savanna.

IGNATIUS I. UVAH and OLUPOMI AJAYI.

Department of Crop Protection, Institute for Agricultural Research, Samaru, Ahmadu Bello University, Zaria, Nigeria.

Abstract

A total of eight seed and soil-applied chemicals (Carbofuran 3 & 5G, terbufos 5G, bifenthrin 10 ec, carbofuran 35 ST, Marshal 25 ST, carbaryl 85 wp, Apron-lus 50DS and Fernasan D) were screened for their efficacy for control of the sorghum stem borer (Busseola fusca Fuller) in a 5-year study from 1986-90. Seed dressings were applied to seed, granules were applied to the furrow at sowing and/or in bands as side dressings after seedling emergence whilst diluted foliar emulsifiable concentrates were dispensed from knapsack sprayers. The results indicated that two sequential applications of carbofuran, either as granules (at 1.0 kg a.i,/ha) at sowing followed at 45 days later by granules or as seed treatment (at 0.5 kg a.i./ha) followed by granules at 30 days after sowing, gave adequate control of the stem borer leading to significantly higher sorghum grain yield in years of high borer infestations. Although Apron-plus 50DS often gave reductions in borer infestations and high sorghum yields, it also failed to control a high infestation in 1990 as did carbofuran 35 ST,

Fernasan D and Marshal 25 ST. These seed dressings, except Marshal, consistently gave better plant establishment than the control.

Introduction

Sorghum is an important source of energy in the diets of the peoples of many nations in tropical and sub-tropical regions of the world. World production is estimated at 63 millions tonnes on some 47 million hectares annually (Sehu Reddy, 1989). Estimates for annual production in Nigeria are 9 million tonnes on over 6 million hectares (IAR, 1984). Under optimum management, yields of up to 3,000 kg/ha are obtainable (IAR, 1989). However, only 500-1800 kg/ha is realised on resource-poor farmers' fields (Ajayi, 1989).

Insect pests constitute a major constraint to sorghum production world-wide (Chundurwar, 1989; Uvah and Alabi, 1989) and stem borers are the most economically important insect pests of the crop (Taneja and Leuschner, 1985; Seshu Reddy, 1989). In Nigeria, *Busseola fusca* Fuller *(Lepidoptera: Noctuidae)* is the most important stem borer species in the major sorghum growing areas (Ajayi, 1989). Other commonly encountered borer species are *Sesamia calamistis* Hampson and *Eldana saccharina* Walker.

Much work has been done in India on chemical control of *Chilo partellus* Swinhoe on sorghum through seed dressings, application of granular systemics to soil, application of dusts, granules and sprays into the whorl and general foliar sprays (Kishore, 1989). Van Rensberge and Walters (1978) were able to obtain substantial reductions in *B. fusca* populations on sorghum by furrow applications of carbofuran 5G at planting in South Africa. Elsewhere, Swaine (1957) and Walker (1960) obtained satisfactory control of the insect from dusts of DDT and endrin, respectively, applied into the whorl. Anonymous (1980) recommends foliar sprays of carbaryl wettable powder (wp) at 1.68 kg a.i./ha at 2,5 and 8 weeks after planting for *B. fusca* control in maize in Nigeria. However, no work has been done on chemical control of *B. fusca*, in sorghum in the Nigerian savanna. The present study was, therefore, aimed at assessing a wide range of foliar, seed and soil-applied chemical formuations for their efficacy for control of stem borers on sorghum.

Materials and Methods

General

Five experiments were conducted during the 1986 to 90 wet seasons. The sorghum variety, SAMSORG-17 (=SK 5912) was utilised in all the experiments. Each experiment was laid out in a randomised complete block design with four replicates on plots of size 4.5m (six ridges) x 5m. Plots were separated by 1.5m of weed-free alleys. Insect populations and activity as well as the development and yield of plants were monitored on a single plot basis involving the following parameters: germination count of plants at two weeks after planting (WAP); establishment count of plants at 6 WAP and at harvest; count of deadhearts at 4 WAP (and 8 WAP for 1990); count of plants with leaf feeding at 4 and 8 WAP; Plant heights at 6 WAP; plant vigour score at 6 WAP (on a scale of 0-10 where, 0 = all plants dead and 10 = all plants highly vigorous and healthy); days to 50% heading, number of stands and of heads on the two central rows at harvest; weight of heads and of grain for the two central rows; 1000-grain weight and, finally, stem borer assessment at harvest. Stem borer assessment involved recording the following on single plant basis for a total of ten plants per plot: number of internodes; number of borer holes; number of internodes with holes; number of larvae and of pupae; length of the stem, and total length of tunnels.

Methods of insecticide application were selected based on the nature of the formulation. Granules applied at planting were placed in the furrow and covered with some soil before the seeds were planted. Side dressed granules were placed in furrows at 2.5 cm away from the base of plants. Seed dressing concentrates were diluted with 25% volume of water and applied evenly by carefully turning seed in a plastic container using a wooden stirrer. Such treated seed was spread out to dry under shade prior to planting. Seed dressing dusts were evenly applied to seed by stirring the mixture carefully in a plastic container. Foliar sprays (wp & ec formulations) were applied using a knapsack sprayer. Sorghum was always planted at about mid-June. Field agronomic practices recommended by Anonymous (1985) were utilised. The specific insecticide treatments for each experiment were as detailed below.

1986 Experiment. During the 1986 rainy season, the efficacy of the seed dressings, Furadan 35 ST (35% carbofuran e.c. seed treatment), Marshal 25 ST (25% dust) were compared with Furadan 5G (5% a.i. granular carbofuran) and Vetox 85 wp (carbaryl 85% a.i.) for control of the sorghum stem borer. The treatments were: Furadan 5G at 1.0 kg a.i./ha at planting only, as a side dressing at 30 DAP only, and at planting followed by (fb) a side dressing of same at 45 DAP; Furadan 35 ST at 0.5 kg a.i./100 kg seed; Marshal 35 ST at 0.5 and 1.0 kg a.i./100 kg seed; Furadan 35 ST at 0.5 kg a.i./100 kg seed fb a side dressing of Furadan 5G at 1.0 kg a.i./ha at 30 DAP; carbaryl 85 wp at 1.5 kg a.i./ha at 2 and 4 WAP, and the control with no insecticide application.

1987 Experiment. In addition to Furadan 5G, Furadan 35 ST, Marshal 25 ST and carbaryl 85 wp tested in the previous year, Apron-plus 50 DS (10% metalaxyl, 6% carboxin and 34% Furathiocarb) and Fernasan D (20% BHC and 25% Thiram) were screened during 1987 for their efficacy for sorghum stem borer control. All treatments in the previous year were repeated, except that Furadan 3G was utilised in place of 5G. The remaining treatments were: Apron-plus 50 DS at 5, 10 and 15 g/kg seed and Fernasan D at 10g/3kg seed.

1988 Experiment. During 1988 rainy season, Furadan (3G and 35 ST), Marshal 25 ST, Apron 50 DS, carbaryl 85 wp and Fernasan D which were tested in the previous year were compared with Counter 5G (5% terbufos granular) and Talstar 10 e.c. (10% bifenthrin) alone or in combination. The treatments included all those in the previous year as well as Counter 5G at 0.5, 0.75 and 1.0 kg a.i./ha at planting, and Talstar 10 ec at 20 and 30 g a.i./ha at 14 and 28 DAP.

1989 Experiment. Again granular Furadan and Counter, Furadan, Apron and Fernasan D seed treatments, and Talstar ec were tested for their efficacy for stem borer control in sorghum. The treatments were: Furadan 3G at 1.0 kg a.i./ha applied at planting or at both planting and 45 days later, Furadan 35 ST at 0.5 kg a.i./100 kg seed fb Furadan 3G at 1.0 kg a.i./ha at 30 DAP, Apron-plus 50 DS at 5, 10 and 15 g dust/kg seed, Fernasan D at 10g dust/3kg seed, Counter 5G at 0.5, 0.75 and 1.0 kg a.i./100 kg seed, Talstar 10 ec at 20 and 30 g a.i./ha at 2 and 4 WAP, and the unprotected control.

1990 Experiment. Due to high variability in the data for 1986 and 1988, it was decided to test Furadan (G & ST), Apron, Fernasan D, Counter and Talstar again in 1990. All treatments utilised in the previous year were adopted, except granular Furadan applied at planting only an Apron seed treatment at 15 g/kg seed.

Results

1986 Experiment. Table 1 indicates that granular carbofuran applied at planting followed by same at 45 DAP performed best with the lowest number of borer holes, proportion of plants with leaf feeding and proportion of stem length tunnelled and also the highest grain yield. Sorghum treated with carbofuran seed dressing fb granular carbofuran also performed well but that treated with only seed dressings generally performed poorly.

Table 1. The efficacy of insecticidal treatments for the control of the sorghum stem borer at Samaru, 1986.

Treatments	Plant height (cm)	N° of holes/10 stems	Tunnel length (cm)	% of stem tunnelled	% head-hearts at 6 WAP	% leaf feeding	Grain yield (kg) 2 central rows)
Furadan 5G, @ 1.0 kg a.i/ha at planting	50.50	28.00	35.07	26.80	5.07	92.73	2.52
Furadan 5G, @ 1.0 kg a.i/ha at planting + side dressing at 45 DAP	50.37	14.40	17.07	8.70	2.77	54.20	2.91
Furadan 5G, @ 1.0 kg a.i/ha side dressing at 30 DAP	45.53	17.73	26.53	21.43	0.90	82.73	2.30
Furadan 35ST, @ 0.5 kg a.i/100 kg seed	46.13	21.47	26.57	21.03	3.63	94.23	2.05
Furadan 35ST, @ 1.0 kg a.i/100 kg seed	51.80	29.10	28.77	25.07	6.53	94.67	2.16
Marshal 25 ST, @ 0.5 kg a.i/100 kg seed	40.40	32.27	33.53	26.77	4.70	96.37	1.40
Marshal 25 ST, @ 0.5 kg a.i/100 kg seed	43.90	26.07	25.87	24.67	3.23	88.73	1.85
Furadan 35ST, @ 0.5 kg a.i/100 kg seed + Furadan 5 G, @ 1.0 kg a.i/ha side dressing at 30 DAP	49.67	18.17	25.47	17.90	0.97	68.97	2.67
Garbaryl 85 WP, @ 1.5 kg a.i/ha at 2 and 4 WAP	37.33	22.33	24.33	19.57	0.97	63.50	2.13
Control, no insecticide	44.63	22.77	21.53	21.43	1.43	88.57	1.95
± SED	3.44	7.24	7.21	7.31	1.73	11.09	0.52

1987 Experiment. The results shown in Table 2 indicate that Fernasan D, Apron and carbofuran seed treatments generally led to significantly better plant establishment than the control. This was also true for granular carbofuran applied at planting. Plots treated with granular carbofuran seed treatment fb granular carbofuran, Apron (at 5 g/kg seed) or Fernasan D had significantly fewer borer holes and a lower proportion of internodes bearing such holes than the remaining plots. Sorghum treated with two sequential applications of granular carbofuran had the fewest borer immatures in their stem and consequently, the lowest total tunnel length per stem. Highest grain yields were recorded in plots receiving carbofuran seed treatment. In terms of both borer control and yield, best performance was recorded from sorghum receiving carbofuran seed treatment fb granular carbofuran.

1988 Experiment. Results (Table 3) show that sorghum treated with granular carbofuran (twice or once at 30 DAP) suffered least leaf feeding and also had low counts of deadhearts. Sorghum receiving carbofuran seed treatment fb granular carbofuran had the least number of borer immatures in their stem and no deadhearts.

Table 2. The efficacies of some chemicals for control of sorghum stem borer at Samaru, 1987.

Treatments	N°, of stands established	Leaf feeding	% of inter-nodes with holes	N°, of holes/ stem	Total tunnel length/ stem (cm)	N°, of larvae & pupae per stem	Grain yield (kg) per 2 rows
Furadan 5G, 1.0 kg a.i/ha at planting	78.7b	51.0	7.60b	2.43b	11.67b	1.93	2.0
Furadan 5G, 1.0 kg a.i/ha at planting + 45 DAP	77.3b	51.3	2.97a	0.83a	4.30a	0.47	2.1
Furadan 5G at 1.0 kg a.i/ha at 30 DAP	73.3a	41.7	2.23a	0.87a	4.00a	0.70	1.4
Furadan 35 ST, 0.5 kg a.i/100 kg seed	77.3b	56.3	7.13b	2.30b	9.13a	0.80	3.0
Furadan 35 ST, 1.0 kg a.i/100 kg seed	75.3ab	54.0	9.90b	3.10b	14.43b	2.40	3.0
Marshal 25 ST, 0.5 kg a.i/100 kg seed	74.7ab	47.3	7.00b	2.40b	9.90b	1.03	2.5
Marshal 25 ST, 0.5 kg a.i/100 kg seed	75.0ab	55.0	8.13b	2.50b	9.17a	0.93	2.2
Furadan 35 ST, 0.5 kg a.i/100 kg seed +							
Furadan 5 G, 1.0 kg a.i/ha at 30 DAP	77.3	57.3	4.07a	1.50a	6.93a	0.83	3.0
Garbaryl 85 WP at 1.7 kg a.i/ha at 2 and 4 WAP	75.3ab	44.3	7.03b	2.00a	6.87a	0.97	2.3
Apron 50 DS at 5 g dust/kg seed	74.0ab	45.3	6.07a	1.60a	6.93a	1.20	1.6
Apron 50 DS at 10 g dust/kg seed	77.0b	41.7	8.27b	2.30b	9.73b	1.00	1.9
Apron 50 DS at 15 g dust/kg seed	76.3b	54.0	10.77b	3.00b	13.63b	1.23	2.4
Fernasan D at 10 g dust/3 kg seed	77.3d	63.3	6.67a	1.80ab	7.53a	1.53	2.4
Control, (no insecticide)	70.0a	45.7	7.63b	2.53b	8.20a	1.83	2.3
± SED	1.79**	0.39	1.93*	0.53**	2.42**	0.54	0.41

Table 3. Efficacy of various chemicals in the control of sorghum stem borer at Samaru, 1988.

Treatments	N° of plants establi-shed/plot	N° of dead hearts/ plot	N° of plants with leaf feeding per plot	Days to 50 % heading	N° of feedig holes/ 10 stems	N° of larvae + pupae per 10 stems	Total grain yield/ 2 rows (kg)	1.000 grain wt (G)
Furadan 3G at 100 kg a.i./ha at planting	81.8	2.0	51.5	11.3	33.3	7.5	1.72	39.9
Furadan 3G at 1.0 kg a.i/ha at planting + 45 DAP	80.3	0.5	13.0	113.8	28.0	6.8	2.23	39.2
Furadan 3G at 1.0 kg a.i/ha at 30 DAP	72.8	0.5	33.5	112.3	36.0	13.3	2.6	39.6
Furadan 35 ST at 1.0 kg a.i/100 kg seed	88.5	3.0	70.8	113.3	37.3	12.0	1.65	38.9
Furadan 35 ST at 0.5 kg a.i/100 kg seed	88.3	2.5	63.5	112.0	44.8	7.3	1.70	38.7
Marshall 25 ST at 1.0g a.i/100 kg seed	69.3	1.0	37.5	113.3	33.8	8.0	1.88	40.5
Marshall 25 ST at 0.5 kg a.i/100 kg seed	92.8	2.0	53.8	112.3	35.3	8.0	1.87	38.8
Furadan 35 ST at 0.5 kg a.i/100 kg seed + Furadan 3 G at 1.0 kg a.i/ha at 30 DAP	80.8	0.0	47.3	112.8	28.3	4.3	2.13	39.1
Carbaryl 85 wp at 1.7 kg a.i/ha	58.0	1.3	29.0	115.8	28.8	4.3	1.20	38.5
Apron-plus 50DS at 5g dust/kg seed	89.8	1.8	53.0	115.0	20.3	5.3	1.73	36.6
Apron-plus 50 DS at 10g dust/kg seed	86.3	2.3	47.0	112.8	26.5	15.8	2.12	40.0
Apron-plus 50DS at 15 g dust/kg seed	75.3	2.3	42.3	115.8	34.8	14.0	1.21	36.2
Fernasan D at 10 g dust/kg seed	90.0	2.0	50.8	113.3	36.5	9.8	1.28	36.9
Counter 5G at 1.0 kg a.i/ha at planting	88.5	2.3	66.3	112.5	28.3	11.8	1.71	38.3
Counter 5G at 0.75 kg a.i/ha at planting	75.3	1.8	54.5	112.0	51.8	15.3	2.53	40.5
Counter 5G at 0.5 kg a.i/ha at planting	81.0	1.3	43.5	111.8	33.3	9.8	1.98	37.7
Talstar 10ec at 30g a.i/ha at 14 & 28 DAP	62.0	2.3	36.0	114.3	30.0	6.5	1.66	37.1
Talstar 10ec at 20g a.i/ha at 14 & 28 DAP	75.5	1.3	48.0	114.5	30.0	3.5	1.78	39.5
Control - no insecticide	63.8	2.0	48.8	113.8	34.0	8.8	1.8	36.5
± SED	9.09**	1.16	13.04	1.24	9.42	5.13	0.435	1.37

Granular carbofuran, applied alone or in sequence after the seed treatment, Apron and Counter recorded appreciably higher yields than the remaining treatments.

1989 Experiment. There was significantly better plant establishment in sorghum treated with carbofuran (granules or seed treatment fb granules), Apron and Fernasan D than with nothing (Table 4). At 6 weeks, plants were of similar height in all the treatments.

Least leaf feeding was recorded in the Talstar-treated sorghum stands. Granular carbofuran applied twice also did well in this regard but, in addition, recorded the least number of borer holes on stems. The treatments had little effect on mean weight per seed. Relative to the control, significantly high yields were recorded in the Apron, Fernasan D and carbofuran treatments.

1990 Experiment. Carbofuran (ST or G), Apron, Counter and Fernasan D gave good plant establishment (Table 5). Least leaf feeding damage and deadhearts were recorded in the carbofuran -treated plots where sorghum also showed best plant vigour and headed earliest. All treatments other than carbofuran, subsequently had 100% deadhearts and their yield was obtained from headed tillers. Sorghum treated with carbofuran consequently had significantly better shelling percentage and also gave over four times as much grain yield as that receiving any of the other treatments including the control.

Table 4. Effect of insecticides on stem borer abundance and damage, and on yield and yield components of sorghum at Samaru, 1989.

Treatments	Plants/ plot at harvest	Plant height at harvest, cm	Days to 50 % heading	Plant with leaf feeding/ plot	Shelling %	Borer holes/ stem	Larvae + pupae/ stem	Grain wt./2 central rows, kg	1,000 grain wt, g.
Furadan 3 G at 1.0 g a.i/ha at planting	79.8cde	22.6	99.8ab	3.3abc	65.4	2.0	0.25	1.5abcde	31.4
Furadan 3G at 1.0 kg a.i/ha each at planting + at 45 DAP	83.0de	221.6	98.5a	3.3abc	65.4	1.3	0.20	1.5abcde	29.0
Furadan 35 ST at 0.5 kg a.i/100g seed +	73.3bcd	215.8	99.8ab	0.5ab	63.4	2.4	0.23	1.3abcde	28.1
Furadan 3 G at 1.0 kg a.i/ha at 30 DAP	86.0de	229.9ab	99.0ab	10.8e	58.0	2.1	0.18	1.8de	30.0
Apron-plus 50 DS at 5 g dust/kg seed	77.8cde	212.6	102.3d	6.8cde	64.9	2.2	0.30	1.6bcde	29.6
Apron-plus 50 DS at 10 g dust/kg seed	85.8de	223.0	100.ab	8.5de	74.0	2.5	0.23	1.9e	29.6
Apron-plus 50 DS at 15 g dust/kg seed	84.3de	220.6	100.8b	11.8e	72.2	2.2	0.13	1.7cde	27.4
Fernasan D at 10 g dust/3 kg seed	67.3abc	207.3	99.5ab	0.0ed	61.0	1.7	0.23	1.0a	30.8
Counter 5G at 1.0 kg a.i/ha at planting	63.0ab	205.0	100.0ab	2.8abc	62.2	1.5	0.20	1.1ab	28.8
Counter 5G at 1.0 kg a.i/ha at planting	63.3abc	206.5	102.3d	4.0abcd	62.5	1.8	0.23	1.3abc	27.5
Counter 5G at 0.75 kg a.i/ha at planting	56.8a	215.3	102.0cd	0.3ah	68.9	2.0	0.18	1.4abcde	29.3
Talstar 10ec at 30g a.i/ha at 2 & 4 WAP	64.5ab	215.4	100.3abc	0.0a	65.7	2.4	0.15	1.2abc	28.2
Talstar 10ec at 20g a.i/ha at 2 & 4 WAP	66.8abc	210.3	100.0ab	5.8bcd	71.1	2.1	0.18	1.2abc	31.3
Control - no insecticide									
± SED	6.53**	9.32ns	0.95**	2.75**	7.04ns	0.71 ns	0.100ns	0.25*	1.60ns

Table 5. Effect of chemicals on sorghum stem borer incidence and damage, and on yield and yield components of sorghum, 1990.

	Plants/ plot at 6 WAP	Dead-hearts/ plot 8 WAP	Leaf-fed plants/ plot at 8 WAP	Plant vigour score (0-10)	Days to 50 % heading	Plant height at 6 WAP cm	N° of larvae + pupae/ 10 stems	Wt of grain/ 2 rows, kg	Shelling %	1000 grain wt g	% stem tun-nelled
Furadan 3G at 1.0 kg a.i/ha at planting & at 45 DAP.	116.3c	6.3a	15.5ab	9.0c	110.5a	90.1c	2.8	1.39b	48.9b	30.8	37.9c
Furadan 35 ST at 0.5 kg c.i/ 100 kg seed	99.0d	5.5a	7.3a	8.0dc	111.0a	85.5abc	3.0	1.91c	56.7	29.4	41.6c
Furadan 3G at 1.0 kg a.i/ha at 30 DAP	97.0cd	12.5bc	40.3bc	7.3bcd	119.0bc	86.2bc	2.0	0.26a	27.7a	26.4	35.2bc
Apron-plus 50 DS at 5 kg dust/kg seed	108.5de	15.0c	48.3cd	7.8cde	118.8bc	87.9bc	1.0	0.31a	30.9a	30.2	25.7ab
Apron-plus 50 DS at 10 g dust/kg seed.	98.8de	14.0c	47.8cd	6.8c	119.8bc	87.9bc	2.5	0.24a	28.1a	24.9	17.2a
Fernasan D at 10 g dust/ 3kg seed	107.3de	12.3bc	72.8bc	7.8cde	122.3c	89.7c	2.0	0.18a	23.5a	25.7	15.6a
Counter 5 G at 1.0 kg a.i/ha at planting	105.0de	12.5bc	73.3dc	8.8de	120.8c	89.0bc	0.5	0.20a	25.5a	28.8	11.1a
Counter 5G at 0.75 kg a.i/ha at planting	106.3de	7.8ab	81.3e	8.0de	119.0bc	89.5b	2.5	0.31a	37.3a	30.2	21.5ab
Counter 5G at 0.5 kg a.i/ha at planting	78.3ab	12.8bc	13.0a	6.3bc	116.3b	80.5a	1.8	0.23a	31.6a	27.3	13.8a
Talstar 10ec at 30g a.i/ha at 2 & 4 WAP	84.8 bc	14.3c	30.5abc	5.8b	120.0c	84.5ab	2.0	0.20a	22.4a	26.1	25.5ab
Talstar 10ec at 20g a.i/ha at 2 & 4 WAP	68.5a	12.3bc	23.5ab	4.0a	122.5c	84.7ab	3.3	0.20a	25.3a	25.0	25.8ab
Control-no insecticide											
± SED	6.04***	2.53**	12.69***	0.75***	1.73***	2.45*	1.25	0.232***	7.67**	4.61	7.62**

Discussion

The study clearly shows that two applications of carbofuran (i.e. either G fb G or ST fb G) consistently gave considerable reductions in stem borer incidence and damage leading to higher sorghum grain yields than the unprotected control. Soil applications of carbofuran, either at planting or as a side dressing after crop emergence or both, have also been shown to be effective against *C. partellus* in India (Kishore, 1989) and *B. fusca* on maize in South Africa (van Rensberg *et al.* 1978). Carbofuran ST + G would be a better alternative to G fb G for stem borer control based on the higher cost of the granules which are also less convenient to apply. Stem borer control with chemicals would only be necessary at locations with risk of high early infestations more likely to cause deadhearts in sorghum.

The seed dressing chemicals, carbofuran 35 ST, Apron-plus 50 DS, Fernasan D and Marshal 25 ST failed to give consistent reductions in stem borer damage and infestations, being particularly ineffective under conditions of heavy stem borer infestations as occurred in 1990. Sharma *et al.* (1973) were also unable to control *C. partellus* with carbofuran seed treatment at 6-10 kg a.i./100 kg seed in India. In the present experiments, carbofuran 35 ST, Apron-plus 50 DS and Fernasan D as well as granular carbofuran applied at planting consistently gave good plant establishment. Such seed dressings may be used to improve plant establishment and thereby contribute to increased output of sorghum grain per unit of land.

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Identification de Sources de Résistance à l'Anthracnose Foliaire du Sorgho causée par *Colletotrichum Graminicola* au Burkina Faso

ADAMA NEYA.

INERA, Ouagadougou, Burkina Faso.

Résumé

L'évolution de la sévérité de l'anthracnose foliaire varie en fonction du génotype et les fortes attaques surviennent dans les conditions d'alternance de sécheresse et de périodes humides. L'utilisation d'une méthode de criblage au champ avec un mélange de huit génotypes sensibles a permis de mettre en évidence la résistance des génotypes testés par l'augmentation du niveau de la pression parasitaire. Le test conduit pendant deux années sur 80 génotypes locaux et améliorés a révélé l'existence de sources de résistance à *C. graminicola*. L'analyse sanitaire des semences a montré que la grande majorité des génotypes locaux a un taux d'infection compris entre 5 et 25% tandis que les génotypes introduits présentent des taux d'infection supérieurs à 50% en dépit de leur bon niveau de résistance horizontale à l'anthracnose foliaire. Les corrélations ont été faites entre le rendement et la sévérité de l'anthracnose foliaire et, celle des grains. L'observation des caractères culturaux des isolats sur milieu P.D.A. révèle l'existence d'un grand nombre de souches, voire de races de *C. graminicola* à mettre en évidence par d'autres tests plus sélectifs. Une stratégie de lutte contre le *C. graminicola* dans la production du sorgho devrait s'orienter sur l'approche de lutte intégrée et l'approfondissement des connaissances sur l'écologie du pathogène pour comprendre la variabilité à l'échelle nationale et sous régionale.

Introduction

Le *Colletotrichum graminicola* (Ces.) Wilson est agent de l'anthracnose foliaire, de l'anthracnose des grains et de la pourriture rouge des tiges qui sont des maladies importantes causant, chez le sorgho, des pertes évaluées entre 7 et 46% (Neya et Kaboré, 1987). Ces pertes peuvent atteindre 50% et même 70%, en cas d'attaque sévère sur des variétés sensibles, suite au mauvais remplissage des grains (Harris et al, 1964 ; Ali *et al*, 1987).

Ces dernières années, de nombreuses variétés locales et introduites ont montré une sensibilité à *C. graminicola* avec des symptômes variant d'une réaction de type hypersensibilité, à la senescence totale des plantes. La présence du pathogène sur les semences constitue une source d'inoculum primaire importante avec des taux qui varient de 8.7% à 22.8% (Kaboré et Couture, 1988).

Face aux limites de la lutte chimique et à ses conséquences sur l'environnement, le développement de génotypes ayant une bonne résistance à ce pathogène constitue un objectif important dans l'amélioration de la production du sorgho.

La présente étude, conduite en 1989 et 1990, est une contribution à l'évaluation de 80 variétés de sorgho par une méthode de criblage au champ afin d'identifier des sources de résistance à l'anthracnose foliaire, à l'anthracnose des grains et à la pourriture rouge des tiges.

Matériel et Méthodes

Evaluation des génotypes au champ. Un lot de 80 génotypes dont 58 locaux du Burkina Faso et 24 introduits a été semé en plein champ à Farako-Bâ en 1989 et 1990 selon un dispositif Bloc Fischer à 3 répétitions. Chaque génotype est semé sur 2 lignes de 11 poquets à la densité de 80 cm entre les lignes et 40 cm entre les poquets. Chaque poquet comporte 2 plants après le démariage. La pression de l'inoculum a été renforcée grâce à une bande infestante constituée d'un mélange de génotypes sensibles à l'anthracnose foliaire et semée 2 semaines avant le matériel à tester de manière à encadrer complètement les parcelles élémentaires, la fumure minérale appliquée a été constituée de l'engrais NPK (4-23-14) à la dose de 200 kg/ha au semis et de l'urée (46% N) à la dose de 100 kg/ha en 2 fractionnements égaux aux 30e et 45e jour après semis.

L'évaluation de la sévérité de l'anthracnose foliaire est faite à l'aide d'une échelle de 1 à 6 (ICRISAT, 1987) sur les quatre dernières feuilles de 10 plants marqués sur la ligne adjacente à la bande infestante. La fréquence de notation a été de 10 jours du 20 Août au 8 Octobre en 1989 et du 13 Août au 12 Octobre en 1990. Les notations ont été également faites sur cinq plantes sur la bande infestante afin de suivre l'évolution de la pression parasitaire. A la récolte, les 10 plantes marquées ont été disséquées longitudinalement pour évaluer la pourriture rouge des tiges à l'aide d'une autre échelle de 0 à 5 (Néya et Kaboré, 1987). Le poids total des grains et celui de 1000 grains ont également été mesurés pour les plantes marquées.

Evaluation de l'anthracnose des grains au laboratoire. L'importance de l'anthracnose des grains contaminés par *C. graminicola* a été déjà signalée par Kaboré et Couture (1988). Les travaux de Cardwell *et al* (1989) ont montré que 23% des plantules issues de semences porteuses de *C. graminicola* ont présenté des lésions d'anthracnose sur les feuilles et les racines primaires, ce qui explique la transmission du pathogène par les semences d'une année à l'autre.

En 1989 et 1990 des analyses ont été faites sur 300 grains par génotype à la récolte. Des échantillons de 100 grains ont été prélevés sur l'ensemble des 10 plantes marquées par génotype et par répétition. Ces échantillons ont été pré-traités à l'alcool à 70% pendant 15 mn puis à l'hypochloride de sodium 1% durant 10 mn (Kaboré et Couture, 1983). Les grains ont été ensuite placés sur du papier buvard en boîte de Petri et incubés à 28°C. L'évaluation des grains porteurs de *C. graminicola* est intervenue après 72 h d'incubation par le comptage des acervules germés.

Les isolats obtenus à partir des acervules germés sur les grains sont mis en culture sur le milieu PDA (Potato Dextrose Agar). Après repiquage, les boîtes de Petri sont incubées àl'obscurité à 28°C pendant 24 h et transférées dans un mini phytotron muni de 6 lampes fluorescentes (40 W chacune) à 28°C. Après 9 jours d'incubation les caractères suivants ont été mesurés : longueur et largeur des conidies, vitesse de croissance du mycélium et couleur des colonies.

Résultats et Discussions

Développement de l'anthracnose foliaire. Dans les conditions pluviométriques de 1989 et 1990 sur le site de l'essai, de longues périodes d'humidité ont marqué les mois de Juillet, d'Août, et la mi-Septembre, surtout en 1990. A partir du 20 Septembre, la campagne 1989 a été caractérisée par de longues périodes de sécheresse qui ont duré jusqu'au 2 Octobre alors qu'en 1990, cette période a été plus humide. Durant les 2 années de criblage, les sévérités de l'anthracnose foliaire se sont stabilisées au niveau 2.5 sur l'échelle utilisée jusqu'au 22 Septembre, période correspondant à la pleine floraison. L'alternance de sécheresse et d'humidité satisfaisante après le 20 Septembre a été favorable au développement de l'anthracnose foliaire comme le montrent les figures 1A et 2A. L'évolution de la maladie sur les 80 génotypes en 1989 et en 1990 révèle que quelle que soit l'année, les génotypes résistants, à majorité locale, sont capables de freiner l'épidémie (Figure 1B et 2B) alors que sur les génotypes sensibles, la progression de l'anthracnose foliaire est plus rapide et atteint le niveau 5 avant la fin de la phase de durcissement des grains.

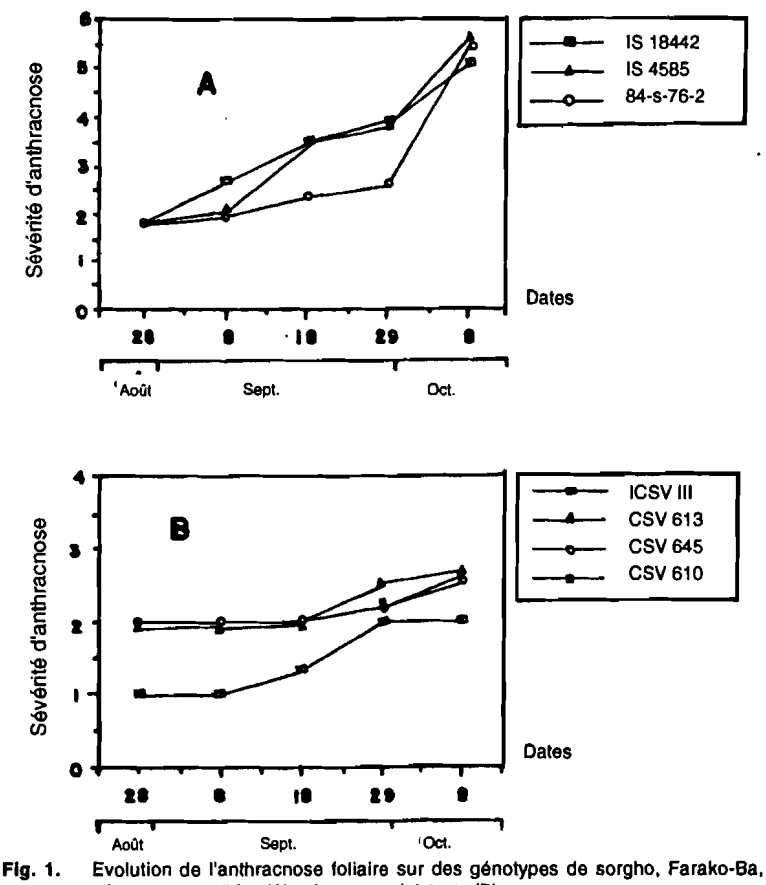

Fig. 1. Evolution de l'anthracnose foliaire sur des génotypes de sorgho, Farako-Ba, 1989 génotypes sensibles (A), génotypes résistants (B)

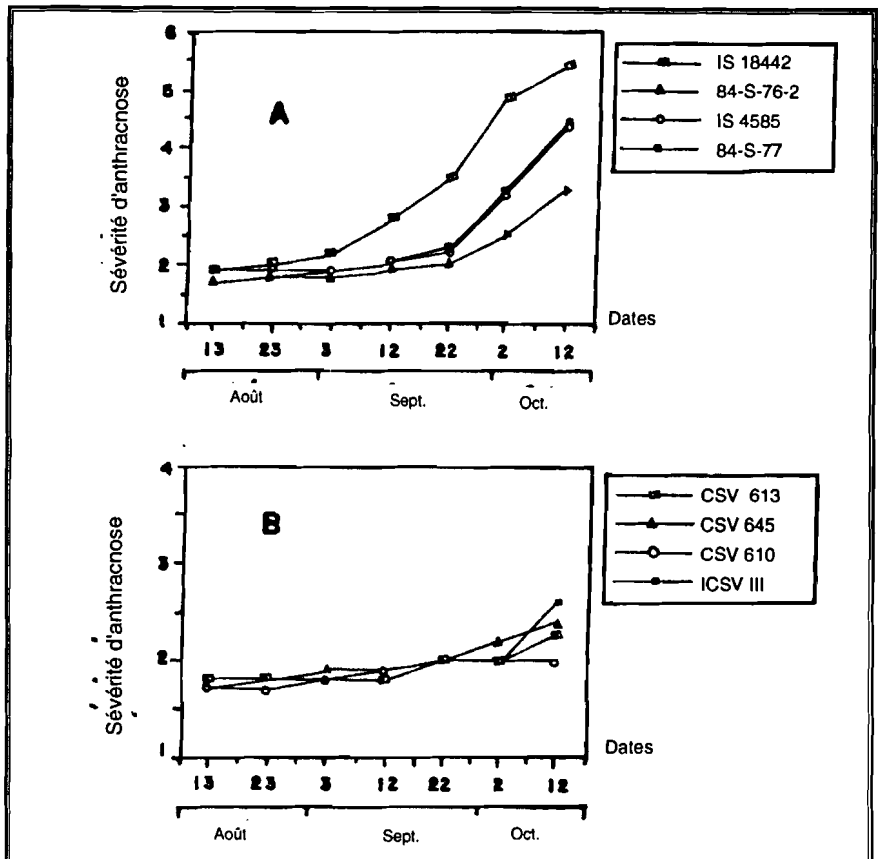

Fig. 2 . Evolution de l'anthracnose foliaire sur des génotypes de sorgho, Farako-Ba, 1990 génotypes sensibles (A), génotypes résistants (B)

Des différences de symptômes ont pu être notées entre les matériels local et introduit. Dans le premier cas, les symptômes, généralement de type hypersensible, se caractérisent soit par de petits points nécrotiques répartis sur le limbe foliaire soit par des tâches de dimension réduite produisant des acervules. Quant aux introductions, l'anthracnose se manifeste sous forme de taches plus larges qui deviennent rapidement coalescentes, entraînant souvent la sénescence prématurée de la plante.

Des corrélations négatives significatives ont été obtenues, d'une part, entre l'anthracnose foliaire et le poids des grains des 10 panicules (Figure 3) et d'autre part, entre l'anthracnose foliaire et le poids de 1000 grains (Figure 4). Ces deux corrélations confirment l'incidence réelle de la maladie sur le rendement et rejoignent les conclusions de Ali et Warren (1987).

Développement de la Pourriture Rouge des Grains. Les observations faites sur des tiges dissequées ont montré des symptômes de pourriture rouge sur 63 génotypes en 1989 et sur 79 génotypes en 1990 même si les niveaux de sévérité sont restés très faibles et ont varié entre 0 et 1,4 sur l'échelle de 0 à 5. Seul le génotype 84-S-130 n'avait présenté aucun symptôme durant les deux années.

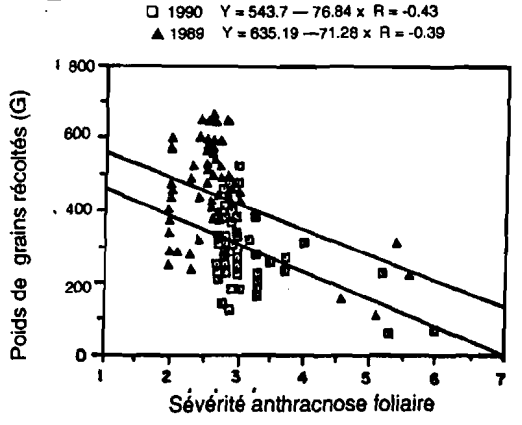

Fig. 3. Corrélation entre la sévérité de l'anthracnose foliaire et le poids de 10 panicules de 80 génotypes de sorgho, Farako-Ba, 1989 et 1990.

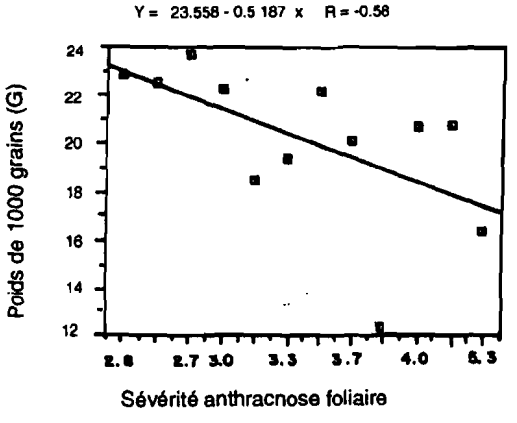

Fig. 4. Corrélation entre la sévérité de l'anthracnose foliaire et le poids de 1000 grains de 80 génotypes, Farako-Ba, 1990.

Evaluation de l'Anthracnose des Grains. Selon la nomenclature que nous avons adoptée, les génotypes ont été répartis en 6 classes en fonction du niveau de contamination des grains par *C. graminicola* : 1 = Aucun grain contaminé, 2 = Jusqu'à 5% de grains contaminés, 3 = De 6 à 25% de grains contaminés, 4 = De 26 à 50% de grains contaminés, 5 = De 51% à75% de grains contaminés, 6 = Plus de 75% de grains contaminés.

L'analyse sanitaire de la récolte de 1989 a révélé que 37,5% des 80 génotypes étaient indemnes contre 10% en 1990 (Fig. 5 et 6). Il est à noter qu'en 1989 la majorité des génotypes à panicule lâche étaient répertoriés en classe 1 (57,72 %) et classe 2 (34,48 %) et 5 (45,45 %) comme le montre la Figure 5. Des résultats similaires ont été notés en 1990 (Fig. 6) même si les taux d'infestation ont été plus élevés qu'en 1989, à cause des conditions pluviométriques favorables durant la phase de formation et de maturation des grains.

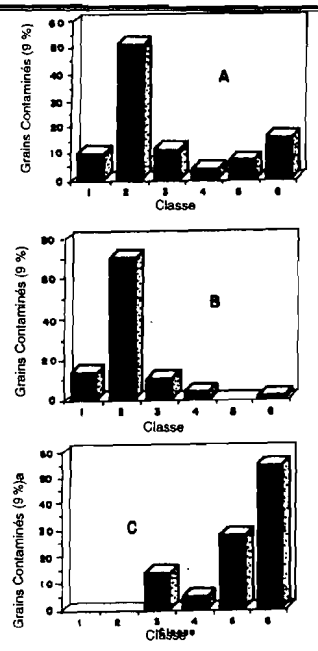

Fig. 5. Taux de contamination naturelle des semences par le *C. graminicola* de génotypes de sorgho (A) dont 58 à panicules lâches (B) et 22 à panicules compactes (C) Farako-Ba, saison humide 1989

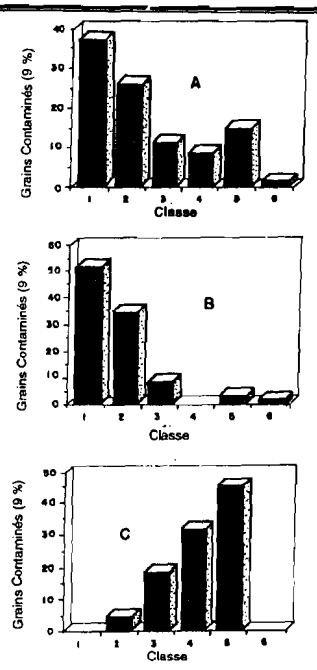

Fig. 6. Taux de contamination naturelle des semences par le *C. graminicola* de génotypes de sorgho (A) dont 58 à panicules lâches (B) et 22 à panicules compactes (C) Farako-Ba, saison humide 1990.

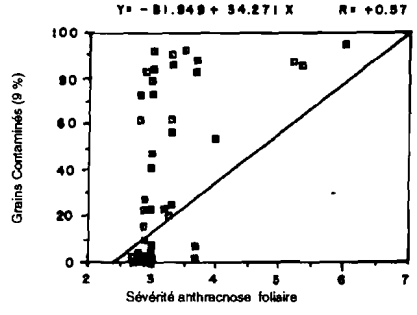

Fig. 7. Corrélation entre l'anthracnose foliaire et le taux de contamination naturelle des grains par C. graminicola de 80 génotypes de sorgho Farako-Ba, 1990.

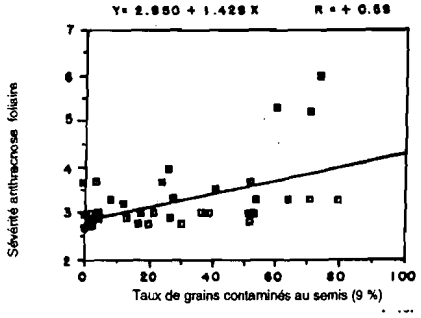

Fig. 8. Corrélation entre le taux de contamination naturelle des grains par *C. graminicola* et l'anthracnose foliaire au stade de durcissement des grains, Farako-Ba, 1990.

La corrélation positive significative entre l'anthracnose foliaire et l'anthracnose des grains laisse supposer que des plantes fortement attaquées par l'anthracnose sont susceptibles de présenter des symptômes d'anthracnose des grains (Figure 7). Par ailleurs la corrélation positive entre le taux de contamination des grains au semis et l'anthracnose foliaire permet d'affirmer que l'inoculum primaire joue un rôle important dans les infections foliaires ultérieures (Figure 8). Cette situation peut être aggravée par l'absence de traitement de semences chez les agriculteurs.

Notons que sur l'ensemble du matériel évalué, 70 génotypes sont résistants à l'anthracnose foliaire, 47 génotypes sont résistants à l'anthracnose des grains et 80 sont résistants à la pourriture des tiges, 44 sont tolérants à l'action combinée des trois maladies (Tableau 1). Il convient de souligner l'importance à accorder au matériel local dans la mise en oeuvre de programmes de recherche intégrée pour l'amélioration de la production du sorgho.

Caractères morphologiques des populations d'isolats. Pour des raisons matérielles, cette étude s'est limitée à des tests préliminaires. Le tableau 2 résume quelques caractères morphologiques de populations d'isolats. Les conidies les plus courtes ont été observées sur les isolats Cg. CVS 576 et Cg. CVS 575 tandis que les conidies les plus longues ont été observées sur les isolats Cg. Ouedzouré et Cg. IS 2257. Tous les isolats ont sensiblement la même largeur de conidies. Les croissances les plus rapides ont été obtenues avec Cg. 84-S-76-2 et Cg. B 58 557. Pour l'aspect couleur de colonie, il apparaît 2 groupes : Colonie à centre gris et pourtour blanc sale (Groupe 1), et Colonie à centre gris et pourtour rose pâle (Groupe 2).

Tableau 1. Répartition de 80 génotypes de sorgho en fonction de leur origine et de leur résistance à l'anthracnose foliaire, à l'anthracnose des grains et à la pourriture rouge des tiges, Farako-Bâ, 1989 et 1990.

Groupes		Génotypes locaux	Génotypes introduits	Total
Anthracnose foliaire résistant		52	18	70
Anthracnose des grains résistant		47	0	47
Pourriture rouge des tiges résistant		56	24	80
Anthracnose foliaire sensible		3	7	10
Anthracnose des grains sensible		9	24	33
Anthracnose foliaire + Anthracnose des grains + Pourriture rouge des tiges	résistant	44	0	44

L'observation des caractères culturaux sur milieu PDA laisse penser à l'existence d'un grand nombre de souches voire de races de *C. graminicola* à mettre en évidence par des tests sélectifs.

Tableau 2. Biométrie et description des colonies de différentes populations d'isolats de *C. graminicola* incubées pendant 10 jours sur milieu PDA à 28°C, Humidité Relative 30 - 55 %.

Population d'isolats	Longueur conidie (u)	Largeur conidie (u)	Croissance du mycelium (mm^2)	Description de la colonie
Cg FRIKAN	24.2	4.4	2330	Centre gris, pourtour blanc sale
Cg GNOFING	24.9	4.4	3228	Centre gris, pourtour blanc sale
Cg OUEDZOURE	26.3	4.4	3661	Centre gris, pourtour blanc sale
Cg S 29	24.6	4.4	3666	Centre gris, pourtour blanc sale
Cg CSV 660	24.1	4.4	3550	" " "
Cg S 13	24.6	4.4	3509	" " "
Cg CSV 576	20.3	4.4	2844	" " "
Cg CSV 573	23.4	4.4	2945	" " "
Cg CSV 575	21.0	4.4	2866	" " "
Cg IRAT 203	27.0	4.4	3251	" " "
Cg S 6	23.0	4.4	3144	" " "
Cg IS 4585	25.9	4.4	2835	" " "
Cg IS 18442	24.4	4.4	2314	" " "
Cg B 58557	24.4	4.4	3812	" " "
Cg IS 9928	24.7	4.4	2237	" " "
Cg IS 2257	27.6	4.4	2341	" " "
Cg S 10	25.2	4.4	3138	Centre gris, pourtour rose sale
Cg FRAMIDA	22.9	4.4	3641	" " "
Cg IS 21658Y	23.9	4.4	2536	" " "
Cg 84 S 82	25.7	4.4	2748	" " "
Cg 84 S 76-2	24.4	4.4	3958	" " "
Cg 84 S 130	24.9	4.4	3004	" " "
Cg ICSV 1002	25.5			

Conclusion

Le suivi de trois formes d'anthracnose sur 80 génotypes indique que le matériel végétal a un comportement variable en fonction de la forme paniculaire et de l'origine (local ou introduit). Les niveaux de sévérité sont restés faibles pour la pourriture rouge des tiges et ont varié de 0 à 5,6 pour l'anthracnose foliaire. Au niveau des taux de contamination des grains par *C. graminicola* les valeurs fluctuent de 0 à 80% en 1989 et de 0 à 95,7% en 1990.

Au regard des taux de contamination élevés sur les grains, le traitement des semences doit être recommandé pour réduire l'inoculum primaire lors des semis. Par ailleurs les activités futures devraient permettre de comprendre le mode d'infection et la période favorable à l'anthracnose de grains en fonction des stades de développement du sorgho. Une stratégie de lutte contre *C. graminicola* dans la production du sorgho doit être axée sur: l'approfondissement des connaissances sur la bio-écologie du pathogène pour comprendre sa variabilité à l'échelle nationale et sous-régionale, et la combinaison judicieuse de trois méthodes de lutte à savoir la lutte chimique, les pratiques culturales saines et l'utilisation du matériel tolérant ou résistant.

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Utilization of Sorghum in Eastern Africa.

B.N. MITARU and C.I. MUNENE.

Sorghum and Millet Food/Feed Systems Project, College of Agriculture and Veterinary Sciences, University of Nairobi, Nairobi, Kenya

Introduction

Sorghum is among the most important cereals in the marginal agricultural areas of Eastern Africa. It is mainly grown by small-scale farmers and used as food, feed, fuel and construction material. The plant residues left in the farm play an important role in improving the moisture-holding capacity of the soil. There has been a tremendous effort by the countries of the region to increase production of sorghum. Although an increase in production mainly due to more surface area planted and, to some extent, yield per unit area has been realized, food production is not keeping pace with population growth rate estimated at more than 3.0%. There is, therefore, an urgent need to increase sorghum production in order to alleviate hunger and malnutrition.

Among the biological factors which constrain sorghum production in Eastern Africa, bird damage constitutes one of the most serious problems. The chasing of birds to reduce crop damage is, therefore, necessary but laborious, time-consuming and costly. At present, the brown sorghum cultivars are reportedly less preferred by birds and are generally grown where bird depredation is a menace. Although such "bird-resistant" cultivars have an agronomic advantage, the grain produced is of relatively low nutritional quality because of tannins.

Sorghum for Human Food

There are on-going research and development programmes aimed at improving the production and utilization of sorghum in the various countries of Eastern Africa. But overall, most of the research presently focuses on increased grain yields. Whereas stable increased grain yield is important, the grain quality aspects are also equally important. Grain from high yielding cultivars should also be suitable for processing and preparation of specific traditional foods (Table 1).

Both traditional and new recipes using sorghum have been developed in a number of countries. Traditionally, foods prepared in homes are based on skill-oriented recipes. Vogel and Graham (1979) have given a detailed description of the various sorghum recipes. In most cases, the traditional food preparation methods are tedious and time-consuming and this has discouraged the use of these foods, especially where labour is scarce.

Where sorghum is the stable cereal, up to 70% of the dietary protein and energy intake is supplied by locally milled sorghum products (Hulse *et al.*, 1980). However, because of low lysine content, sorghum products should preferably be mixed with other food items that are rich in lysine (Maclean *et al.*, 1981; Eggum *et al.*, 1982).

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a) ***Processing of Sorghum.*** Traditional processing of sorghum includes dehulling and grinding of the grain, an operation that is time-consuming. It has been reported that in one hour a woman pounds and processes only between 2-2.5 kg of sorghum (Alnwick et al., 1987). In the sorghum growing areas of Tanzania, women spend several hours each day pounding and processing sorghum. The brown varieties of sorghum have always required more time than white varieties. The introduction of mechanical dehuller and grinding mills has removed much of the drudgery involved in sorghum processing and has made sorghum products more available especially to the busy urban communities.

Table 1. Some traditional foods prepared from sorghum and millet in Eastern Africa.

Country	Local Food	Description of Food
Ethiopia	Nifro	Rice-like product
	Injera	Fermented pan cake like product
Kenya Uganda Tanzania	Uji	Pourable gruel variable in consistence and viscosity
	Ugali	Stiff porridge
	Busaa	Alcoholic drink
Somalia	Ambuulo	Boiled grain food
	Dango	Pop corn-like (popped in hot sad or heated oil)
Soor	Thick porridge	
	Mushaari	Thin porridge (pourable gruel)
	Anjeero	Thin pancake
	Muufo	Thick pancake
Sudan	Kisra	Unleavened naturally fermented pancake
	Asida	Stiff porridge
	Madida/Nasha	Thin porridge
	Araky/merisa Abrey/Hulu-mur	Alcoholic drink

b) ***Sorghum Grain Characteristics.*** A recent collaborative study involving the University of Nairobi, ICRISAT, Ethiopia's Institute of Agricultural Research and the Sudan SAFGRAD Lead Centre for sorghum has evaluated traditional food quality of selected 16 sorghum cultivars commonly cultivated in the four countries (Table 2). It is evident from the study that dehulling on the whole improved the organoleptic qualities of the traditional foods studied. However, dehulling quality of the grain had a wide variation among cultivars (Subramanian and Jambunathan, 1990; Badi *et al.*, 1990; Keya and Mbugua, 1990). Although variation for the different food qualities existed among the cultivars, grains of SPV 475, Dabar and IS 24129 had comparatively higher rating for overall food quality.

Work at the University of Nairobi has shown that "ugali" (a stiff porridge) from a white local sorghum was classified along with maize "ugali" which is most preferred for its taste (Keya and Mbugua, 1990). Although any type of sorghum may be used for making "ugali", there is a general preference for white sorghum for this form of (thick) porridge as opposed to brown sorghum which makes thin porridge ("Uji"). The study has also shown that hard grains are more difficult to grind and cannot produce very fine flours. In addition, smaller grains require longer dehulling time due to their thin pericarp and innerly embedded germ.

Table 2. Assessment of quality of traditional foods prepared from 6 selected sorghum cultivars.*

cultivar	Mean quality score					
	Injera		Nifro	Ugali	Kisra	Roti (indian)
	Whole flour	Dehulled flour				
M 35-1	3.8	4.7	2.4	6.6	1.9	3.3
SPV 475	4.4	4.8	2.5	6.6	1.9	3.4
SPH 221	3.8	4.5	2.3	6.5	1.6	2.9
Hageen dura 1	4.0	4.5	-	6.2	1.4	3.4
M 35-1 (IC)	3.4	4.5	1.6	6.2	1.2	2.3
Gambella	3.6	4.7	2.1	6.3	1.8	-
Melkmash	3.5	4.4	1.7	5.9	2.1	-
Kenya local	3.3	4.8	2.0	6.5	2.0	3.0
Safra	3.3	4.3	1.8	7.3	2.3	-
Tetron	3.8	4.5	2.7	6.9	2.1	-
Dabar	4.2	4.6	2.5	6.3	2.7	2.8
Lulu dwarf	3.9	4.7	2.8	5.1	1.9	3.0
IS 8686	3.2	4.8	2.4	6.7	2.3	2.6
IS 24129	2.8	4.8	2.5	6.2	2.7	3.1
IS 24150	2.8	4.7	2.4	6.1	2.7	3.0
IS 24259	3.5	4.7	2.2	4.6	2.7	2.9
Local check	3.2	4.3	1.5	-	1.9	-
Mean	3.6	4.6	2.2	6.3	2.1	2.9
SE ±	0.11	0.04	0.10	0.16	0.11	0.08

Food Quality Scores

Injera: 1 = poor; 5 = Excellent; *Nifro*: 1 = Poor; 3 = Good; *Ugali*: 1 = Poor; 9 = Excellent; *Kisra*: 1 = Poor; 3 = Good; *Roti*: 1 = Poor; 4 = Excellent.

* ***Source***: Subramanian and Jambunathan (1990).

c) ***Commercialization of Sorghum Foodstuffs.*** The emerging trends in sorghum industrial processing and consumption include composite flour bread, other baked goods, starch and glucose. The use of sorghum for bread and biscuits partly depends on the type of milling available. Hammer milling does not generally produce flour of a fine quality required for bread and biscuit making.

Dehulled sorghum (Supa mtama in Kenya) is a commercial product intended for cooking in the same way like rice. The grains are dehulled by dry abrasion methods using rice or attrition dehullers or other commercially available dehulers. The white sorghum cultivars which give good and preferred products include NES 7360, IS 8595, 2K X 17 and IS 76 (Arunga, 1989).

Sorghum meal and flour are obtained by hammer milling and are marketed for "ugali" and "uji" in Kenya, Uganda and Tanzania. In Burundi, the sorghum flour is used in the composition of Musalac, a food product for babies and pregnant women. Sorghum flour is also one of the ingredients in Faffa, a weaning food in Ethiopia. Undehulled brown sorghum meals/flours are not preferred by consumers, except in regions where the brown sorghum is a traditional crop. The undehulled products, apart from having high fibre content, have anti-nutritional components such as tannins and phytates.

Sorghum and Animal Feed

The conventional use of grain sorghum is mainly for human food while the stalks are sometimes used to feed animals. Otherwise, the common practice is to leave the stalks in the farm as mulch. While in countries like the United States of America sorghum grain is produced mainly for animal feed, in most of Africa the priority is for human food. In such a circumstance, the use of sorghum grain as an alternative animal feed resource is favoured only where there is surplus production.

It has been demonstrated that sorghum grain can completely replace maize in pig and chicken diets. Reconstitution (high moisture storage) of the high tannin sorghum grain de-activates tannins and improves the nutritive value of these sorghums for non-ruminants (Mitaru, 1982 and 1983). Other simple and practical methods for de-activating sorghum grain tannins include the use of wood ash. In areas where brown ("bird resistant") sorghum grain is produced, an attempt could be made to de-activate tannins and use the grains in the non-ruminant feeds instead of maize and white sorghums which are preferred for human food.

Studies in Kenya have shown that apart from being drought tolerant, sorghum also outyields maize in drier areas in terms of forage dry matter and grain (Onyango, 1986). This makes sorghum an attractive forage crop for semi-arid areas where most of the livestock are found. However, some sorghum cultivars have anti-nutritional factors such as hydrogen cyanide and tannins which limit their utilization by animals (Onyango and Wanyoike, 1989). Where sorghum is grown specifically for forage, it is better grazed at pre-flowering stage when protein yield is more and total sugars less than at latter growth stages. However, most farmers do not normally graze their animal on forage sorghum when it is short, leafy and highly digestible due to fear of hydrogen cyanide poisoning. In such a situation sorghum

may be used as a green chop after wilting for about 24 hours to facilitate complete release of hydrogen cyanide from the macerated cells.

Silage is made from either forage or grain sorghum, but forage sorghum yields higher total dry matter, although the latter makes better quality silage because of its higher grain/stalk ratio (Onyango and Wanyoike, 1989). The hydrogen cyanide and tannin contents are reduced during the ensiling process. Silage from forage sorghum generally has a lower dry matter digestibility than maize silage (Mitaru, 1978). In countries where maize is the staple food, sorghum could thus be used as a silage crop.

The nutritional value of sorghum stalks depends on several crop factors, including the cultivar, plant maturity and ensiling. Cultivars with stalk carbohydrates are generally more palatable and more digestible than those with low sugar content. Treatment of stalks with chemicals such as urea and sodium hydroxide improves their digestibility.

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Quality of Composite Wheat/Sorghum Bread and Confectionery.

R.E. ALUKO, L.B. OLUGBEMI and C.C. NWASIKE

Food Science and Technology Research Programme, Institute for Agricultural Research, Samaru, Ahmadu Bello University, Zaria, Nigeria.

Abstract

Composite flour was produced from different ratios of mixtures of wheat and sorghum. Bread and confectioneries were baked from each mixture and evaluated for quality attributes. Increasing the amount of sorghum in composite flour diminished the quality of the baked products. At the laboratory level, good and acceptable bread was produced up to 50% substitution with sorghum. The use of improvers such as "Premier" and "Spectrum" increased loaf volume only at 30% level of sorghum substitution, with the latter being more effective. Shelf-life studies showed that the composite wheat/sorghum bread can keep for only 2 days without any sign of quality deterioration. Addition of a mould growth inhibitor extended shelf life to between 3-4 days. Addition of dried extracted gluten significantly increased the loaf volume of wheat/sorghum bread and reduced the number of cracks on the surface of the loaves.

Snacks of acceptable quality were produced from wheat/sorghum composite flour containing up to 60% sorghum. Beyond this level, the products obtained were of very low quality. Increase in level of sorghum led to increase in the amount of water needed to prepare the dough as well as the period required for proper baking. The golden brown crust colour of the baked products became dull as the level of sorghum substitution increased.

Proximate analysis of the bread products showed higher contents of oil and fibre in the composite bread than in the 100% wheat bread. The higher oil content coupled with the higher moisture content of the composite loaves probably accounted for their shorter shelf-life. However, the higher fibre content of the composite bread is of desirable nutritional significance. The composite loaves were 7.14-22.61% lower in protein content, compared to the 100% wheat bread. This may necessitate the fortification of composite bread with high protein flours. The suitability of malted sorghum for composite bread production was also investigated and the implications of the results discussed.

Introduction

Baking is a process through which cereal flours (mostly wheat flour) are converted into attractive, palatable and easily digested products. Such products include bread, biscuits, "chin-chin" and "puff-puff". Basically, the process involves mixing of the cereal flour with water, yeast, salt, fat and other desirable ingredients to form a dough of desired consistency. The dough can then be manipulated to various sizes and shapes which are subsequently hardened and cooked in a hot chamber to give what are variously known as bakery products (Kent, 1984).

The most used cereal in the baking industry world-wide is wheat. This is because wheat protein possesses a unique characteristic of forming gluten when mixed with water. This gluten has elastic properties that allow the dough to be moulded into various shapes. The gluten is also able to expand and trap gases produced by fermenting yeasts in the dough, giving a light and spongy product after baking (Kent, 1984). Most other cereal proteins lack this gluten-forming ability and, therefore, give baked products of lower quality than those from wheat flour.

In 1987, the Federal Government of Nigeria placed a ban on the importation of wheat grain and flour into the country and directed more resources towards increased local production of the crop. However, the present local production cannot meet the level of demand of the commodity by millers and bakers. The need thus arose for additional sourcing of other suitable raw materials for the baking industry to complement the shortfall in wheat production. This involves blending of the little quantity of wheat available with any of the other more abundant locally produced cereals such as sorghum, maize and millet to give what is referred to as wheat composite flour. The term "wheat composite flour" is used in this presentation as the combination of wheat flour and non-wheat flour for the production of leavened bread and other western-styled baked products (FAO, 1973).

The Food Science and Technology Research Programme of the Institute for Agricultural Research, Samaru, Nigeria, has done a lot of work in this direction. This report gives a brief account of the work on the formulation, utilization and quality improvement of wheat/sorghum composite flour.

Production of Flours From Wheat and Sorghum Grains

The wheat and sorghum grains used were procurred from local sources. The grains were first dehulled in a local machine dehuller. The machine separated most of the seed coat particles from the dehulled grains. Manual winnowing completely separated the dehulled grains from the remaining seed coat particles. The clean dehulled grains were then passed through a hammer mill and the flour from the first passage through the machine was re-milled 2-3 times until a fine flour was obtained. To obtain flour of desired particle size for baking, the milled flour was passed through a local sieve equivalent to about 120 mesh.

Formulation of Wheat/Sorghum Flour & Processing Into Bread

Three types of composite flour were produced:

a) 70% wheat + 30% sorghum
b) 60% wheat + 40% sorghum
c) 50% wheat + 50% sorghum.

These flours were then processed into bread, having added sugar to the tune of 10% of the flour, yeast (1.5%), fat (1.6%), salt (1.1%) and water in variable amounts. The content of the flour in the formula was assumed as 100%.

It was necessary to increase the quantity of wheat/sorghum composite flour in order to obtain bread of comparative size to the 100% wheat flour (control). Thus, the following quantities of flour were used:

100% wheat	-	170g
70/30 wheat/sorghum	-	230g
60/40 wheat/sorghum	-	240g
50/50 wheat/sorghum	-	250g

Each type of flour was made into dough by the bulk fermentation method. All the ingredients were added together at once and mixed at high speed in a Kenwood Mixer for a period ranging from 15 to 20 minutes. The dough was then left to ferment in the mixer until it almost doubled its initial size. This was followed by "knocking back" of the dough (using the mixer), scaling and moulding. The moulded doughs were put in oiled baking pans and allowed to proof ("rise") to maximum volume. Baking followed in an electric oven at temperatures ranging from 230-250°C. The higher temperature was for doughs from wheat/sorghum composite flours. After baking, the loaves were allowed to cool and their volume determined by amaranthus seed displacement and expressed as a ratio of the weight of the loaf, i.e. Specific Loaf Volume (SLV).

Baking Quality of Wheat/Sorghum Flour

The effects of variety and level of substitution on the quality of wheat/sorghum bread were determined. Flours from six different lines/cultivars of sorghum were blended with that of Siete cerros, the most widely grown bread wheat variety in Nigeria.

The loaf quality of the composite bread samples and 100% wheat bread are shown in Table 1. At 30% sorghum substitution, Specific Loaf Volumes(SLV) were higher than those obtained from 40% substitution. Mean SLV at 30, 40 and 50% levels of sorghum substitution were 2.21, 2.07 and 2.23 cm3/g, respectively. Bread produced up to 50% level of sorghum substitution was generally acceptable, even though the higher the level of substitution the lower the overall quality. There were no detectable consistent differences among the varieties of sorghum used in terms of bread quality.

Organoleptic Evaluation of Wheat/Sorghum Bread

Bread baked from composite wheat/sorghum (70/30) flour was subjected to organoleptic assessment among consumers in the Samaru locality. The composite bread was compared with 100% wheat bread which the consumers are used to. The results are shown in Table 2. The appearance, taste and smell of the composite bread were rated higher than the texture. The lower rating of texture is possibly due to the coarse nature of the crumb and the fact that the loaf disintegrated more than for 100% wheat bread. However, about 70% of the test population rated the overall quality either very good or good. Compared to wheat/maize bread which was rated good by about 65% of the test population (unpublished data), the wheat/sorghum bread seems more acceptable.

Table 1. Effects of varieties and levels of substitution with sorghum on quality of wheat composite flour

Flour	Specific loaf volume (cm^3/g loaf)	Drop in specific loaf volume (%)	Appearance	Texture
Control (100 % wheat flour)	3.1	-	Very smooth golden brown crust. No cracks.	Fine
30 % substitution *with sorghum* wheat + FFBL	2.32	30.1	Smooth golden brown crust. No cracks.	Fine
Wheat + L. 533	2.16	34.7	Smooth golden brown crust. Crack along one side.	Fine
Wheat + L. 181	2.22	32.9	Smooth golden brown crust. Crack along one side.	Contained large hole.
Wheat + L. 1499	2.33	29.6	Smooth golden brown crust. No cracks.	Fine
Wheat + SK. 5912	2.05	38.1	Slightly rough and golden brown crust. No cracks.	Open with large holes.
Wheat + Mori	2.19	33.8	Smooth golden brown crust. No cracks.	Fine
40 % substitution *with sorghum* wheat + FFBL	1.92	42.0	Dull brown and slightly rough crust. No cracks.	Fine
Wheat + L. 533	2.00	39.6	Dull brown and slightly rough crust. Few cracks along one side.	Fine
Wheat + L. 181	2.30	30.5	"	Fine
Wheat + L. 1499	1.95	41.1	Dull brown and slightly rough crust. Few cracks along one side.	Fine
Wheat + SK. 5912	2.25	32.3	"	Fine
Wheat + Mori	2.00	39.6	Brown and slightly rough crust. Few cracks along one side.	Fine
50 % substitution *with sorghum* wheat + FFBL	2.23	32.6	Rough, pale crust. Few cracks on the surface.	Fine
Wheat + L. 553	2.17	34.4	"	Fine
Wheat + L. 181	2.15	35.0	Smooth, pale crust. No cracks.	Fine
Wheat + L. 1499	2.15	35.0	Smooth pale crust. Few cracks on one side.	Open with small holes.
Wheat + SK. 5912	2.18	34.1	Very rough, pale crust. Lots of cracks on the surface.	"
Wheat + Mori	2.49	24.8	Very rough, pale crust but no cracks.	Open with large holes.

Table 2. Organoleptic evaluation of wheat/sorghum (70/30) bread.

Index	Appearance	Texture	Taste	Smell	Overall rating
Very good (%)	24	18	28	19	23
Good (%)	45	32	45	45	46
Fair (%)	26	35	23	26	27
Poor (%)	5	15	4	10	4

Effect of Improvers on Volume of Wheat/Sorghum Composite Bread

Two types of exotic improvers, namely "Spectrum" and "Premier", were used to enhance the loaf volume of wheat/sorghum bread. Each of the improvers at 2% level was added to wheat/sorghum flours containing 30, 40 and 50% sorghum flour. The volume of bread baked from such flours was then compared to that of bread from flours containing no improver. The results are shown in Table 3. It was evident that the improvers were effective in enhancing loaf volume only at the 30% level of substitution. Beyond this level, the volume-enhancing property of the improvers could not over-ride the volume-diminishing effect of sorghum flour. At 30% level of sorghum substitution, Spectrum was more effective than Premier in improving loaf volume. Apart from the relatively unpleasant taste of the bread containing improvers, their use is not recommended on account of cost.

Effect of External Addition of Gluten on Loaf Volume

It is a well known fact that the "rising" property of wheat flour during baking is as a result of its gluten content. Gluten is absent in sorghum flour and, thus, its use in composite flour formulation leads to a reduction in the volume of the baked bread. The use of extracted gluten to increase the bread volume of composite flour is, thus, a way of improving the quality of composite bread.

Table 3. Effect of addition of improvers on the quality of composite wheat/sorghum bread.

Improvers (2 %)	Spectrum			Premier			No improver	
Level of sorghum substitution (%)	30	40	50	30	40	50	30	40
Water absorption (%)	71	71	71	78	73	71	73	71
Fermentation (Min.)	45	36	32	32	24	25	34	36
Final proof (Min.)	38	31	30	27	26	31	26	34
Baking time (Min.)	34	34	34	42	31	32	36	34
Specific loaf volume (cm/g loaf)	2.97	2.68	2.72	2.74	2.63	2.48	2.67	2.73
Total bread score (%)*	71	67	58	72	70	64	74	71

* Total bread score: Appearance (40), Crust colour (10), Crumb colour (10), Texture (10), Grain (10), Crumb stability (10), Eating quality (10).

Addition of gluten at 1, 2 and 4% levels to 50/50 (wheat/sorghum) increased loaf volume from 600-670 cm3 (Table 4). At 60% level of sorghum substitution, the increase was more pronounced, from 600 cm^3 for the loaf without added gluten to 820 cm3 with 4% externally added gluten. Apart from the increase in loaf volume, the addition of gluten resulted in a reduction in the number and severity of cracks on the surface of the loaves. The higher the amount of gluten added, the less the number of cracks.

However, it must be stressed that the commercial use of extracted gluten for improving composite bread quality is not recommended for the Nigerian baking industry. It is indeed economically unwise, since the extracted gluten would have to be imported. This will defeat the spirit of conserving the Nation's scarce foreign exchange earnings which necessitated the banning of wheat importation.

Table 4. Effect of addition of gluten on the weight and volume of wheat/sorghum bread.

Type of composite	Added gluten (%)	Loaf weight (%)	Loaf volume (cm^3)
50 % wheat + 50 % sorghum	0	385	600
" " "	1	395	640
" " "	2	400	665
" " "	4	410	670
50 % wheat + 60 % sorghum	0	395	600
" " "	1	400	620
" " "	2	410	720
" " "	4	420	820

Shelf-life of Wheat/Sorghum Bread

The shelf-life of composite wheat/sorghum bread with and without added preservatives was determined during the hot humid season as well as in the dry cool (Harmattan) season. Two exotic preservatives, namely "Mycoban" and "Poland product", were used. Mycoban was added to a maximum of 0.3% of the flour while the Poland product was added up to 5%. There were no significant differences in weight between loaves with and without preservatives. At the 30 and 40% levels of wheat substitution with sorghum, the loaves containing Mycoban, which is the better of the two preservatives, remained fresh for up to 3 days during the hot season and for 4 days during the cool Harmattan season. The loaves containing the Poland product as well as those without any of the preservatives remained fresh for only 2 days in both seasons. The control (100% wheat) bread remained fresh for 5 days.

Malted Sorghum as Component of Wheat Composite Flour

Malting has been reported to improve the nutritive value of sorghum grain (Wu and Wall, 1980). It follows, therefore, that composite flour containing malted sorghum should have a higher nutritive value than the one containing unmalted sorghum. However, the composite flour containing malted sorghum will be expected to give bread of comparable organoleptic qualities to that containing unmalted sorghum. An investigation was, therefore, undertaken to compare the baking and organoleptic qualities of composite wheat/malted sorghum bread with those of wheat/unmalted sorghum bread.

Malted sorghum was produced according to the method of Wu and Wall (1980). Two types of malted grains were used for the composite flour formulations: (a) malted grains with roots and shoots and, (b) malted grains without roots and shoots. The grains were milled to pass through 0.5mm screen in a laboratory Wiley mill. The malted flours were used in composite flour formulations at 30% level of substitution. Bread was produced according to the procedure discussed earlier.

The results of the baking tests are shown in Table 5. Generally, the SLV of the bread containing unmalted sorghum was not significantly different from that of the bread containing malted sorghum. With the exception of the first day of germination, the loaves containing malted sorghum without roots and shoots had slightly higher SLV than those containing malted sorghum with roots and shoots. There was a general decrease in SLV of loaves containing malted sorghum with roots and shoots as malting progressed from day one to day four. This may be attributed to the increase in the quantity of roots and shoots as germination progressed. These parts do not seem to contribute much to the volume of the bread. However, the SLV of bread containing malted sorghum without roots and shoots did not change appreciably over the 4-day malting period.

Table 5. Bread-making quality of composite wheat/malted sorghum flours.

Treatment	Time (days)	Type of malted grain	Specific loaf volume ($cm^{3/8}$ loaf)	Bread characteristics
Control (ungerminated)	0	-	2.35	Smoth light brown crust. No cracks, white and cohesive crumb.
Germinated	1	With roots and shoots	2.37	Smooth light brown crust, white and cohesive crumb, No cracks.
"	1	Without roots and shoots	2.25	Smooth light brown crust, white and cohesive crumb. No cracks.
"	2	With roots and shoots	2.28	Smooth dark brown crust and crumb. No cracks. Crumb disintegrated easuly
"	2	Without roots and shoots	2.35	"
"	3	With roots and shoots	2.15	"
"	3	Without roots and shoots	2.25	"
"	4	With roots and shoots	1.95	"
"	4	Without roots and shoots	2.30	"

One major feature of the composite wheat/malted sorghum bread was the virtual non-cohesiveness of the crumb particles particularly from the second day of malting upwards. This was noticeable right from the time the oven fresh loaves cooled down. On the other hand, the loaves containing unmalted sorghum and the one-day old malt retained some degree of cohesiveness uptill the second day of baking. The fall in the degree of cohesiveness of the crumb structure with increase in day of malting may be attributed to the fall in the starch content of sorghum during malting (Wu and Wall, 1980). It is evident from these results that only the one-day old malt is suitable for baking good and acceptable bread. Increase in the germination period produces grains whose bread-making qualitites are not desirable.

Nutritional Qualities of Wheat/Sorghum Bread

The contribution of bread to the nutritional status of its consumers cannot be over-emphasised. Thus, a change from the conventional 100% wheat bread to the composite wheat/sorghum bread must not lead to significant changes in its nutritive value. This becomes note-worthy when it is realised that sorghum protein is lower both in quantity and quality than wheat protein.

The proximate composition of wheat and sorghum flours used in the composite flour formulations was determined by the appropriate AOAC (1980) method and the results are shown in Table 6. The wheat flour had a significantly higher protein content than each of the sorghum flours. The sorghum flours did not show any varietal differences in protein content. The proximate composition of composite bread at different levels of wheat substitution by sorghum was determined by the appropriate AOAC (1980) method and the results are shown in Table 7. The composite bread samples were lower in protein content than the 100% wheat bread. Increase in dilution of wheat flour with sorghum flour from 30 to 50% caused a decrease in protein content ranging from 7.14 to 22.61%. The lower protein content of the wheat/sorghum bread is a reflection of the lower protein content of sorghum when compared to wheat. It may be necessary therefore to increase the nutritional quality of wheat/sorghum bread especially at higher levels of sorghum substitution by fortifying it with legume-based protein rich flour like soyabean.

Table 6. Proximate composition of wheat and sorghum flours used in composite flour formulation*

Type of flour	Moisture (%)	% Dry matter				
		Ash (%)	Oil (%)	Protein (%)	Crude fibre (%)	Available carbohydrate (% by difference)
A) Sorghum						
L. 181	13.15	0.90	7.19	7.92	1.87	67.88
FFBL	11.21	1.05	7.39	8.73	2.26	68.43
Mori	11.06	1.24	7.57	8.58	1.68	68.93
SK. 5912	10.58	1.16	7.78	8.53	2.33	68.70
L. 1499	12.76	0.97	8.22	7.52	1.95	67.38
L. 533	12.48	0.91	7.57	8.78	2.18	67.00
B) Kano wheat flour	11.86	1.21	6.35	15.18	1.08	63.47

* Mean of 2 determinations.

Conversely, the wheat/sorghum bread had higher crude fibre content than the 100% wheat bread. This difference increased with increase in the level of sorghum in the bread. The nutritional significance of fibre lies in its ability to increase the motility of the gut and ensure the excretion of more bulky and softer stools. In this way, fibre aids in the prevention of diseases such as carcinoma of the rectum and colon, atherosclerosis, constipation and diverticulosis (Davidson et al., 1975). Thus, the higher crude fibre content of the wheat/sorghum bread is nutritionally advantageous.

The wheat/sorghum bread had significantly higher moisture content than the 100% wheat bread. This is thought to be responsible for the faster rate of deterioration in the wheat/sorghum bread when compared to the 100% wheat bread.

Table 7. Proximate composition of 100% wheat and composite loaves of bread.

Bread sample	Moisture (%)	Ash (%)	Oil (%)	Protein (%)	Reduction in protein (%)	Crude fibre (%)	Available carbohydrate (%) by difference)
	% Dry matter						
100 % wheat	32.95	0.78	0.81	11.63	-	3.28	50.55
70 % wheat + 30 % FFBL	35.98	1.26	1.05	9.66	16.94	5.85	46.20
70 % wheat + 30 % L. 181	37.61	1.22	1.52	10.37	10.83	4.88	44.40
70 % wheat + 30 % L. 1499	37.54	0.80	1.11	9.95	14.44	4.81	45.79
70 % wheat + 30 % Mori	30.03	0.83	1.39	9.95	14.44	4.36	45.44
70 % wheat + 30 % SK. 5912	36.94	1.36	1.43	10.80	7.14	5.68	43.79
70 % wheat + 30 % L. 533	36.10	0.86	1.48	10.31	11.35	4.47	46.78
60 % wheat + 40 % FFBL	35.80	1.22	1.33	10.67	8.25	6.98	44.00
60 % wheat + 40 % L. 181	34.11	0.84	1.34	9.66	16.94	5.46	48.59
60 % wheat + 40 % L. 1499	36.98	1.31	1.37	9.89	14.96	5.63	44.82
60 % wheat + 40 % Mori	34.77	0.78	1.26	9.95	14.44	5.51	47.73
60 % wheat + 40 % SK. 5912	33.20	0.88	1.53	9.30	20.02	6.87	48.22
60 % wheat + 40 % L. 533	34.55	0.83	1.63	9.89	14.96	5.92	47.18
50 % wheat + 50 % FFBL	37.94	1.85	1.42	10.13	12.90	7.52	41.14
50 % wheat + 50 % L. 181	38.32	1.42	1.30	9.00	22.61	6.35	43.61
50 % wheat + 50 % L. 1499	36.62	0.76	1.69	10.25	11.86	6.82	43.86
50 % wheat + 50 % Mori	38.43	1.20	1.66	10.31	11.35	6.24	42.16
50 % wheat + 50 % SK. 5912	38.72	0.73	1.56	9.36	19.52	7.38	42.25
50 % wheat + 50 % L. 533	36.49	1.04	1.05	10.55	9.28	6.75	44.12

Quality of Wheat/Sorghum Confectionery Products

a) ***Bread Rolls***: This was produced using the following formula: Composite flour = 100% + sugar = 16% of flour + yeast = 3% of flour + salt = 1.5% of flour + fat = 3.5% of flour + water in variable amounts.

The flour, sugar, fat and salt were measured into the mixing bowl. The yeast was separately mixed with warm water and kept for about five minutes to become activated. The activated yeast was then added to the dry ingredients and mixed thoroughly into a dough of desired consistency using optimum amount of water. The dough was covered and allowed to rise to double its initial size and then cut and rolled into different shapes. They were allowed to proof to maximum height before baking in the oven at 250°C. The results are shown in Table 8.

The amount of water required for dough of required consistency increased with increase in the level of sorghum flour. This was reflected in the yield of dough which also increased with increase in level of sorghum substitution. Baking period

was longer at higher levels of sorghum substitution. This might be due to the lower level of lysine in sorghum when compared to wheat flour. Lysine is involved in the caramelization process which produces the golden brown colour of baked bread. This was further evident by the fact that the intensity of the golden brown crust colour decreased with increase in the level of sorghum substitution.

Table 8. Effect of substituting wheat flour with sorghum on the quality of composite bread rolls.

Flour composition	Absorption of water (%)	Final proof (Min.)	Yield of dough (%)	Baking time (Min.)	Specific roll volume (cm/g)	Total bread score (%)	Characteristics
70 % wheat flour + 30 % sorghum flour	69.9	30	170.2	15	3.42	77	Good
60 % wheat flour + 40 % sorghum flour	69.9	20	170.2	20	2.97	68	Good
50 % wheat flour + 50 % sorghum flour	71.8	20	176.4	30	2.57	62	Fair
40 % wheat flour + 60 % sorghum flour	71.8	20	176.4	35	2.56	48	Acceptable
30 % wheat flour + 73 % sorghum flour	72.8	25	177.4	50	2.41	35	Taste of sorghum flour, hard texture,
20 % wheat flour + 80 % sorghum flour	74.5	25	186.6	60	1.89	28	Taste of sorghum flour, hard texture, broken surface very brittle

The Specific Bread Volume (SBV) decreased with increase in the quantity of sorghum flour contained in the composite flour. The total bread score which is a measure of organoleptic quality of the bread was also inversely related to the level of sorghum flour. Composite flour containing either 30 or 40% sorghum flour produced bread rolls with good characteristics, while those containing 50 or 60% levels were of average quality. At 70% level and above, the astringent taste of sorghum became very pronounced in the product. Moreover, the surface became very rough, hard and broken in many places and the crumb was very brittle. All these features rendered the composite bread rolls containing more than 60% sorghum a very low quality product and consequently unacceptable.

b) ***Puff-puff:*** This was produced according to the following formula: Composite flour = 100% + sugar = 20% of flour + yeast = 3% of flour + water in variable amounts.

The flour and sugar were measured into a mixing bowl. Yeast was weighed into a cup containing a little quantity of warm water (37-38°C) and kept aside for about five minutes to get activated. The yeast was then added to the flour and sugar in the bowl and mixed together with water until a smooth paste was obtained. The mixture was left to rise and double in size. Small quantities were then scooped from the mixture, dropped in hot oil and allowed to fry till the colour became deep brown. The results obtained are shown in Table 9.

The quality of the wheat/sorghum puff-puff varied according to the type of sorghum used. Among the three types of sorghum tested, the Farafara variety which is white in colour, produced puff-puff of the best quality. While total snack score (Max. = 40) ranged from 30 to 39 for Farafara, it was 18 to 37 for the other two varieties. Farafara produced puff-puff of good quality even at 50% level of substitution while for SSV.9, only the 30% substitution was good enough. Sorghum variety KSV.12 did not produce good puff-puff even at 30% level of substitution. At 75% level of sorghum substitution, it was still possible to fry puff-puff using Farafara flour, but for KSV.12 and SSV.9, the dough disintegrated in the frying oil. The brown colour of the puff-puff became duller with increase in the quantity of sorghum present in the dough.

c) ***Cookies:*** These were produced according to the following formula: Composite flour = 100% + sugar = 30% of flour + fat = 37.5-60.5% of flour + baking powder = 3% of flour + water in variable amount.

All the ingredients, except water, were first mixed together thoroughly in a mixing bowl. Water was added to the dry mixture and made into a soft ball. The ball was flattened into a sheet of about one-third inch thick and cut into various shapes before baking in the oven at 250°C. The results are shown in Table 9.

Table 9. Organoleptic quality of composite wheat/sorghum snacks.

Type of snack	Control (100 %) wheat flour)	Sorghum lines/varieties (level of substitution)								
		K S V. 12			S S V. 9			Farafara		
		30 %	50 %	75 %	30 %	50 %	75 %	30 %	50 %	75 %
Puff-puff:										
T S S*	40	27	25	18	30	35	22	39	38	30
Reduction in TSS (%)	-	32.5	37,5	55	7.5	12.5	45	2.5	5.0	25
Characteristics	V. good	Heavy, small volume	Heavy, small volume, dark colour	Dough disinter-grates during frying	Good	Heavy dark	Dough disinte-grates during frying	V. good	Good	Small volume and heavy
Cookies:										
T S S*	40	28	26	-	26	26	-	34	32	-
Reduction in TSS (%)	-	30	35	-	35	35	-	15	20	-
Characteristics	V. good	Pale, rough texture	Pale, rough texture		Pale, rough tex-ture, tends to crumble easily	Pale, rough texture, tends to crumble easily		Fair	Rough texture	

* TSS = Total Snack Score: (texture 10, colour 10, taste 10, acceptability 10, Max. = 40 points)

As was observed for puff-puff, the Farafara sorghum flour produced cookies of higher quality than KSV.12 and SSV.9 flours. Total snack score ranged from 32-34 for cookies made from Farafara flour and 26-28 for KSV.12 and SSV.9 flours. Also the colours were darker and there was increased tendency to crumble at higher levels of sorghum substitution.

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PART V

Cropping systems and *striga* research

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Soil Testing as a Tool for Soil Fertility Management in the Semi-Arid Zone of Sub-Saharan Africa.

A.A. AGBOOLA and G.O. ADEOYE.

Department of Agronomy University of Ibadan, Ibadan, Nigeria.

Abstract

Agriculture in many parts of the semi-arid region of Africa is now undergoing a rapid transformation from peasant farming which practices shifting cultivation to commercial agriculture under intensive culture. The effect of this trend has been a rise in the use of commercial fertilizers to increase and maintain the fertility status of the soil.

The low productivity of crops is undoubtedly due to a variety of factors of which the blanket use of fertilizers without soil testing is one. Results of various experiments have confirmed that crop yield increases 2 to 5 fold by proper fertilisation through soil testing.

Poor response to fertilizer use has also been traced to the use of fertilizer technology developed under monoculture to multiple cropping. Such problems have been solved by soil testing programmes based on site characterisation and developing fertilizer factor using fractional recovery to predict the amount of fertilizer (kg) required to increase soil nutrient status by one mg. This approach has proved effective and efficient for both multiple and sole cropping.

Introduction

In Africa, human population is increasing at more than 3% annually while food production is stagnant in some areas and declining in others, thus creating a food deficit estimated at 30%. At present, Africa has inadequate foreign exchange to devote in the importation of basic food items from other nations. Unfortunately, most African soils are invariably very fragile and inherently infertile for the sustainance of agriculture (Agboola, 1990). Such fragile soils have, therefore, to be well managed in order to ensure the sustained needs for food and fibre.

One of the resources needed for the improved use of fragile and infertile soils is fertilizer for the provision of nutrient elements. In order to efficiently use fertilizers, the soil must be well understood in terms of its physical, chemical and biological characteristics. Because the soil easily gets saturated following improper use of fertilizers even in small amounts, and is therefore, prone to nutrient imbalance, the need for soil testing becomes an inevitable component of attaining sustainable agriculture.

Soil testing involves the rapid chemical analysis of the soil in order to determine, assess and evaluate its nutrient status with the aim of making fertilizer recommendations. The use of fertilizer based on soil testing has revolutionised

agriculture in the temperate world, but the approach is yet to find complete acceptance and, indeed, understanding in much of Africa. This presentation is, therefore, intended to highlight the essentials of soil testing with the view of adopting the approach as a tool for soil fertility management especially in semi-arid Africa with its characteristic infertile, shallow and fragile soils.

Present Approach

Fertilizer recommendations to farmers in virtually all of Africa is presently not based on the prior determination of the nutrient status of the soil, but rather on blanket and generalised application rates developed through multi-locational trials. While the present practice may be the best possible approach in consideration of available facilities, expertise and knowledge relating to efficient fertilizer use and soil management, it is technically "faulty" in the fact that the use of fertilizers in any one field or crop has little bearing with the soil on which the application is made.

Soil Parameters for Determination

While under temperate conditions the determination of such few soil parameters as PH, extractable P and K may suffice in the routine soil analysis for fertilizer recommendations, in the tropics and especially under semi-arid agriculture, additional measurements such as organic matter, soil physical characteristics and a few relevant micro-nutrients need to be included in the soil testing programme. Under low organic matter contents, as is characteristic of especially semi-arid soils, response to applied inorganic (chemical) fertilizers is limited. Indeed, there is a high correlation between soil organic matter and all other soil nutrients.

The need to include soil physical parameters is dictated by the universal fact that satisfacory plant growth depends upon an effective rooting system such that any physical factor tending to limit root extension is liable to reduce uptake of moisture and nutrients and, therefore, limits crop growth and yield. Associated with this is the effect of the clay content of the soil which has a direct effect on crop performance and yield.

Among micro-nutrients which may need to be determined as part of an effective soil testing programme, especially under semi-arid conditions, are zinc and copper. Sulphur may also be determined.

Soil Sampling

There is need to develop a sound soil sampling procedure especially since laboratory analysis is normally based on relatively minute soil quantities to represent large hectarages. If the soil sampling technique is poor, then the results obtained will necessarily turn out poor. Indeed, the highly variable nature of tropical soils even within short distances makes the need for the proper sampling of soils imperative.

Field experience has shown that there is no significant difference between sampling at 0-15 cm and 0-30 cm. Consequently, a sampling depth of 0-15 cm is

suggested. With regard to the number of representative composite samples that are adequate for routine analysis, Agboola and Adeoye (1988) have reported this to be highly dependent on the soil types, nutrient elements of interest, sampling time and cropping history, but have suggested 30 composite samples per hectare and 30 core soil samples per 20m2.

Choice of Soil Extractants

In any soil testing programme, the need for suitable extractants is essential. On the basis of differences in soil geology, mineralogy as well as physical and chemical characteristics and forms of soil nutrients, extractants developed for use under temperate environments are not necessarily suitable for tropical soils. The need for the correct choice of extractants and, by implications, analytical methodology cannot be over-emphasized.

In recognition of the need for suitable soil extractants, the University of Ibadan, Nigeria, has developed various Bifluorides ($NH_4F.HF$) as extractants for soil P and K. The correlation between O.1M $NH_4F.HF$ at different p^Hs3-8 and the standard Bray P-1 extractant is highly significant between p^{H0} 5 and 7. which is the critical p^H range for nutrient availability to most crops in tropical soils (Table 1). Plant uptake does not correlate well in heterogenous soils when Bray P-1 is used as the soil P extractant. The main advantage of $NH_4F.HF$ as an extractant is that is is self-buffering, having both a basic and an acidic end. The use of either IN NH_4OAC at pH=7 or 0.1M $NH_4F.HF$ as K extractants is a question of choice (Table 2). Both extractants have been shown to work well for K evaluation in heterogenous soils, but repeated experience at Ibadan has also shown that IN NH_40AC p^H 7 is unsuitable for K evaluation in sedimentary soils while 0.1M$NH_4F.HF$ performs well. With regard to modifications in shaking/stirring time and the lag before the filtering of extractants, the results in Table 2 have confirmed that 5 minutes shaking or stirring is adequate for NH_4OAC p^H 7 instead of the 30 minutes specified; but samples shaken/stirred for 5 minutes cannot be filtered until after 5 minutes.

Table 1. Correlation (r) between plant P-uptake and various Bifluoride and Bray extractant in homogenous and heterogenous soils of humid tropics.

Plant uptake	0.1M $NH_4F.AF$					Bray's P-1
	p^H 3.0	p^H 5.0	p^H 5.4	p^H 6.0	p^H 8.0	
Homogenous soils	0.480**	0.731***	0.703***	0.699***	0.740***	0.663**
Heterogenous soils	0.511**	0.832***	0.811***	0.722***	0.566***	0.382 ns

* Significant at 5%
** Significant at 1%
*** Significant at 0.1%
ns Not significant

Chemical Soil Test for Fertilizer Recommendation

The philosophy for an effective chemical soil test for making fertilizer recommendation must be based on the need to maintain the native fertility of the soil at an optimum level at all times. In this way, the amount of fertilizer needed to satisfy the soil sorption capacity is catered for in the fertilizer calculation so that enough nutrient is released for the crop use. This infers that the nutrient requirement of each crop will dictate its critical level in the soil to give optimum yield. By "critical" level it is inferred the soil nutrient level below which there is assured response to fertilizer input and above which there is no assured response. Thus, the critical level is, indeed, an important tool in fertilizer recommendations.

Table 2. Simple correlation coefficient (r) relating extractable K by shaking and stirring with IN NH_4N $NH_4F.HF$ extractant to K uptake by Maize.

Lag period before filtering	5 minutes				15 minutes				30 minutes			
	IN NH_4 OAC		0.IN NH_4 F.HF		IN NH_4 OAC		IN NH_4 F.HF		IN NH_4 OAC		O.IN NH_4 F.HF	
	Shaking	Stirring	Shaking	Stirring	Shaking	Stirring	Shaking	Stirring	Shaking	Stirring	Shaking	Stirring
Immediately	0.13 ns	0.69***	0.18 ns	0.72***	0.41	0.86***	0.63***	0.33 ns	0.52***	0.84***	0.65***	.67***
5 minutes	0.77***	0.70***	0.67***	0.61***	0.85***	0.66***	0.60***	0.15 ns	0.73***	0.81***	0.55**	.68***
15 minutes	0.71***	0.53**	0.04 ns	0.47**	0.73***	0.59***	0.60***	0.76***	0.66***	0.76***	0.59***	.33 ns
20 minutes	0.16 ns	0.66***	0.62***	0.69***	0.59***	0.80***	0.53**	0.67***	0.75***	0.79***	0.59***	.33 ns

* Significant at 5%
** Significant at 1%
*** Significant at 0.1%

Scientists at the University of Ibadan have computed and used "fertilizer factors" developed from the concept of fractional recovery - the proportion of added P extracted by an extractant after a period of time to determine their fixation power. A fertilizer factor is taken as the amount of a nutrient element (in kg) that is required to raise the soil test level by 1mg. Table 3 gives a range of fertilizer factors for the savanna region of Nigeria. Essentially, therefore, a fertilizer factor of less than 1.0 indicates that the soil may not need the application of fertilizer for that element.

To exemplify the use of critical level and fertilizer factor in the computation of fertilizer recommendations, assume a critical level of P nutrient using Bray P-1 = 10 mg/kg; soil test level of available P = 7 mg/kg; and fertilizer factor for P = 3.1 mg/kg; then the mount of P required for the particular soil/location:

= (10-7) 3.1 x 2
= 3 x 3.1 x 2
= 18.6 or approximately **20 kg P/ha**

The use of the fertilizer factor has been found to be applicable for both sole and inter-cropping.

Table 3. Range and mean fertilizer factor (mg/k) for savanna region in Nigeria.

Nutrient	Mean	Range
P	3.1	1.0-6.9
F	1.9	0.8-4.0
Cu	2.1	0.8-5.0
Mn	0.8	0.2-2.5
Zn	6.4	4.7-8.4
K	4.5	2.1-8.2
Mg	2.0	2.1-6.0

With regard to organic fertilizers, the use of fertilizer factor at Ibadan especially in the humid tropics has led to the suggestion that where the soil nitrogen level is less than 0.15% N, about 2 tons of organic fertilizer/manure should be applied along with the other basal nutrients as determined by chemical soil tests.

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Production Agronomy of Sorghum-Based Systems in the West African Semi-Arid Tropics: Present Status and Research Challenges.

S.V.R. SHETTY, D. SOGODOGO and M.V.K. SIVAKUMAR*.

ICRISAT/Mali Bilateral Programme, Bamako, Mali.
and
**ICRISAT Sahelian Centre, Niamey, Niger.*

Abstract

During the last 20 years the productivity of sorghum (*Sorghum bicolor* L.) in the West African semi-arid tropics has remained stagnant. It is estimated that to meet the food demands of the growing population in the Sahelian countries, sorghum production should be accelerated at the rate of 4% per year over the next 15 years. In this paper, the current state of knowledge on the agronomy of the crop is reviewed and research priorities for the nineties identified. In the presentation, research on sorghum-based cropping systems in Mali has received particular attention in order to highlight the importance of effective collaborative research and the need for strengthening the national research system in the region.

From a description of the resource base of sorghum systems, the paper identifies variations in rainfall, soils, cultivars as well as traditional systems as the major constraints limiting production. A summary of soil and water management research along with appropriate management techniques to improve infiltration, storage and use of soil water is given. Fertility management studies related to crop response to fertilizer rates and placement, organic matter recycling and N-contribution by legumes are reviewed. The advantages and disadvantages of traditional cultivars and systems are described and on-going research on inter, relay, ratoon, sequential and rotational cropping systems are also reviewed. Evidence primarily from collaborative research in Mali is used as the basis for promising developments in systems manipulation that have been attempted towards increased sorghum production and strengthening the national programmes to meet future research challenges. Finally, the current available technologies and their prospects for improving the stability and productivity of sorghum based systems in the Sudano-Sahelian and Sudano-Guinean zones are synthesized along with future research priorities. The importance of and needs for close links between resource management and crop improvement research, long-term operational scale integrative studies, research on sustainability, strategies for meeting dual objectives of producing technologies and strengthening national research base are emphasized.

Introduction

Sorghum (*Sorghum bicolor* L.) is one of the major rainfed food crops of the West African semi-arid tropics (WASAT) and is grown in all the countries, stretching from the Atlantic ocean in the west to Chad and Central African Republic in the

east. It is an important component of local food production and consumption systems of Nigeria, Burkina Faso, Cameroon, Mali, Niger, Gambia, Senegal and Chad. It is usually grown in association with other crops such as pearl millet, maize, cowpea, groundnuts, cotton and vegetables. Although sorghum production in WASAT has, in general, kept pace with the growing population during the last 20 years, the yields/ha have remained stagnant, with some estimates showing a declining trend (Matlon, 1987). For example, in Burkina Faso calculated yields of sorghum in 1980 at the 1963 productivity levels were negative to the extent of 32%, indicating that increased hectarage accounted for the total production. It is now estimated that to meet the food demands of growing population in the Sahelian countries, sorghum production should be accelerated at the rate of at least 4% per year during the next 15 years (Dione, 1991).

Several factors are responsible for the low sorghum productivity in WASAT. One of the most important is climatic. The low and highly variable rainfall coupled with the high demand for water imposed by the constantly high temperatures and radiation throughout the year causes large variability in crop yields from year to year. In a large belt across West Africa during the period 1968 to 73, there were serious crop failures. In such dry years, the demand for food far exceeded the limited production capacity with traditional agricultural methods. Even more serious is the apparent degradation of soils and vegetation. Hence, there is an urgent need to develop new technologies based on resource management research which is aimed at making the most efficient use of the limited climatic and soil resources for achieving greater yield stability while protecting the productivity of the fragile soils in the region. Development and diffusion of improved technologies to improve productivity and increase in cropping intensity are, therefore, considered essential to attain self-sufficiency.

Resource Base of Sorghum Production Systems

Sorghum is one of the important crops in the Sudanian and Northern Guinean savanna zones. It is also grown in the Sahel especially near swamps and on the better soils. The major sources of variation in the production of sorghum in the WASAT are rainfall and soils and low potential systems.

a) ***Rainfall in WASAT.*** In West Africa, the rainfall gradients are very steep (Fig. 1). The further south one goes from the Saharan margin, the greater the rainfall. The mean annual rainfall increases 30 fold from 100 mm near the Sahara desert to 1500 mm extreme south near 12 latitude --approximately one mm/km. The rainfall is usually limited to the months of May to October. Aridity prevails during the rest of the year and is most pronounced from December to February. The increasing rainfall from Sahara down to the Equator creates distinct vegetation patterns in West Africa.

As earlier mentioned, rainfall is low, variable and undependable. It shows large variations in time and space. Temporal or time dependent variations are quite common. The coefficient of variation of annual rainfall ranges between 15-30%. For example, the variation in mean annual rainfall at Banfora in Burkina Faso (Fig. 2) over the last 64 years is about 25%. Although the mean annual rainfall at this

location is 1148 mm (as represented by the horizontal line), from 1968 onwards the rainfall has been below normal and in 1983 it was only 480 mm. Rainfall in West Africa is variable not only from year to year but also from month to month within the same year.

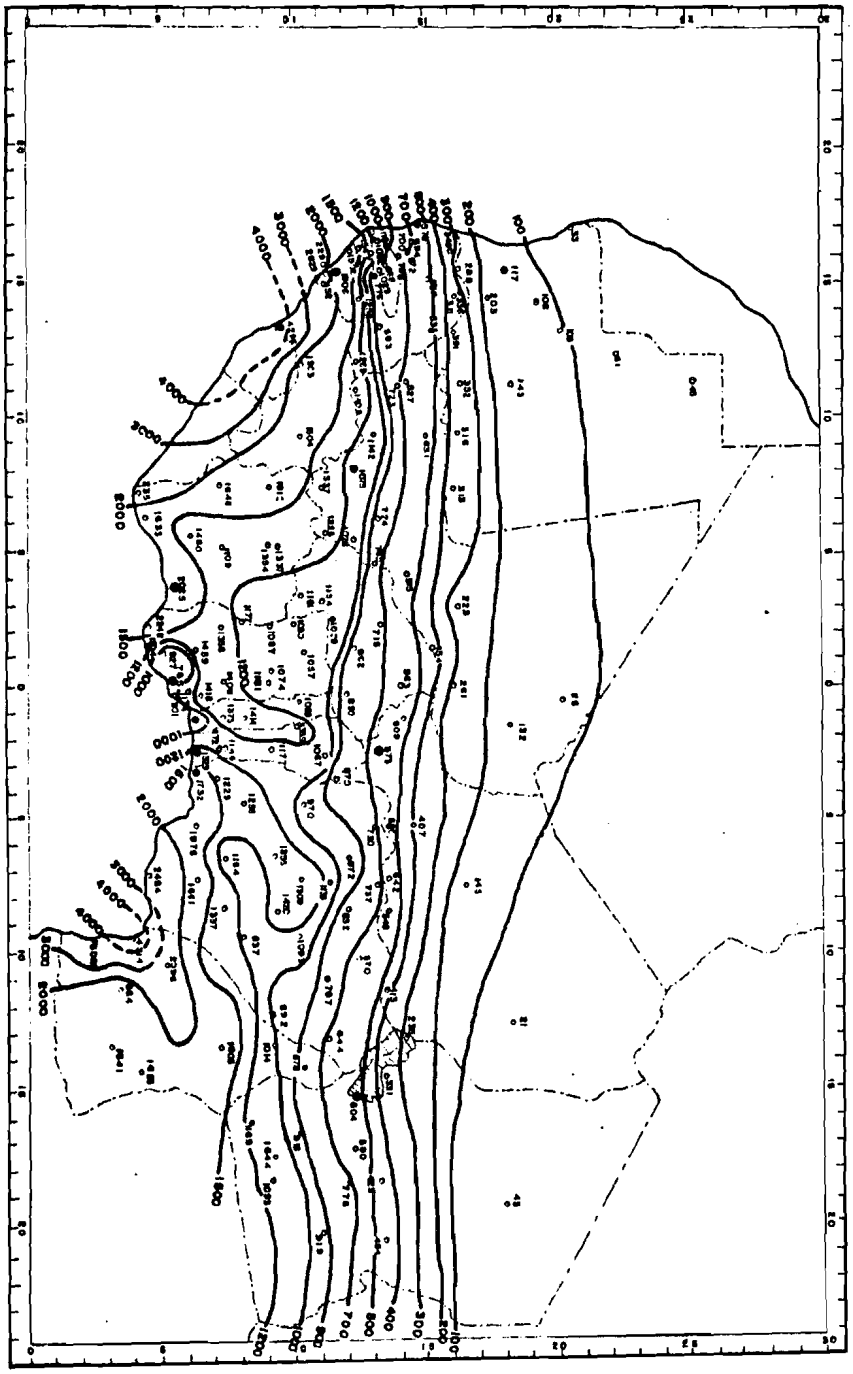

Fig. 1. Mean annual rainfall in West Africa

This sort of variation leads to instability in the traditional crop production systems. The unusual feature of WASAT is the extreme persistence on the order of one or two decades. Persistent periods with rainfall 30-50% above or below the mean are common. For example, in 1950 rainfall all over West Africa was above normal and at some locations rainfall was as much as 250% above normal. However, since about 1970 rainfall has been below normal over the entire region.

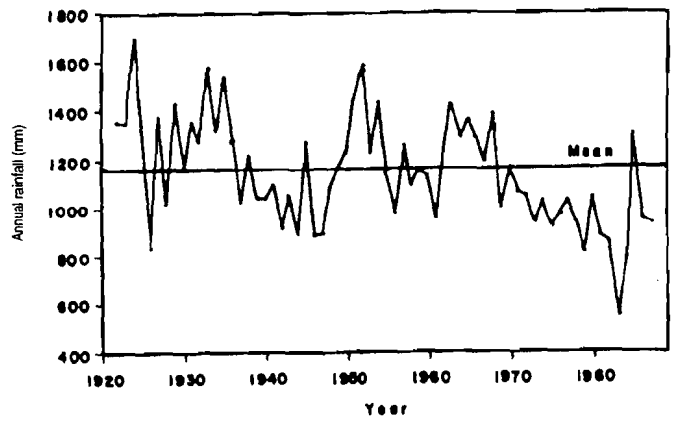

Fig. 2. Annual rainfall variation at Banfora, Burkina Faso

The rainfall fluctuations are associated with a preferred geographic pattern of rainfall variability. This feature was examined using long-term rainfall data for Burkina Faso. Data were averaged for all years before and after 1969 to examine the effect of the droughts after 1969 on the long-term averages of rainfall. Rainfall isohyets were displaced almost upto 150 km in some places, reflecting thereby the serious risk to cropping. These patterns indicate that conditions of abnormal rainfall are nearly continental in extent.

Rain in West Africa often occurs in short but intense rain storms. The rainfall intensities usually range between 20-60 mm/hr, with high values reaching 120-160 mm/hr and resulting in heavy soil loss. Under such conditions, run-off is quite common leading to a low effective rainfall.

In the Sudanian bioclimatic zone, the mean annual rainfall varies from 700-1000 mm and the length of the growing ranges from 100-150 days. In the Northern Guinean zone, the high mean annual rainfall, ranging from 100-1300 mm, permits a longer growing period for the crops in excess of 150 days. Leaching of nutrients and soil erosion are the major problems in this zone. Throughout the WASAT the rainfall variability is high during the early (planting period) and later (flowering and maturity period) parts of the growing season. The annual potential evaporation varies from 2-4 times the average annual rainfall, highest in May and September, again during planting and grain filling periods. The risks due to early and late season moisture stress are, therefore, greater.

b) ***Soils of WASAT.*** There are about 16 major soil types in West Africa which vary widely in their physical and hydraulic properties and hence the potential they offer for sorghum production. Using the length of the growing season as the major criterion, Sivakumar (1986) described the soil climatic zonation for the sorghum growing zones.

Generally, in the Sudanian zone, Luvisols are the major soil unit while in the Northern Guinean zone Luvisols, Lithosols, Nitosols and Acrisols are the major soil units. However, within the rainfall zones various soil types occur, usually linked to specific position in the topography. Shallow, gravelly soils are associated in upland areas whereas deeper sandy loam or silty loam soils occur in the slopes. Soils of the sorghum production systems are mostly Alfisols, with low clay (mostly kaolinitic type) content whose water-holding capacity is low. The soils are highly weathered, with low exchangeable cations-CEC being less than 10 meq/100 gm. The soils are poor in inherent fertility and organic matter. They are particularly inert, tend to restrict water infiltration and are susceptible to compaction which, when combined with their shallow depth, result in low water-holding capacity and poor fertilizer use efficiency. Further, under continuous cultivation most of these soils are fragile, subject to high risk of acidification, aluminium toxicity and erosion.

Low water-holding capacity with irregular rainfall and low soil fertility combine to make sorghum farming risky. Moreover, drought conditions during the last 15 years have accentuated the problem of low soil moisture, resulting in poor sorghum production in the Sudano-Sahelian zone.

c) ***Traditional Varieties and Cropping Systems.*** Traditional sorghum varieties are tall, late, photoperiod sensitive and have poor harvest indices. Average grain yields in the normal rainfall years range from 400-900 kg/ha in drier to wetter areas. In some areas, stover is used for fencing, roof construction and also as animal feed. The maturity cycle is closely related to the rainfall duration and latitude of a given location. Though their yield potential is low, they are well adapted to the traditional agriculture, with good seedling vigour under conditions of environmental stress. However, they have low response to improved soil, crop, water and fertility management treatments. The sorghum-based farming systems over the years have evolved to adapt to the local conditions. In the south where the season is long, various cereal/cereal or cereal/legume combinations are common. The systems also vary with soil types. A combination of short season photoperiod insensitive cereal such as millet with a full season photoperiod sensitive sorghum is common. In the north where the rainy season is shorter, a shorter cycle photoperiod sensitive sorghum is planted often with cowpea as a secondary crop.

Cropping systems on post-rainy residual moisture are locally important in basins along the Senegal river, Niger river and Lake Chad. Typically, residual moisture sorghums are late maturing and responsive to photoperiod.

The sorghum-based cropping systems in WASAT are highly diversified, with a large number of crops cultivated in often complex intercrop and rotation systems. Even in major sorghum areas, sorghum rarely occupied greater than 50 percent of total cultivated area. These diversified systems aim to satisfy different dietary

requirements and to make efficient use of labour and other resources. The systems have historically been extensive with low use of non-labour inputs. The crop is normally grown at low density ranging from 10,000 to 20,000 plants/ha. Application rates of organic matter are low, chemical and fertilizer use are negligible and mechanical tillage before planting is practised only in some areas.

Recently, demographic pressures are forcing reduction in fallow periods and sorghum cultivation is expanding to marginal soils that are fragile with low production potential. Labour availability is also decreasing as more labour are attracted to urban areas. In spite of these new trends, traditional low input system is predominant, resulting in stagnant yields and decline in the aggregate output per capita (Matlon, 1987). Further, these patterns have resulted in increasing problems of soil degradation and thus threatening sustainability.

Agronomy of Sorghum-Based Systems

In WASAT, sorghum is grown as a single crop or it may be a component of more complex multiple cropping systems. However, most of the past agronomic research was oriented towards development of production technologies to overcome the constraints to sole crop production. It is only recently that a concerted effort was made to consider cropping systems in crop management research. A brief review of sorghum agronomic research results available in WASAT is summarized below.

a) ***Soil and Water Management.*** Most sorghum soils are prone to degradation resulting in severe erosion and run off. The soil and climatic conditions of WASAT also impair root development and, thus, water and nutrient uptake. The following are some of the soil management techniques studied to manipulate the water infiltration, storage and use of soil water.

i. ***Soil Tillage*** Experiments conducted at moderately high fertility have shown that ploughing has consistent beneficial effects on crop growth, with sorghum yield increases averaging about 25%. This is attributed to better root growth and development, reduced weed emergence, improved soil porosity and structure, hydric regime, soil organic matter and microbial activity and improved infiltration, water conservation and stored water uptake by better root development (Nicou and Charreau, 1985). Repeated ploughing has been found to accelerate oxidation and mineralization of humus by contributing to microbial activity and biochemical processes. End of the season ploughing has also been shown to improve conservation of water during the dry season by reducing evaporation and through the suppression and incorporation of vegetation on the soil surface (Dancette and Nicou, 1974).

Though ridging is known to trap water, prevent run off and make more water available to the plants, earlier research on ridging of sorghum has shown inconsistent results, depending on environmental and management factors. However, recent research in Mali (Kouyate and Wendt, 1991) has clearly shown that depending on rainfall, the yield advantages through ridging ranged from 10% (1986, above normal rainfall) to 195% (1987, below normal rainfall). Research results have also shown that the benefits of tied-ridging depend on environmental

conditions. Yield response is higher under conditions of soil moisture stress and where soil fertility is not limiting. Average increments of up to 950 kg/ha of sorghum have been observed by ICRISAT on a research station where medium to high doses of NPK fertilizer have been applied (Perrier, 1987). Deep ploughing and tied-ridging together have shown to have contributed to improved fertilizer and water use and thus improved sorghum productivity irrespective of the amount of rainfall received (Kouyate and Wendt, 1991).

It is now well known that ploughing does improve sorghum productivity. There are also clear indications that combining tillage with additional management treatments such as deep ploughing, added fertilizer and tied-ridging would also improve both water and fertilizer use efficiency. However, at the farmer's level only a small portion of total sorghum area is ploughed before planting and that which is ploughed is generally poorly done, resulting in insignificant yield effects (Matlon, 1987).

ii) ***Mulching.*** Leaving crop residues on the soil surface and the application of free cut straw as a soil cover are known to reduce run-off and erosion, increase infiltration, improve soil structure, reduce evaporation and soil temperature and enhance soil organic matter. However, the current results on the yield effects of mulching are often contradictory (Matlon, 1987, Nicou and Charreau, 1985). These differences may again be explained by variation in soil types, topography and rainfall patterns. Though ICRISAT has observed yield increases varying between 50-200% for both local and improved sorghum varieties with rice straw mulching in Burkina Faso, these are yet to be confirmed in on-farm tests (ICRISAT, 1985). The unavailability and increasing demand for straw seriously challenge mulching as a general recommendation throughtout WASAT. Another problem associated with the use of mulches is the need for special equipment for planting and weeding and for use of herbicides.

iii. ***Contour Bunds and Strip Cropping.*** Although practices such as construction of dirt contour bunds across gentle field slopes and contour placement of narrow bands of permanent vegetation between cultivated fields and rock based small-scale water harvesting bund systems in the environmentally degraded areas have been successful in bringing highly eroded, abandoned fields back into production, their potential in increasing yield on currently cultivated fields has not yet been determined.

It is evident from the limited literature available for WASAT that no soil and water management technique is universal and that the performance of each of them depends on rainfall, soil type, topography and farming system. A combination of tillage and anti-erosion techniques offers some advantages and at the same time some constraints as well. Reviewing the past work on soil and water management, Nicou and Charreau (1985) recommended early tillage in low lands, tillage and contour planting in mid slopes (depending on contours) and shallow cultivation and tied-ridging after rains in upper slopes and in areas that could not be tilled before sowing.

b) **Soil Fertility Management**

Nitrogen and phosphorous are the most limiting nutrients in the soils of predominant sorghum growing areas. Potassium and some minor and trace elements can also be limiting under intensive cropping. Past research has clearly shown profitable economic returns to combined application of N and P at relatively low rates (Pieri, 1985). In Mali, 19 out of 21 experiments have shown response to added N and 21 out of 28 experiments have shown response to added P, leading to the recommendation of 46 kg N and 22 kg P205 to sorghum (Traore, 1988). Similar results were also observed in Nigeria (Harkness *et al.*, 1987).

However, in most of the fertilizer trials in West Africa the gains noted were only about 5-10 kg sorghum per kg of fertilizer. Further, there is also increasing evidence that continuous applications of nitrogenous fertilizer can result in long-term reduction in soil fertility. IRAT trials (Pieri, 1985) have shown that chemical fertilizer applications over the long-term result in decline in sorghum yields due to soil potassium deficiences, acidification and aluminium toxicity. Only large applications of transformed organic products such as compost and animal manure were found to counteract these negative effects. Manures combine all the advantages of positive effects on potassium nutrition, suppression of aluminium toxicity and positive effects on nitrogen supply. The use of organic manures, mulching, and composting, therefore, significantly help in maintaining soil fertility. Cropping systems involving legumes also help in nitrogen balance by contributing biologically-fixed nitrogen (Schmidt and Frey, 1990). Farming techniques such as tillage, manuring and liming increase N-fixation by legumes (Pieri, 1985).

In some areas, the susceptibility of sorghum to extreme levels of certain elements such as high aluminium in acid soils, high iron and manganese levels has also been demonstrated (Doumbia, 1990).

Because of the presence of large scale deposits of rock phosphate in West Africa, considerable emphasis is now being given to accelerate its production and distribution. Trials have confirmed significant effects (particularly residual) of granulated rock phosphate. However, present use of rock phosphate is considered less economical because of high transportation costs and the difficulties encountered in its application and incorporation and the generally long delay in realizing the full yield benefits. Recent research on acidulated forms of rock phosphate show promise in overcoming some of these problems.

It is now well known that in WASAT soil fertility maintenance is a prime technique to improve crop productivity. Generally, sorghum does not receive artificial fertilizers because of economic considerations. This could, however, change if better prices were paid for the grain. A combination of low rates of mineral fertilizer, recycling of organic residues, application of animal manures, incorporation of legumes in the cropping systems for biological N-fixation and also optimum use of local mineral sources such as natural phosphates help in long-term maintenance of soil fertility to improve productivity and stability of the crop.

c) ***Weed Control.*** Though in some areas weeding with oxen is practised, most of the weeding is done by hand. Because of labour shortage and soil condition, weeding is seldom completed early enough to avoid yield losses (Shetty, 1978). Many herbicides have been evaluated for sorghum in the region particularly in Nigeria and Mali (Lagoke and Konate, personal communications), but the adoption of herbicides at the farm level is negligible. Development of low-cost weeding equipments and the use of animal traction are being encouraged in WASAT (Rao et al., 1989).

d) ***Improved Cultivars.*** Local sorghum cultivars are characterized by good seedling vigour, tillering ability, rapid root development, photoperiod sensitivity and good resistance to biological and physical stresses. However, they have a limited yield potential with poor harvest index (Goldsworthy, 1970) and their response to added inputs is also poor. Further, their long cycle makes them sensitive to late season droughts which have occurred frequently since the last two decades. Plant breeders in West Africa have made considerable progress in developing improved high-yielding cultivars that could be tailored to more productive cropping systems. Plant breeders greatly increased grain production by reducing plant height, but the short types are generally more sensitive to stresses and time of sowing. They are sensitive to newer pests and the photo-insensitive cultivars require greater precision in planting date and are liable to run into pest (stem borer, shoot fly, head bugs) and disease (grain mold) and thus grain quality problems and also nutrient deficiences. Therefore, though a number of improved cultivars have been developed by various national and international research programmes and recommended through various research networks (ICRISAT, SAFGRAD, IRAT, INSAH), the adoption rate of these cultivars at on-farm level is negligible.

The constraints for large scale adoption of improved sorghum cultivars are both technical and socio-economic (Matlon, 1987). One of the major constraints is the poor grain quality of improved cultivars. Most of the improved cultivars have soft grains which can have 50% bran loss during grain processing and also have poor food stability and consumer acceptance. Soft grain often results from stresses during grain fill, including head bug feeding and grain molds. Breeders have, therefore, been considering the hard grain traits towards selecting improved breeding progenies (Beninati et al., 1989).

The integration of improved cultivar and improved agronomic practices is important in improving the productivity of sorghum in WASAT. Though there are indications that improved cultivars respond better to crop density and fertility (Sogodogo et al., 1988; Pieri, 1985; Shetty, 1989), ploughing (Nicou and Charreau, 1985) and other soil management practices (ICRISAT, 1985), the extent of responses in WASAT is not very encouraging when compared to that observed elsewhere. It is known that the tall, late, photoperiod sensitive cultivars do not respond much to increased population density (Goldsworthy, 1970; Shetty, 1984). But short cultivars and dwarf hybrids are known for their responsiveness to increased density and added fertility. Our agronomic studies with the available improved cultivars have shown some responses which are well below those observed in south-east Asia. These disappointing results can be ascribed to lack of management responsiveness in the improved cultivars and poor soil resource base in

WASAT. Improving the soil base to support improved cultivars with associated improved management techniques is, therefore, important to obtain better adoption of the improved cultivars.

Time of planting of improved, short season cultivars is always important. It is assumed that the short season, improved cultivars can be tailored to most assured rainfall periods and avoid moisture stress. Though some cultivars have shown this flexibility for time of planting, the yield losses observed in delayed plantings are significant (IER, 1990). Compensations for loss of nitrogen (due to nitrogen flush with early rains) and incorporation of resistances for biological stresses are, therefore, needed to realize the full potential of the early-maturing improved cultivars.

The grain yield of photoperiod insensitive types may have to be sacrificed, unless much better stem borer, mold and bird resistances are obtained. The place of photoperiod insensitive cultivars thus needs more investigation under WASAT conditions (Doggett, 1988).

Operational systems research integrating different agronomic management practices and varieties have demonstrated the synergistic effects of various treatments when combined together as against their individual effects (ICRISAT, 1988; Sogodogo and Shetty, 1991; IER, 1990). However, when the improved cultivars are introduced to farmers' conditions, they have failed to exhibit their known potential. It is, therefore, necessary to aim at improving the soil productivity first and then incorporate the improved cultivars into such better resource management systems.

e) ***Improved Cropping Systems.*** As indicated earlier, sorghum is widely grown as an intercrop. It is grown with a wide array of crops such as millet, cowpea, groundnuts, cotton and vegetables in various combinations. A study by Norman (1975) in northern Nigeria has shown that among the many cropping systems grown, only 8% of the area was planted to sole sorghum while about 50% of the area was planted with sorghum as an intercrop. Similar findings are also reported by Shetty *et al.* (1987) for Mali. Work done in Nigeria, Niger, Burkina Faso and Mali have clearly underlined the importance of intercropping in view of its maximum utilization of resources and stabilization of yields (Fussell and Serafini, 1985).

Intercropping has been considered as an appropriate technology as there are important yield and socio-economic advantages to the system. It is not within the scope of this paper to discuss in detail all the cropping systems where sorghum is involved, but an attempt is made herebelow to summarize the work done in the region on some of the major production systems.

i. ***Intercropping With Long Season Sorghum.*** In the major sorghum growing areas of WASAT, the temporal complementarity between crops is exploited by growing the traditional long season, photosensitive sorghum with early-maturing crops. Two well documented traditional systems are sorghum/millet in Nigeria (Norman, 1972) and sorghum/cowpea throughout West Africa (Fussell and Serafini, 1985; Stoop, 1986; Shetty *et al.*, 1987). In the millet/sorghum system, the millet is sown at the beginning of the rains and sorghum is sown a little later. This system

could give yield advantages of 50% and up to 75% greater monetary returns than sole sorghum (Andrews, 1972). If proper plant spacings were adopted, a reasonable crop of cowpea or groundnut could be grown after the millet and between the rows of sorghum and monetary advantages could be increased to 89% relative to sole sorghum. Andrews (1974) has also shown that the system could gain the benefit of higher grain yields if a dwarf sorghum in introduced into the system. Agronomic research on this system has emphasized the need for high populations of each component crop for optimum resource use (Baker, 1979; Willey *et al.*, 1982). Baker (1979) has also highlighted that the total resource use may be further improved by including yet a third crop of complementary growth pattern.

Cowpea and groundnut are the other major crops that have been reported as intercrops with long-season sorghums. They illustrate the wide range of objectives that the farmer may have in terms of the proportion of sorghum he requires and how significant yield improvement can be achieved without jeopardizing these objectives. In the sorghum/cowpea system, usually cowpea is sparsely planted as a secondary crop with a full stand of sorghum; in the sorghum/groundnut system the farmer sows predominantly groundnut. Improvements of these traditional systems have been reported mainly through increasing population density of legumes, addition of N to the cereal and manipulating the date of planting and harvesting of the component crops (Fussell and Serafini, 1985; Stoop 1986; Shetty *et al.*, 1985; Sogodogo and Shetty, 1989). However, as the traditional late, and tall sorghums are highly competitive to low growing and shade-susceptible legumes, any significant improvement in the productivity of these systems would come mainly if less competitive and more productive sorghum cultivars are used in place of the local cultivars.

ii) ***Intercropping With Short-Season Sorghum.*** Recently,intercropping research in WASAT considered the availability of shorter cycle and shorter height sorghum realizing that from the cropping systems point of view they provide increased time and opportunity for other crops in the system. Studies from Mali (Shetty 1988; Sogodogo and Shetty, 1989; Shetty *et al.*, 1990) have clearly shown the advantages of these early and shorter height cultivars intercropped with cowpea and groundnuts. Substantial yield improvements of both the cereal and legumes were obtained when such systems were grown with improved agronomic management factors. Improved packages of practices involving optimum land preparation, date of planting, plant population, spatial arrangement and fertility conditions have been developed for sorghum/cowpea and sorghum/groundnut systems involving improved shorter season and shorter height sorghum cultivars.

Recent interests in food self-reliance (rather than self-sufficiency), crop diversification and incorporation of commercial crops into traditional low value food crop systems have further underlined the importance of these improved cultivars. Cotton and groundnuts are now being considered important components of sorghum systems. Agronomic studies in Nigeria (Baker, 1979) have shown that if both cotton and sorghum are planted early, profits can be increased. In Mali, a planting pattern of 4 rows of groundnut to 1 row of sorghum is being recommended in groundnut growing areas to optimize the productivity of the system (Shetty *et al.*,

1990). It is hoped that increasing the proportion of high value crops in the system would attract both the application of inputs and improved cultivars into the traditional system. It can also be expected that intensified cereal/legume intercrop would not only fix more nitrogen, but also leave more residual N than left by the traditional system. Though detailed studies on resource use patterns of sorghum/legume mixtures are lacking in WASAT, studies conducted elsewhere (Willey *et al.*, 1982) do indicate the efficient water, light and nitrogen use by the intercrop system, thus resulting in a yield advantage of about 30%.

Other aspects of intercropping which are of significance include possible reduction in weed (particularly *Striga*) and pest incidence and possible beneficial nitrogen effect from the legume. A particularly relevant aspect of intercropping is the greater yield stability that is often emphasized for the long-season sorghum systems of West Africa (Norman 1972; Baker 1978).

iii. ***Relay and Sequential Systems***. The length of the growing period in the Sudano-Guinean zone varies from 110 days in the north to about 200 days in the south. While there is little scope for manipulating planting dates in the north, the longer growing season in the higher rainfall southern locations provides greater opportunities for systems manipulation with appropriate genotypes and management (Shetty, 1984). Multi-locational screening trials across the latitudes have enabled us to select appropriate genotypes with the phenology and physiological responses that would place the production of sorghums in the most favourable periods (ICRISAT, 1984 and 1987). The series of agronomic trials conducted to examine the performance of these cultivars under relay and sequential systems have revealed the potential of these alternative systems (Shetty, 1988) over traditional sole or mixed crop system. In Mali, the authors were able to design and evaluate a number of alternative, relay crop systems by introducing short season cultivars into a more assured part of the rainy season and utilizing the remaining season with other short season crops such as early cowpeas or groundnuts. Though growing sorghum as a sequential second crop was not successful, substantial yields of cowpea and groundnuts were harvested in addition to near-normal yields of sorghum as relay crop (IER, 1990; Sogodogo and Shetty, 1991). More agronomic research is needed for optimum resource use to bring stability of production at higher management through more productive inter-and relay cropping systems.

iv. ***Ratoon Systems.*** The advantage of sorghum's ability to ratoon has been realised through ratoon cropping in some sorghum growing countries such as USA, Australia and India (Willey et al., 1982), but the system is not well known in WASAT. A ratoon crop avoids land preparation, seeding and problems of establishing a good stand from seed. It saves the cost of cultivation and reduces labour demands at a critical post-harvest period. As the period between sprouting and harvest is always shorter in a ratoon crop than that from sowing to harvest in a seeded crop, the system also has the advantage of a shorter total growing period requirement. Pest and moisture stress are the major problems in ratoon systems. Under WASAT conditions, ratooning is impossible with the traditional long season sorghums. However, in our preliminary studies in Mali, the authors were able to identify some short season, improved sorghum cultivars which exhibited satisfactory ratoonability (IER, 1989 and 1990). At Sotuba where moisture

conditions are insufficient for two full crops, one full crop and a "partial" second crop were achieved. Further, alternative systems such as taking an early fodder crop (about 40-45 days) and allowing the ratoon grain crop to mature during the drier conditions after rains is also feasible. More agronomic studies are needed to identify suitable genotypes and management systems to recommend appropriate ratoon systems in WASAT.

v. ***Rotational Systems***. Many of the general principles of crop rotation such as the control of soil-borne pests and diseases, weeds (including Striga) and maintainance of fertility are also applicable to sorghum. Use of rotational systems involving legumes for harvesting nitrogen fixation benefits is gaining importance throughout the world because of economic and sustainability considerations. For example, the yield level attained by sorghum in a sorghum-soybean rotation system was equivalent to 76 kg/ha applied nitrogen (Clegg, 1982). Similar observations have also been recorded under WASAT conditions (Traore, 1988). One aspect of crop rotation which needs special mention is the depressive effect that sorghum may have on the growth and yields of following crops (Willey *et al.*, 1982). This has been ascribed to depletion of moisture and locking-up of nitrogen during the decomposition of roots through microbial action. The West African sandy soils with little clay or humus show the toxic effects more markedly than do heavier soils or those containing organic matter (Doggett, 1988). Sorghum following sorghum is often the common system in West Africa and moisture and nutrient depletion are, therefore, important considerations. Falllowing may improve yields under such conditions and should be considered in the rotation.

4. **Strengthening National Programmes.**

In WASAT, it is only recently that the national agricultural research systems (NARS) are giving importance to sorghum research. Very little work was done prior to the Second World War and the crop was given low priority in the national research system. Except for a few countries (such as Nigeria and Mali), the research infrastructure needed for the improvement of sorghum-based systems are still lacking. Many donor and international agencies have, therefore, given high priority to strengthening the research capabilities of NARS institutions. International and regional organizations such as ICRISAT, CIRAD, INTSORMIL, CILSS and SAFGRAD are engaged in supporting sorghum research through joint research projects, training, workshops, planning meetings, surveys, consultancies, library and documentation services and publication and other networking activities. Many models of strengthening NARS have been tried by different agencies. As one of the major themes of this Conference is the assessment of strategies to strengthen NARS, the strategy and experiences of a joint effort by the Institut d'Economie Rurale, (IER), ICRISAT and the United States Agency for International Development (USAID) in Mali are briefly described below.

In response to IER's need for improved research capability in sorghum and pearl millet-based systems research, ICRISAT, through funding from the Ford Foundation and USAID, initiated a cooperative programme in Mali in 1976. The major objective of this bilateral programme is to strengthen the capacity of the Government of Mali in supporting research on sorghum and millet-based systems in the semi-arid zones of Mali. The activities of the programme include: (1)

supporting research on sorghum and pearl millet improvement; (2) assisting research on sorghum and millet-based systems, and (3) establishing a strong research base through institutional strengthening activities such as infrastructural development, training and helping to link national researchers to international research networking.

ICRISAT placed a production agronomist and a cereal breeder within the IER system to execute the above project activities in collaboration with the Mali researchers. The achievements of the project over the years have been documented through various evaluations (USAID, 1989) and annual reports of ICRISAT and IER. Some of the major accomplishments of strengthening the Mali national sorghum research programme are described below.

a) ***Strengthening Research Infrastructure.*** In order to meet the critical research infrastructure needs, several of the existing research facilities were improved and provided with basic requirements for field trials and experimentation. The major effort, however, was concentrated on developing a central research station at Cinzana to serve the semi-arid zone of Mali. Other facilities such as a cereal technology laboratory and cold storage for seed were also created. The programme played a key role in the development of facilities and training of personnel for the Cinzana Research Station which serves as a model for the development of other research stations in Mali. The station has allowed scientists to conduct appropriate research on various dryland crops; a capacity that did not exist prior to the project and one which has the potential for spillover impact in other countries of the region. The station is currently well managed and staffed by an all-national team. The construction of a food technology laboratory at Sotuba Station has enabled the Mali programme to become the first in West Africa to conduct systematic food quality testing as part of its breeding work. The laboratory has also taken the lead in developing alternative food products.

In the area of training, the programme provided long-term training opportunities for 11 Malian researchers, 7 of whom have now returned and are contributing significantly to research programmes. Under the short-term training component, 59 middle-level researchers and technicians were deputed to ICRISAT-Centre in Hyderabad, many of whom now form an integral part of the Mali research programme on semi-arid crops and cropping systems. These participants form the backbone of Mali sorghum and pearl millet research. Further, 67 final year students from Katibougou Agricultural College have completed internships under the guidance of experienced researchers of the programme.

The cooperative programme has helped in organising a series of in-country workshops on specific research themes which have increased the level of scientific activity and interaction among diverse groups of researchers and extension personnel. Further, the programme has encouraged linkages between Mali and other donor-supported programmes which have further strengthened research on semi-arid crops in Mali.

b) ***Systems Research.*** In developing a good base for cropping systems/agronomy research, the programme attempted to involve the existing "cellules" within the IER. The level of scientific manpower in these cellules were upgraded by encouraging

the researchers and technicians to undergo short-term training. The facilities for on-station and on-farm research were also provided to improve the quality of research. A few key traditional systems were only chosen for initial research. An interdisciplinary cropping systems research team which worked collaboratively on resolving the major constraints to production was thus established for technology development and transfer.

In addition, the breeding programmes have made substantial progress which is not within the scope of this paper to discuss. Overall, the cooperative programme has helped to establish a sound research base, including both the physical and human resources to sustain the research. Some of the reasons for the success of this cooperative endeavour are: effective NARS, IARC and donor relationship; long-term commitment by the partners concerned; continuity by long-term technical assistance team; identifying institutional strengthening as priority, targeting research efforts, multidisciplinary approach; stimulating national researchers through research stipends; encouraging short-term training and attendance in workshops and conferences, and research leadership and donor coordination. Some of the constraints the programme has experienced are: poor research-extension linkage, poor linkages between socio-economic and agricultural research divisions, inadequate numbers of national staff, lack of research prioritization, uncertain long-term funding resulting in less emphasis on long-term research, lack of good administrative support to researchers, duplication of efforts by donors, different expectations by different partners, unnecessary burdens on national researchers by too many external agencies and networks and lack of incentives to researchers.

Though at country level many bilateral programmes have been in operation, most of these programmes are short-term and often too ambitious. Research infrastructure development and training did not receive much attention resulting in unsustainability of the research programmes.

At the regional level, the West and Central Africa Sorghum Network (SAFGRAD/ICRISAT) has a major mandate to strengthen NARS in sorghum research. The Network is crop improvement research-oriented with limited emphasis on agronomy/systems research. Further, the Network has limited resources for training and technology transfer. Lack of scientific manpower and weak linkage between technology development and trasnfer continue to be major bottlenecks at the national level.

Synthesis and Research Needs

Generalization of technologies across WASAT cannot be done because of diverse sets of sub-regions comprising a range of agroclimatic and demographic conditions with varied technical potentials. The current available technologies and their prospects for improving the productivity of sorghum-based systems in the two major zones can be summarized as follows:

a) ***Sudan Zone***. In the northern Sudan zone, because of agro-climatic deficiences, land and water conserving techniques such as anti-erosion and run-off management techniques to arrest the degradation of soil base, and stress-reducing technologies

such as short cycle sorghum cultivars tolerant to physical and biological stresses have shown much potential. Stabilizing production and preventing further decline in productivity should be the goal in this region. Yield increasing techniques such as the use of input responsive cultivars, application of fertilizers and pesticides should be considered only after major and sustainable iprovements in soil base to reduce top soil loss and to conserve nutrient and moisture have been undertaken.

The southern Sudanian zone has higher potential for yield increasing packages because of its better resource base. In areas with heavier soils, gains in productivity through tillage, including tied-ridging, are also higher. Low rates of chemical fertilizer in conjunction with frequent application of organic matter combined with adapted and input-responsive cultivars can result in higher productivity gains. In order to improve nutrient use efficiency and to avoid risks, moisture conserving and run off management systems should be integrated into yield-increasing packages of technologies. Animal traction offers considerable advantages in removing labour constraints, expand areas under cultivation and to facilitate appropriate tillage operations. In addition to animal traction as a power source more closely integrated crop-livestock systems yield greater long-term benefits in terms of biomass recycling through composting, which is necessary for sustainable improvement of soil base. Alternative crop-livestock systems, including more productive forage sorghums and intercrop forage/legumes, better composting and improved mechanisation through alternative equipment and better animal nutrition, would be more feasible in this region.

b) ***Sudano-Guinean Zone.*** Due to higher and more assured rainfall, a longer growing season and better soils, the potential for improving sorghum productivity is greater in the Sudano-Guinean zone. Both yield increasing and labour saving techniques can be profitable because of better resource base. Further, the diversified cropping systems and the untapped resources of this zone favour research towards the improvement of overall productivity of the systems on a year-round basis.

As described earlier, the possibility of taking two or more crops by intercropping, sequential cropping and ratooning is greater through careful tailoring of crop varieties and appropriate soil and rainfall management. Further, incorporation of cash crops such as cotton and groundnuts and more productive and input responsive crops such as maize and upland rice into the sorghum systems should be considered to improve the overall productivity on a year-round basis. These more productive systems could not only attract improved management responsive cultivars but also stimulate the use of production inputs on component cereal crops. It is expected that the synergistic effect of integrating improved physical resource base with the improved cropping systems can be much higher in this particular zone.

An assessment of the available technologies to improve the productivity of sorghum-based systems in WASAT indicates that though the potential technologies are available, their large scale adoption has been negligible. The reasons for non-adoption of the technologies are related to both socio-economic and technical constraints. In order to understand the yield gap between research station and farmers' fields, on-farm diagnostic studies should be conducted. Such studies also

help to determine important physical, biological and socio-economic constraints for adoption and to measure the potential of alternative techniques under on-farm situations. Early on-farm testing is also important to provide feed-back to "fine-tune" the technology, if necessary, before recommending it for large-scale adoption.

In WASAT, past experiences have shown that the recommendation of either agronomic techniques or variety alone would result in limited adoption. This signifies the importance of close link between resource management and crop improvement research. A farming systems approach is also needed for crop improvement. Before technology development, regional zonification and recommendation domains should be identified and refined, recognising key differences in agroclimatic and socio-economic situations. It should be underlined that for more productive and sustainable systems, improvement and at the same time conservation of physical resource base should go hand in hand with the improvement of sorghum varieties.

c) ***Research Needs of the Nineties.*** The future research thrust should aim at the development of management strategies to increase production and productivity while considering potential environmental degradation. While attaining this research objective, closer links among researchers at all levels (multi-disciplinary, national, regional and international), developmental (extension) agencies and farmers should be developed. The following specific aspects need particular attention during the 1990s:

i) ***Operational Scale Integrated Studies.*** Long-term, operational scale studies of existing technology components and improved production systems (integrating available component technologies) in comparison with the traditional systems will help analyze gaps and quantify the contribution of individual factors. Such studies will not only provide production and economic data relevant to sustainability, but also highlight constraints to production and demonstrate the production potential.

ii) ***Natural Resource Monitoring***. The data which have been examined, so far, present an idea regarding the extent of the limited resources available for increasing sorghum production in West Africa. The African farmer has to live with this reality. Fortunately, technological means for exploiting the limited climatic and soil resources do exist as has been elaborated earlier. Traditional approaches to crop improvement and planning have been based on themes that would emphasize a single discipline such as crop breeding, crop agronomy, etc. If stability in yields is the ultimate aim, then all factors that contribute to variability in yields should be monitored simultaneously on a long-term basis, analysed and conclusions should be drawn for practical application. An inter-disciplinary approach is important for this purpose that contributes to the development of an effective natural resource management strategy.

iii) ***Research on Productivity and Stability.*** Agronomic research to improve the productivity and stability of both sole and multiple cropping systems should be intensified. Identification of appropriate management responsive cultivars and development of appropriate packages of technologies should continue. The goal of this research should be on promoting growth in less productive areas and maintaining and enhancing growth in already productive areas.

iv) ***Sustainability Research***. Sustainability is the main issue of the 1990s. Agronomic research should involve successful management of resources to satisfy changing human needs while maintaining or enhancing the quality of the resource base (Plucknett and Wright, 1990). Focussing on cropping systems that achieve greater efficiency in utilizing the resources (moisture, soil quality, solar energy, etc) and promoting component research that maximize the integration of biological processes to maintain and enhance soil fertility and protect production systems from biological and physical stresses should receive greater emphasis. Soil management research to minimize soil erosion, studies to determine the fate of residues in soil and their contribution to structure and fertility (particularly N-status) and investigations on crop rotations involving legumes will contribute to the development of sustainable sorghum systems. Long-term studies on the role of nitrogen-fixing legumes in rotations and intercropping systems, the effect of erosion on crop productivity and the impact of organic amendments will provide basic information for developing sustainable sorghum-based production systems. It is worth considering a proposal for a network of production agronomists in West Africa to assess sustainability of sorghum production in trials which would involve comprehensive measurements of soil properties at regular intervals.

v) ***Strengthening National Research Base***. In achieving the goal of sustainable sorghum production, primary attention should be devoted to strengthening the three core institutions of research, training and extension that form the institutional base. The resource and technology transfer model of assistance must be replaced by a human capability/institution building model of development. Regional and international programmes should have dual objectives of producing technology and strengthening NARS for sorghum research. Donor assistance to programmes should be evaluated not only on the basis of the volume of new sorghum technologies produced, but also on the new measures of the performance of research institutions over time. The question of what can be done to strengthen NARS in a cost-effective and sustainable manner so that they can become more productive partners in producing new technologies should be addressed by all concerned.

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Influence des Génotypes de Sorgho et de Niébé sur la Population de l'Association Sorgho-Niébé à Sotuba

D. SOGODOGO et S.V.R. SHETTY.

ICRISAT/Mali

Résumé

Trois génotypes de sorgho ont été combinés à trois génotypes de niébé au cours d'une étude sur les associations de cultures réalisée à Sotuba en culture pluviale en 1988 et 1989. Parmi les variétés de niébé testées, la KN1 et la TVU 76-07 ont donné les meilleurs rendements de fane sèche : respectivement 95 % et 57 % de leur rendement de culture pure. En production de grain, c'est la variété locale Amary sho qui a été la plus performante avec en moyenne 59 % de son rendement normal. Quant aux variétés de sorgho, la locale Sakoïka a été la plus productive tandis que la variété Malisor 84-7, de courte taille, a été la plus favorable à l'expression du potentiel de rendement du niébé. Pour la production fourragère, la combinaison Malisor 84-7/KN1 a été la meilleure, tandis que l'association Sakoïka/Amary Sho a donné les meilleurs rendements de grain.

Introduction

Le système traditionnel de culture sorgho-niébé est caractérisé par l'utilisation de variétés locales des deux espèces, un semis simultané dans le même poquet ou décalé parfois, dans des poquets alternés. L'architecture du sorgho étouffe dans la plupart des cas, la croissance du niébé qui lui est associé. Cette situation rend le plus souvent le niébé moins apte à l'association. Dans cette association de cultures, les plantes interagissent les unes sur les autres, de manière favorable ou défavorable à une des composantes du système, parfois au niveau génotypique. (Steiner, 1985; Willey, 1979).

Les systèmes de culture constituent donc un élément important de l'environnement des cultures. Ils provoquent des changements considérables de rendements au niveau de chaque génotype, avec une influence directe sur leur morphologie. L'objectif du présent essai est d'étudier l'influence des génotypes de sorgho sur le rendement de l'association sorgho-niébé.

Matériels et Méthode

L'essai a été conduit à la station de recherche agronomique de Sotuba (12°39'N, 7°56'0, 320 m d'altitude) en 1988 et en 1989 en culture pluviale. Les températures maximales peuvent y atteindre 39°C en Avril et les minimales 15°C en Décembre et Janvier (Sivakumar, 1984) avec une pluviométrie moyenne annuelle de 974 mm autorisant un cycle optimal de 120 jours pour les cultures (Valet, 1988).

Le sol est ferrugineux tropical lessivé hydromorphe à tâches et concrétions. Il est limono-sableux en surface et limono-argileux en profondeur et est pauvre en matière organique (0,5 %). Sa capacité d'échange cationique est faible (4,4 meq/100) et son ph est acide.

L'essai était un factoriel (3x3+6) à 4 répétitions. Trois variétés de sorgho, Malisor 84-1, Malisor 84-7 et Sakoïka (Tableau 1) ont été combinées à trois variétés de niébé, Amary sho, TVU 76-07 et KN1 (Tableau 2). Les cultures pures de chacune des variétés ont servi à déterminer les différents rapports de surface équivalente.

Le semis a été effectué avec des semences traitées au furadan (10 g/100 g de semence) à raison de 2 lignes de sorgho pour 1 ligne de niébé, avec une géométrie de 0,75 m x 0,5 m pour le sorgho et 1,5 m x 0,25 m pour le niébé, le démarriage étant effectué à 2 plants par poquet pour les deux cultures. Nous avons appliqué au semis 100 kg/ha de phosphate d'ammoniaque et à la montaison 50 kg/ha d'urée uniquement au sorgho. Le niébé a été traité au decis (0,5 l/ha) puis au Timul 35 (2 l/ha).

Les mesures ont porté sur le rendement dont l'analyse de la variance nous a permis d'établir les effets des génotypes; la PPDS a été utilisée pour la séparation des moyennes.

Tableau 1. Caractéristiques des génotypes de sorgho testés dans l'association à Sotuba en 1988 et 1989.

Génotypes	Hauteur (m)	Couverture de l'architecture	Durée du cycle en jour
Malisor 84-1	2,00	modérée	90-100
Malisor 84-7	1,50	modérée	100-110
Sakoïka	4,50	modérée	120-130

Tableau 2. Caractéristiques des génotypes de niébé testés dans l'association à Sotuba en 1988 et 1989.

Génotypes	Mode de croissance	Durée semis 50 % floraison
Amary Sho	Rampant	60
TVU 76-07	Rampant	75
KN1	Erigé	55

Résultats et Discussion.

Les Tableaux 3-6 rassemblent les résultats obtenus de 1988 à 1991. A l'exception de l'association KN-1 x Malisor 84-7, les rendements fourragers du niébé en association étaient inférieurs à ceux obtenus en culture pure (Tableau 3). La petite taille de Malisor 84-7 a favorisé la production de fanes à cause de la bonne infiltration de lumière. La sénescence précoce des feuilles du cultivar de niébé Amany Sho est à l'origine de ses rendements fourragers faibles par rapport aux autres variétés.

Les rendements grainiers du niébé associé au sorgho étaient inférieurs à ceux obtenus en culture pure (Tableau 3). Il semble qu'ici, la persistence des feuilles chez le sorgho Malisor 84-1 explique la faiblesse des rendements des niébés qui lui sont associés. La senescence progressive des feuilles inférieures du cultivar Sakoïka de sorgho font que, malgré sa grande taille, suffisamment de lumière atteint le niébé associé, d'où les rendements meilleurs par rapport à ceux occasionnés par l'association avec Malisor 84-1. Ces rendements restent cependant inférieurs à ceux exprimés par les niébés associés à Malisor 84-7, de petite taille. Notons que la Locale Amany Sho a donné le meilleur rendement de grain, à l'opposé de son comportement pour la production fourragère.

Quant aux génotypes de sorgho, seuls les associations impliquant le cultivar Sokoïka ont produit des rendements de matière sèche et de grain comparables ou supérieurs à ceux obtenus en culture pure (Tableau 3). Il est à signaler que les meilleurs rendements du sorgho ont été obtenus en association avec le niébé Amany Sho.

Tableau 3. Rendements du sorgho et du niébé cultivés en association exprimés en pourcentage (%) des rendements obtenus en culture pure.

Variété de niébé	Sorgho associé					
	Malisor 84-7		Malisor 84-1		Sakoïka	
	Grains	Fanes/ paille	Grains	Fanes/ paille	Grains	Fanes/ paille
a) Rendement du niébé						
KN-1	42	117	30	84	33	86
TVU76-07	49	74	39	46	41	51
Amany Sho	69	22	50	19	57	16
b) Rendement du sorgho						
KN-1	72	76	71	70	99	104
TUV76-07	71	94	72	81	105	87
Amany Sho	94	94	83	73	112	101

Ces résultats (voir aussi Fig. 1 et 2) montrent l'existence d'interactions entre génotypes de sorgho et de niébé. Ainsi, les génotypes de sorgho exprimant une bonne tolérance àla compétition inter et intraspecifique seraient ceux dotés d'une bonne capacité de tallage. Les variétés de niébé tolérant la compétition pour la lumière seraient les plus rentables dans les systèmes étudiés.

Tableau 4. Influence de génotypes de sorgho et de niébé sur la production grainière de l'association sorgho-niébé à Sotuba.

Traitements	Rendement kg/ha			
	Sorgho		Niébé	
	1988	1989	1988	1989
Génotypes de sorgho	**	NS	**	NS
Malisor 84-7	2210	2040	509	458
Malisor 84-1	3070	2115	400	308
Sakoïka	3550	2044	342	433
ES +/-	130	161	35	63
Génotypes de niébé	**	NS	NS	*
TVU 76-07	2760	1999	410	250
Amary sho	3220	1336	421	425
KN-1	2840	1863	421	525
ES +/-	130	161	35	63
Interaction	NS	NS	NS	NS
CF %	15	27	29	54

* Significatif à 5% ** Significatif à 1% NS: Non Significatif

Tableau 5. Influence de génotypes de sorgho et de niébé sur la production fourragère de l'association sorgho-niébé à Sotuba.

Traitements	Rendement kg/ha		
	Sorgho	Niébé	
	1988	1988	1989
Génotypes de sorgho	**	*	**
Malisor 84-7	770	1280	1237
Malisor 84-1	1560	930	874
Sakoïta	1610	900	930
ES +	60	100	72
Génotypes de niébé	NS	**	**
TVU 76-07	1270	740	707
Amary sho	1360	490	848
KN-1	1300	1880	1485
ES +	60	100	72
Interaction	NS	NS	NS
CV %	15	35	25

* Significatif à 5% ** Significatif à 1% NS: Non significatif

Tableau 6. Influence des génotypes de sorgho et de niébé sur la profitabilité de l'association sorgho-niébé à Sotuba, 1988.

Traitements	Surface Equivalente Relative (S.E.R.)					
	Fourrage			Grain		
	Sorgho	Niébé	Total	Sorgho	Niébé	Total
Génotypes de sorgho						
Malisor 84-7	0.81	0.43	1.24	0.72	0.56	1.28
Malisor 84-1	0.75	0.31	1.06	0.78	0.44	1.22
Sakoïka	0.97	0.30	1.27	1.10	0.38	1.48
Génotypes de niébé						
TVU 7607	0.81	0.61	1.42	0.81	0.42	1.23
Amary sho	0.87	0.08	0.95	0.95	0.48	1.43
KN-1	0.83	1.15	1.98	0.83	0.49	1.32

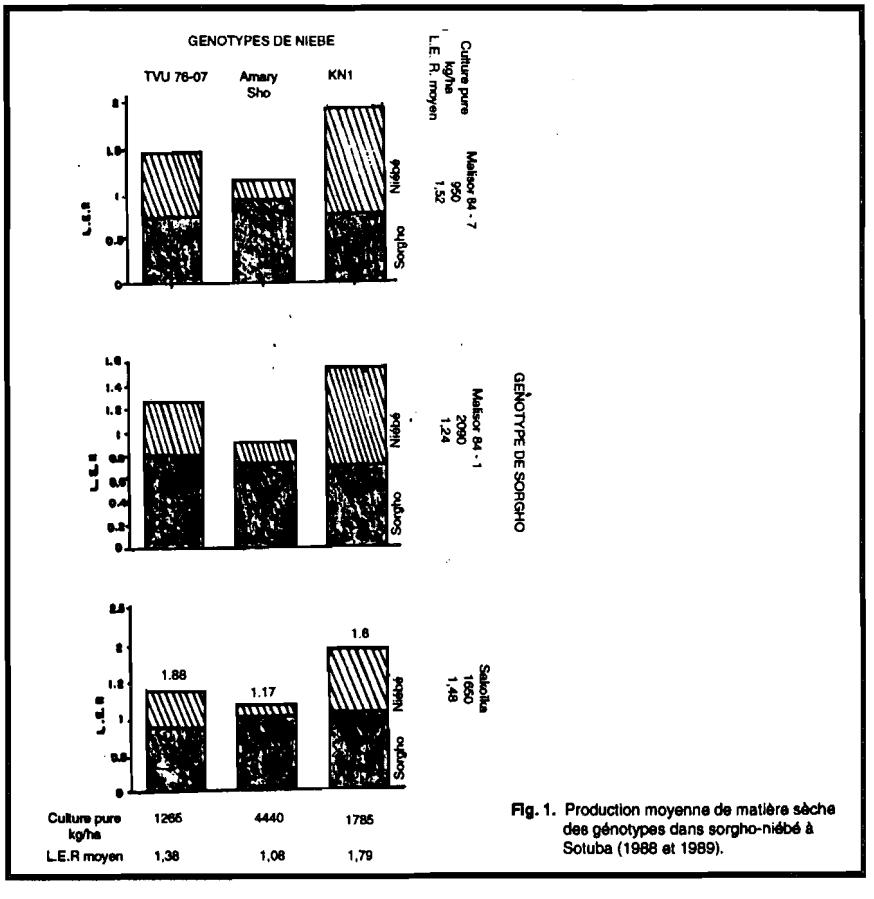

Fig. 1. Production moyenne de matière sèche des génotypes dans sorgho-niébé à Sotuba (1988 et 1989).

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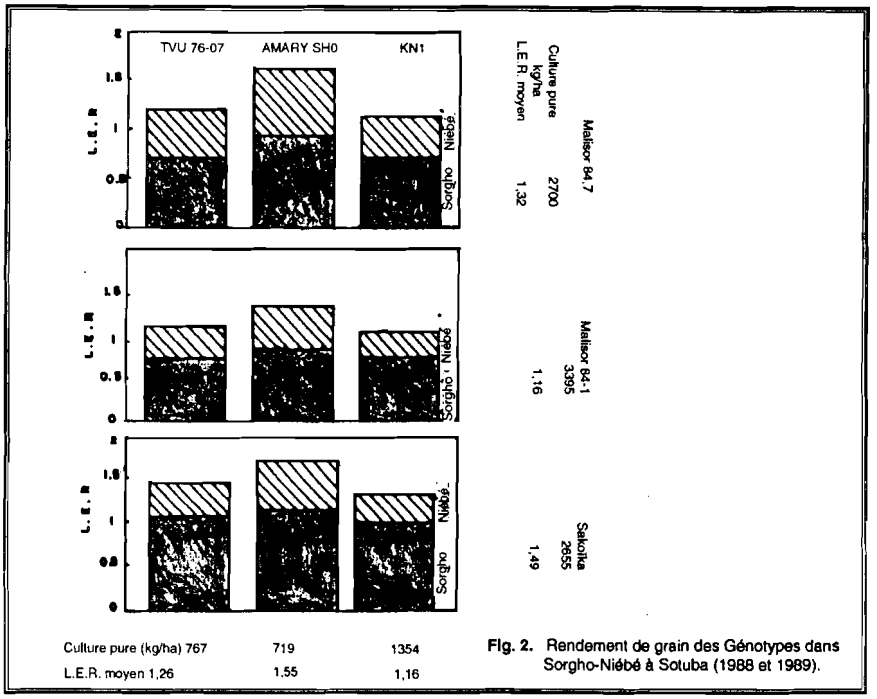

Fig. 2. Rendement de grain des Génotypes dans Sorgho-Niébé à Sotuba (1988 et 1989).

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Premiers Résultats Obtenus sur des Rotations de Sorgho et Légumineuse en Culture Pure ou Associée et de Cotonnier.

PATRICK SALEZ et KALIFA TRAORE.

(IRAT/CIRAD)/Projet Régional Sorgho ICRISAT/IRAT, Bamako, Mali.

Résumé

Des rotations incluant le sorgho et une légumineuse (arachide, niébé ou soja) en culture pure et associée, ainsi que du cotonnier, ont été étudiées en 1989 et 1990 à Samanko (près de Bamako) et Longorolla (près de Sikasso), sous différents régimes de fertilisation.

Une légumineuse en culture pure constitue le meilleur précédent du sorgho, avec des gains moyens de rendement de 20 à30% par rapport à la succession sorgho-sorgho. Les associations sorgho-légumineuse n'ont pas d'arrière-effet sur le sorgho qui leur succède ; elles présentent par contre un arrière-effet important sur le cotonnier, en l'absence d'engrais ou avec un apport minéral. Avec la fumure organo-minérale, on ne peut dissocier les arrière-effets des différents systèmes culturaux.

Les successions de cultures associées présentent un avantage de rendement par rapport aux successions de cultures pures (1< L.E.R. < 1.40) mais elles ne se montrent pas plus avantageuses que des rotations de cultures pures faisant intervenir une légumineuse en année 1 et un sorgho en année 2.

Introduction

L'évolution des productions des cultures et de la fertilité du sol dans des rotations impliquant le sorgho, une légumineuse (souvent l'arachide), et le cotonnier, a été étudiée, dans le passé, en Afrique de l'Ouest (Pichot et. al., 1981; Loynet, 1987; Gigou, 1977). L'effet d'apports de fertilisants organiques et minéraux sur la production de cultures continues de sorgho et arachide a également fait l'objet de publications (Kwakye, 1988).

Les systèmes de cultures associées sorgho-légumineuse, couramment pratiqués en Afrique de l'Ouest et Centrale, ont été comparés aux cultures pures sous l'angle agronomique (Shetty, 1988). Les comparaisons étaient cependant ponctuelles et concernaient toujours une seule saison culturale (sur une même parcelle). Dans la mesure où les mobilisations minérales des cultures associées diffèrent en général nettement de celles des cultures pures correspondantes, du fait d'interactions entre plantes différentes (Salez, 1988), il paraît nécessaire, pour comparer ces divers systèmes sur un plan agronomique, d'entreprendre des expérimentations de longue durée, faisant intervenir des rotations de cultures pures et de cultures associées.

Dans ce but, deux essais ont été mis en place en 1989 : l'un comparant divers systèmes à base de sorgho et de légumineuse avec ou sans apport d'engrais, sur deux

sites ; l'autre comparant divers systèmes à base de sorgho, de légumineuse et de cotonnier, avec ou sans fertilisation, sur un site.

Matériel et Méthodes

Sites expérimentaux. Les deux sites utilisés pour ces essais sont les stations de recherche de Samanko (15 km de Bamako) et Longorola (8 km de Sikasso). Ces sites diffèrent essentiellement par la pluviométrie et la texture du sol. En effet, en 1989 et 1990, alors que Samanko recevait respectivement 871 mm en 69 jours, et 952 mm en 84 jours, Longorola en recevait 1111 mm en 71 jours, et 992 en 87 jours. A Samanko le sol se caractérise par une teneur variant de 8 à 13 % pour l'argile et 63 à 68% de sable entre 0 et 20 cm; à Longorola le sol est plus riche en argile (13 à 18%) à la même profondeur.

Essai A. Le premier essai, évolution de la production dans des rotations de cultures pures et associées de sorgho et légumineuse, a été mis en place en 1989 à Samanko et Longorola. Cet essai nous a permis de comparer les associations sorgho-légumineuse (arachide, niébé, soja) aux cultures pures correspondantes sous deux régimes de fertilisation (0 et 80 kg N/ha sous forme d'urée apportée - au semis et - à 35 jours après semis). Les 14 traitements ainsi obtenus ont été évalués selon un dispositif en Bloc de Fisher avec 8 répétitions.

La parcelle élémentaire était de 27 m2 et la parcelle utile de 24 m2. L'essai a reçu en 1989 une fumure de fond de 30 kg P/ha sous forme de supersimple. En 1990, afin d'étudier les arrière-effets, on a séparé l'essai en deux, les 4 premiers blocs sont plantés en sorgho pur et ne reçoivent pas d'engrais, tandis que les 4 autres blocs reçoivent les mêmes systèmes de cultures que la première année, ainsi que 30 kg P/ha en fumure de fond.

Les cultures associées sont constituées de 3 lignes de légumineuse espacées de 0,30 m, entre 2 lignes de sorgho distantes de 1,20 m. Deux sarclages sont effectués sur cultures associées et trois sur cultures pures. Le niébé a été traité deux fois au Thimul 35 (à 3 litres/ha).

Les paramètres suivants ont été étudiés : les composantes du rendement, les poids secs et exportations minérales et l'évolution des éléments minéraux dans le sol selon les systèmes culturaux pratiqués.

Essai B. Le deuxième essai, évolution de la production dans des rotations culturales incluant le sorgho, une légumineuse et du cotonnier, a été mis en place à Samanko en 1989, selon deux blocs de Fisher avec des parcelles élémentaires de 90 m2. Au sein de chaque parcelle élémentaire, sont choisis au hasard 4 carrés de rendement de 14,4 m2 (3,60 m x 4), constituant 8 répétitions par traitement.

Les traitements, au nombre de 18, sont des combinaisons factorielles de 6 systèmes de rotation et de 3 niveaux de fumures. Les rotations évaluées sont : sorgho-sorgho, arachide-sorgho, cotonnier-sorgho, sorgho-cotonnier, sorgho x arachide-cotonnier et sorgho x niébé-cotonnier. Les niveaux de fumure sont : 0, fumure minérale recommandée pour chaque culture (100 kg/ha complexe coton (14-

22-12) avant semis + 50 kg/ha urée à 35 jours après semis (JAS) pour le sorgho, 200 kg/ha complexe coton avant semis + 50 kg/ha urée à 35 JAS pour le cotonnier, 200 kg/ha phosphate super simple avant semis pour l'arachide, 130 kg/ha super simple avant semis + 100 kg/ha urée à 35 JAS pour les associations sorgho x légumineuse) et fumure minérale + compst (5 T/ha) à base de *Pennisetum*. En seconde année, pour l'étude d'arrière-effets, nous avons semé la variété CSM 388 de sorgho à raison de 89000 plants/ha (0,90 m x 0,25 m x 2 gr./poquet) et la variété ISA2DS de cotonnier à raison de 82000 plants/ha (0,90 m x 0,27 m x 2 gr./poquet).

Resultats et discussions

Essai A. A Longorola, le niébé cultivé en pur présente un arrière-effet significativement supérieur à celui du sorgho sur la culture de sorgho qui lui succède (Tableau 1). Il augmente le rendement de sorgho de 65% (gain de 700 kg/ha). A Samanko, c'est l'arachide cultivée en pur qui tend à constituer le meilleur précédent cultural même si son effet sur le rendement du sorgho qui lui succède ne diffère pas significativement de celui d'un précédent sorgho; par contre, l'effet " précédent arachide " est plus net et significatif quant à la matière sèche de paille du sorgho : Le poids sec de tige est augmenté de 49% lorsque le précédent est une arachide au lieu d'un sorgho (Tableau 1).

Tableau 1. Arrière-effets de divers systèmes culturaux sur le rendement d'une culture pure de sorgho.

Précédent cultural 1989	Rendement Sorgho SAMANKO 1990 (kg/ha)			Rendement Sorgho LONGOROLA 1990 (kg/ha)
	grain	paille	indice de récolte	
Sorgho	1713 ab	5048 b	0,23 a	1061 b
Arachide	1975 a	7534 a	0,19 b	1414 ab
Niébé	1681 ab	6703 ab	0,19 b	1754 a
Soja	1845 ab	6734 ab	0,20 b	1346 ab
Sorgho x Arachide	1527 ab	6390 ab	0,17 b	1185 b
Sorgho x Niébé	1377 b	5516 b	0,20 b	1515 ab
Sorgho x Soja	1605 ab	5997 ab	0,19 b	1249 ab
Moyenne	1675	6270	0,20	1360
Effet fertilisation	NS	NS	NS	NS
Effet système	S	S	S	S
CV (%)	18,7	21,1	12,5	26,7
ETR (kg/ha)	313	1323	0,02	363
ETM Système (kg/ha)	111	468	0,01	128

Les moyennes suivies d'une même lettre ne diffèrent pas significativement au seuil de 5 % (test de Newman-Keüls).

L'étude des corrélations entre rendement et poids de 1.000 graines d'une part et entre rendement et nombre de graines/panicule d'autre part montre que la variable explicative du rendement est le poids de 1.000 graines (corrélation significative avec le rendement r = 0,69). L'effet " précédent cultural " agit donc sur le rendement en grains en augmentant la dimension des graines. Notons que l'apport de fumure azotée en année 1 n'a pas eu d'arrière effet significatif sur le rendement du sorgho cultivé en année 2.

Dans les cas d'autosuccession culturales, les résultats consignés dans le Tableau 2 montrent que les rendements du sorgho sont significativement réduits par l'association avec une légumineuse. Les trois légumineuses utilisées ayant le même effet sur la production du sorgho associé. L'apport d'urée se traduit pas des augmentations de rendement du sorgho atteignant 60% et 40% à Samanko et Longorolla respectivement en 1989 contre 30% et 20% pour ces deux localités en 1990.

Quant aux deux légumineuses,leur comportement est le même pendant les deux années : baisse significative du rendement et du poids de matière sèche totale en présence du sorgho, absence de réponse à l'engrais azoté, aussi bien en culture pure qu'en culture associée ; seul le sorgho bénéficie donc de l'engrais en culture associée (Tableau 3).

Les L.E.R. des cultures associées, étudiés chaque année et pris globalement sur les deux années, permettent de comparer l'évolution des productions dans des systèmes purs et associés. Les L.E.R. sur deux années sont calculés après avoir effectué la somme des rendements des deux années sur une même parcelle. Les résultats présentés au Tableau 4 montrent que la comparaison des systèmes culturaux sur deux années avantage les cultures associées.

Tableau 2. Arrière-effets de différents systèmes se succédant à eux-mêmes sur la même parcelle : rendements du sorgho en année 2.

Systèmes	Rendements en 1990 SAMANKO (kg/ha)			Rendements en 1990 LONGOROLA (kg/ha)		
	ON*	80N*	MOY.	ON	80N	MOY.
Sorgho	1305	1654	1480a	1094	1528	1311 a
Sorgho x arachide	732	899	815 b	658	812	735 b
Sorgho x niébé	621	994	807 b	738	664	733 b
Sorgho x soja	572	664	608 b	681	784	701 b
Moyenne	808 b	1048 a	928	793 b	947 a	870
Effets système		S			S	
Effets fertilisation		S			S	
CV (%)		22,8			20,1	
ETR (kg/ha)		211			175	
ETM système (kg/ha)		75			62	
ETM Fertil. (kg/ha)		53			44	

Les moyennes suivies d'une même lettre ne diffèrent pas significativement au seuil de 5 % (test Newman-Keuls).

* ON = sans engrais

* 8ON = avec 80 kg N/ha.

Tableau 3. Arrière-effets de différents systèmes se succédant à eux-mêmes sur la même parcelle : Rendements des légumineuses en année 2.

	Rendement Graines Légumineuses (KG/HA)					
	SAMANKO			LONGOROLA		
Systèmes	Arachide	Niébé	Soja	Arachide	Niébé	Soja
Culture pure	800 a	351	956 a	1299 a	957 a	770 a
Culture associée (avec sorgho)	364 b	296	727 b	700 b	608 b	486 b
Moyenne	582	323	842	999	783	628
Effet fertilisation	NS	NS	NS	NS	NS	NS
Effet système	S	NS	S	S	S	S
CV (%)	28,3	16,0	15,4	12,5	25,1	32,4
ETR (kg/ha)	165	52	130	125	196	204
ETM système (kg/ha)	58	18	46	44	69	72

Les moyennes suivies d'une même lettre ne diffèrent pas significativement au seuil de 5 % (test de Newman-Keüls).

Tableau 4. Evolution des L.E.R.* dans les cultures associées sorgho / légumineuse.

Sites	Associations	1989	1990	Total
	Sorgho x Arachide	1,15	1,01	1,10
SAMANKO	Sorgho x Niébé	1,17	1,39	1,24
	Sorgho x Soja	1,33	1,17	1,23
	Sorgho x Arachide	1,04	1,10	1,06
LONGOROLA	Sorgho x Niébé	-	1,19	-
	Sorgho x Soja	1,17	1,17	1,18

Rappel : * **L.E.R. = Rdt espèce a associée** + **Rdt espèce b associée**
Rdt espèce a en pur — Rdt espèce b en pur
* L.E.R. d'une culture pure = 1.

Tableau 5. Production de diverses successions culturales non fertilisées, sur 2 années.

Sites	Successions culturales		Production totale sur 2 ans (kg graines/ha)	
	Année 1	Année 2		
	A	A	A = 1.157	S = 1.934
	S x A	S x A	A = 1.151	S = 1.000
	Nb	Nb	Nb = 570 ;	S = 1.833
Samanko	S x Nb	S x Nb	Nb = 352 ;	S = 1.055
	Sj	S	Sj = 878 ;	S = 1.806
	S x Sj	S x Sj	Sj = 1.323 ;	S = 1.031
	A	S	A = 1.200 ;	S = 1.232
Longorola	S x A	S x A	A = 1.639 ;	S = 1.072
	SJ	S	Sj = 1.046 ;	S = 1.347
	S x Sj	S x SJ	Sj = 1.506 ;	S = 1.073

N.B. S = sorgho
A = arachide
Nb = niébé
Sj = soja

La comparaison des rotations légumineuse-sorgho et des rotations de cultures associées montre que la succession arachide-sorgho, testée à Samanko, est globalement plus productive que la rotation des associations culturales (Tableau 5). Elle présente en effet une production d'arachide équivalente, et double pratiquement la production de sorgho (+ 93%), résultat de l'arrière-effet de l'arachide sur le sorgho qui lui succède, mis en évidence précédemment. Au niveau de tous les autres systèmes culturaux, on observe, globalement, sur deux années, que : (i) les rotations légumineuse/sorgho en culture pure présentent une production de céréale plus importante que les successions de cultures associées correspondantes (+ 75% à Samanko et de + 15 à + 25% à Longorola), (ii) les successions de cultures associées présentent, par contre, une production pour la légumineuse plus importante que les rotations légumineuse-sorgho en culture pure (+ 37% pour l'arachide, + 14% pour le niébé, de + 44 à 51% pour le soja).

Essai B. L'arrière-effet des cultures pures sur le sorgho, tous niveaux de fertilisation confondus, se résume comme suit : 1876 kg/ha après arachide, 1434 kg/ha après sorgho, et 1418 kg/ha après cotonnier, avec un coefficient de variation de 20,6%, un écart-type résiduel de 325 kg/ha et un écart-type moyen de 66 kg/ha. Ainsi, une fois de plus, l'arachide représente le meilleur précédent du sorgho avec un arrière-effet supérieur de 30% à ceux du sorgho et du cotonnier.

Les cultures associées de sorgho et légumineuse ne présentent pas d'effet résiduel sur le sorgho qui leur succède. De même, le cotonnier, pourtant considéré par certains auteurs comme un bon précédent du sorgho (Chantereau et Nicou, 1991, Loynet, 1987), ne se différencie pas, ici, du précédent sorgho.

Aucun effet allélopathique du sorgho sur lui-même n'est constaté, contrairement aux observations de Burgos-Leon et. al., (1977) et Loynet (1987). L'absence d'un tel effet pourrait être liée à la précocité des premières pluies en 1990 (début mai, sur les deux sites). Ces pluies ont pu lessiver les résidus toxiques du sorgho. En effet, il faut signaler que 195 mm de pluies sont tombés en 7 jours à Samanko et 270 mm en 18 jours à Longorola dans les six semaines ayant précédé le semis du sorgho.

Tableau 6. Arrière-effets de différents systèmes culturaux sur le cotonnier à Samanko.

Précédent cultural (année 1)	Fertilisation (années 1 et 2)	Rendements coton graines kg/ha (année 2)
Sorgho x Niébé	F2	1.085 a
Sorgho x Niébé	F1	1.072 a
Sorgho x Arachide	F2	1.037 a
Sorgho	F2	1.007 a
Sorgho x Arachide	F0	998 a
Sorgho	F1	699 b
Sorgho x Arachide	F1	649 b
Sorgho	F0	632 b
Sorgho x Niébé	F0	304 c
Moyenne		832

CV = 27,3 %
ETR = 227 kg/ha
ETM = 80 kg/ha
NB. : F0 = sans fumure
F1 = fumure minérale recommandée pour chaque culture
F2 = F1 + 5 T/ha compost

Quant aux arrière-effets de différents systèmes culturaux sur le cotonnier, l'association sorgho-arachide est meilleur précédent que le sorgho (+ 68% de rendement en coton graines), qui se montre supérieur au précédent "association sorgho-niébé", en l'absence d'engrais (Tableau 6). Par contre, en présence de fumure minérale, l'association sorgho-niébé devient le meilleur précédent (+ 53% de rendement en coton graines, par rapport au précédent sorgho) les deux autres systèmes étant pratiquement équivalents (Tableau 6). En présence de fumure organo-minérale, une fois de plus on ne peut dissocier les effets "précédents culturaux", d'où l'importance de la fumure dans les effets des précédents culturaux (Tableau 6).

Les moyennes suivies d'une même lettre ne diffèrent pas significativement au seuil de 5 % (test de Newman-Keüls).

Conclusion

Si l'on compare une succession de cultures associées à une rotation de cultures pures de légumineuse, puis de sorgho, la légumineuse cultivée en pur a un effet résiduel important sur le sorgho qui lui succède. Une telle rotation présente, sur deux années, une production de céréale largement supérieure à la rotation des cultures associées (+ 75 à 93% à Samanko). La succession des cultures associées reste cependant plus avantageuse pour la production de légumineuse, en particulier dans le cas du soja.

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Maize-Sorghum Intercropping in Northern Ghana: Effect of Land Preparation and Fertilizer on Growth and Yield.

G.K.S. AFLAKPUI, J.E. AMPONG, S.A.R. ZIBLIM and L.W. CHANASE.

Ghana Grains Development Project, Crops Research Institute, Kumasi, Ghana.

Abstract

Field experiments were conducted in 1989 and 90 to assess how planting on ridges, mounds or on the flat influence the response of maize + sorghum intercrop to applied fertilizer and weed infestation. Sorghum grain yield was similar whether planted on ridges, mounds or on the flat. But maize planted on mounds and ridges in 1989 gave 80 and 77% higher grain yield, respectively, than flat planting. Fertilizer application increased maize and sorghum grain yields by 434 and 65% in 1989 and 131 and 94% in 1990, respectively. A single hand weeding was as effective as two hand weedings in controlling weeds at all three sampling dates for all land preparation methods. Ridging reduced weed population compared to mounds when sampled at 5 and 8 WAP; planting on mounds resulted in lower weed pressure than on the flat but only at 2 WAP in 1989. In 1990, weed infestation was highest on the flat at all sampling dates. No significant interactions were detected amongst all three factors for the variables measured.

Introduction

Maize is almost always grown under rainfed condition and increasingly on marginal lands in Ghana (Edmeades, 1985). The crop often suffers significant yield losses due to unpredictable periods of drought throughout the season, especially in northern Ghana where there is a unimodal distribution of rainfall (Boateng, 1959). As a result, maize is scarcely grown as a sole crop, but with other crops such as sorghum, groundnut and millet in an attempt to avert risks. Soils in northern Ghana are also variable in depth, fertility and water-holding capacity. Some of the soils are characterized by iron pan or iron stone boulders and laterites, thus making them very marginal for cereal production (FAO, 1971; Adu, 1981).

Sorghum is an important crop to the farmer in northern Ghana, since it serves as an insurance crop in case of failure of the maize crop (NAES, 1988). The local late-maturing sorghum varieties are also not very competitive to maize since they start booting by the time the maize has flowered.

Planting crops on ridges or mounds is generally advantageous in situations of hard pans or high water tables by providing large soil volume conducive to root growth and development. Observations in parts of northern Ghana have indicated that farmers adopt planting on ridges and mounds for soils with long cropping histories and high weed pressures. Farmers also contend that ridging or mound reduces weed

pressures and gives better crop yield. Studies conducted on soils of different depths have indicated no advantage of planting maize on ridges on deep soils (GGDP, 1982). Maize grain yield was, however, increased by ridging on shallow soils. The present study was, therefore, designed to assess how planting on ridges, mounds or flat influence the response of maize + sorghum intercrop to applied fertilizer and weed infestation.

Materials and Methods

Field experiments were conducted at Wa in 1989 and Babile in 1990 both in the Upper West Region of Ghana on Verempere (Plinthaquox) and Babile (Plinthaqualf) soil series, respectively, as part of the on-farm research programme of the Ghana Grains Development Project. The soil characteristics of the experimental sites are indicated in Table 1.

A randomized complete block design, 3x2x2 factorial with two splits and three replications was used. Land preparation method was on the main plot, weed control on the sub-plot and fertilizer on the sub-sub-plot. A 120-day white dent maize variety, Okomasa, was used and planted at 90 x 40 cm in plots 6 m long. Local, full season sorghum variety was planted between maize rows. Ridges were made by bullocks and mounds by hoes. Maize and sorghum were planted simultaneously on ridges, mounds or on the flat and hand weeded once at 4 weeks after planting (WAP) or twice at 3 and 6 WAP. Starter fertilizer was applied to maize on the required plots 10 days after planting (DAP) at 50:50:0 kg N, P205 and K20/ha and side dressed with sulphate of ammonia at 50 kg N/ha 6 WAP.

Table 1. Some physico-chemical properties of soils at the experimental sites in northern Ghana.

	1989 = Wa		1980 = Babile	
Soil properties	0 - 15 cm	15 - 30 cm	0 - 15 cm	15 - 30 cm
Sand (%, w/w)	80.5	62.5	83.0	80.5
Silt (%, w/w)	10.5	16.0	12.0	13.0
Clay (%, w/w)	9.0	21.5	5.0	6.5
P^H (H_2O)	5.8	5.8	5.5	5.1
C (%, w/w)	0.39	0.31	0.43	0.18
N (%, w/w)	0.03	0.01	0.04	0.01
P (ppm)	14.3	4.1	4.1	1.3
K (ppm)	215	105	137	69

The response variables measured included weed counts at 2, 5 and 8 WAP, maize and sorghum densities and grain yield. Data was taken on bordered plants within each plot. Maize grain yield was calculated at 15% moisture using the grain moisture determined at harvest with a portable moisture meter for the adjustment

and assuming 80% shelling. Sorghum yield was recorded as sun-dried grain. Data was chacked for homogeneity of variance and weed count scores transformed prior to analysis by MSTAT software. Significant treatment effects were determined using single degree of freedom contrasts or the F-test.

Results and Discussion

a) ***Grain Yield.*** Planting sorghum on mounds, ridges or flat gave similar grain yield in both years, except for the lower, values on mounds in 1990 (Table 2). However, maize planted on mounds or ridges gave 80 and 77% higher grain yield, respectively, than flat planting in 1989. In 1990, maize grain yield was similar for mounds, ridges or the flat. A rough estimate indicated that the experimental site (Babile) in 1990 had deeper soil than the 1989 site (Wa). In a previous study, it had been demonstrated that maize grain yield was significantly increased by ridging on shallow soils but not on deep soils (GGDP, 1982). Fertilizer application increased maize and sorghum yields by 434 and 65% in 1989 and 131 and 94% in 1990, respectively (Table 2). The level of K in the soils on which the experiments were conducted was higher than average (Table 1). The P and organic matter content were very low and this might explain the good response of the crops to applied fertilizer.

Table 2. Effect of land preparation, fertilizer application and weed control on grain yield (kg/ha) of maize + sorghum intercrop in northern Ghana.

	Wa (1989)		Babile (1980)	
Treatments	Maize	Sorghum	Maize	Sorghum
Land Preparation				
Mounds	1866	1213	1846	290
Flat	1035	1540	1718	487
Ridges	1838	1360	1909	536
S.E (±)	256.9	132.1	155.8	25.4
Fertilizer Application				
No fertilizer	498	1034	1104	286
Fertilizer	2662	1709	2546	556
S.E (±)	209.7	107.9	127.2	19.1
Weeding				
1 Weeding	1736	1371	1870	456
2 Weedings	1424	1371	2079	485
S.E (±)	209.7	107.9	127.2	19.1
C.V. (%)	56.3	33.4	29.6	19.3
Contrasts				
Mounds vs Flat	*	NS	NS	*
Ridges vs Flat	*	NS	NS	NS
1 vs 2 weedings	NS	NS	NS	NS
Fert vs No fert	*	*	*	*

Note
* = Significant at 5%
NS = Not Significant

The greater sorghum yield under no fertilizer in 1989 compared to maize depicts sorghum as a hardier crop than maize (Purseglove, 1983). This is also evidence in support of farmers' practice of using sorghum as an insurance crop when faced with fertilizer procurement problems. Sorghum yield was generally very low in 1990, probably due to a high incidence of barrenness that was observed during harvest.

Research conducted elsewhere in northern Ghana has shown maize to be highly responsive to nitrogen fertilizer even when grown after legumes; tall local sorghum was much less responsive to nitrogen fertilizer (NAES, 1986). The higher percentage increment in maize grain yield relative to sorghum when fertilizer was applied may be attributed to the higher multiplicative ratio and greater nutrient use efficiency of maize compared to other cereals (Dobley and Steele, 1979). Ofori (1971) reported that nitrogen fertilizer is beneficial in increasing sorghum yield, although this response can be hidden by high incidence of barrenness in some varieties (Mercer-Quarshie, 1970).

There were no significant treatment effects on plant populations at harvest in 1989 and as such the differences observed in grain yield cannot be attributed to plant density effects (Table 3). In 1990, however, sorghum plant population at harvest was 130 and 120% higher, respectively, for flat and ridge plantings compared to mounds. This low plant population on mounds was due to termite and ant attacks.

Table 3. Effect of land preparation, fertilizer application and weed control on plant population (plants/m2) at harvest in maize + sorghum intercrop in northern Ghana.

	Wa (1989)		Babile (1990)	
Treatments	Maize	Sorghum	Maize	Sorghum
Land Preparation				
Mounds	5.13	4.57	5.20	1.58
Flat	5.19	4.49	4.97	3.65
Ridges	5.57	5.37	5.50	3.49
S.E (±)	0.38	0.42	0.47	0.54
Fertilizer Application				
No fertilizer	4.87	4.72	4.60	1.75
Fertilizer	5.22	5.20	5.34	4.07
S.E (±)	0.31	0.34	0.39	0.44
Weeding				
1. Weeding	5.45	4.76	4.84	3.26
2. Weedings	5.14	4.86	5.61	3.56
S.E (±)	0.31	0.34	0.39	0.44
C.V (%)	24.6	30.3	31.4	64.0
Contrasts				
Mounds vs Flat	NS	NS	NS	*
Ridges vs Flat	NS	NS	NS	NS
1 vs 2 weedings	NS	NS	NS	NS
Fert vs No fert	NS	NS	NS	*

Note
* = Significant at 5%
NS = Not Significant

Weed Control. Ridging reduced weed population compared to mounding at 5 and 8 WAP while planting on mounds resulted in lower weed pressure relative to flat planting only at 2 WAP in 1989. In 1990, weed pressure was significantly higher on the flat than for either mounds or ridges at all sampling dates (Table 4). The observation that ridging resulted in lower weed pressure relative to mounds in 1989 is not readily explicable on the basis of available data, since mounds may be considered as discontinuous ridges. A single hand weeding 4 WAP was equally effective as two hand weedings 3 and 6 WAP in controlling weeds. Similar results of single hand weeding being equally effective in controlling weeds in sole maize has earlier been reported in Ghana (GGDP 1985 and 1987). The effectiveness of a single versus two hand weedings is, however, a factor of the initial weed pressure and cropping history. The application of fertilizer did not affect the level of weed infestation at any of the sampling times. There were also no significant interactions among treatment factors for the response variables measured in this study.

Table 4. Effect of land preparation, fertilizer application and weed control on weed pressure (nc/m2) in maize + sorghum intercrop in northern Ghana.

	Wa (1989)			Babile (1990)		
Treatment	2WAP	5WAP	8WAP	2WAP	5WAP	8WAP
Land Preparation						
Mounds	9.72	11.15	12.67	15.44	16.07	15.34
Flat	12.93	11.67	11.80	21.57	22.01	21.80
Ridges	7.57	8.74	9.37	14.01	14.73	14.40
S.E (±)	0.75	0.80	0.91	0.90	0.87	0.89
Fertilizer Application						
No fertilizer	9.97	10.50	11.37	16.58	17.19	16.81
Fertilizer	10.18	10.54	11.19	17.47	18.02	17.55
S.E (±)	0.61	0.65	0.75	0.74	0.71	0.73
Weeding						
1 Weeding	10.63	10.78	12.40	16.67	17.23	16.75
2 Weedings	9.52	10.26	10.16	17.37	17.97	17.61
S.E (±)	0.61	0.65	0.75	0.74	0.71	0.73
C.V. (%)	25.6	26.2	28	18.4	17.2	18.1
Contrasts						
Mounds vs Flat	*	NS	NS	*	*	*
Ridges vs Flat	*	*	*	*	*	*
1 vs 2 weedings	NS	NS	NS	NS	NS	NS
Fert vs No fert	NS	NS	NS	NS	NS	NS

Note
* = Significant at 5%
NS = Not Significant

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Productivity of Maize-Sorghum Mixture as Influenced by Component Crop Density Arrangement.

K.A. ELEMO.

Institute for Agricultural Research, Samaru, Ahmadu Bello University, Zaria, Nigeria.

Abstract

Productivity of maize-sorghum mixture was examined at two crop densities and four arrangement patterns of the components in the Northern *Guinea* savanna agro-ecological zone of Nigeria from 1986 to 88. The study aimed at determining the appropriate component crop density and arrangement for optimum yields of sorghum cv. KSV8 and maize cv. TZESRW.

The crop density x arrangement interaction effect on all parameters measured was not significant. Establishment of the mixture components at full sole crop density generally increased sorghum grain and stover yields but decreased maize cob weight per plant and sorghum panicle weight per plant as compared to growing the components at half sole density. Although maize stover yield was also increased by full sole crop density, the grain yield was not significantly affected. Sorghum appeared to be more competititve in the mixture than maize and seemed to have benefited more from the association, particularly when it was arranged in closer proximity to maize. Cultivating the components in alternate single rows across ridges appeared most promising, but alternate double ridge arrangement tended to reduce yield advantage as compared to alternate single ridge and alternate stands along and across ridges.

Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is the most important cereal staple food crop in the Nigerian savanna with most of the production coming from fields of small-scale farmers. Because the local sorghums are photoperiod sensitive, they are sown at the onset of rains, mature the grains on residual soil moisture and harvested towards the end of the season. Mixed cropping is widespread, since pronounced complexity arises from the multiple objectives of crop enterprises which are to produce food and cash (Elemo *et al.*, 1988). In the Northern Guinea savanna, sorghum-millet mixture used to be the most predominant (Norman, 1968 and 1974) but in recent times, maize (*Zea mays* (L.) has been gaining popularity as a component of mixture with sorghum. Availability of fertilizer technology and adaptable varieties, among other factors, have pushed maize production further into where the cultivation has hitherto been restricted. Crop combinations with maize have been found to yield better than the standard millet-sorghum mixture (Anon, 1974).

However, literature is scanty on maize-sorghum mixture. Lere (1985) found crop proportion of 2:1 (67:33) maize to sorghum as producing better grain yield than 1:1 (50.50), irrespective of row arrangement. Chobe (1987) reported increased grain yield of maize but decreased sorghum yields as the maize proportion in the mixture increased. Crop proportion 67:33 with maize cultivar TZESRW as component was found to give the highest yield advantage irrespective of row arrangement.

For intercropping to give yield advantage, the total plant density optimum may be higher than for either sole crop (Willey, 1979), since individual plants could be at less stress than in sole crop (Andrew, 1972). Ridge cultivation is a common practice in the Northern Guinea savanna agro-ecological zone of Nigeria and the possible crop arrangements have not been extensively studied. This work was, therefore, initiated to determine the influence of component crop density and arrangement on the productivity of maize-sorghum mixture.

Materials and Methods

A field experiment was executed during the wet seasons of 1986 to 1988 at the research farm of the Institute for Agricultural Research, Samaru (11° 11' N, 07° 38' E, 686 m) located in the Northern Guinea savanna agro-ecological zone of Nigeria. The trial site was characterized by a leached sandy loam soil (16% clay, 50% silt and 36% sand) derived from crystalline basement complex. The soil, on the average, tested pH 5.3 (in 1:1 soil-water suspension) 0.40% organic carbon, 0.06% N, C.E.C. of 3.60 mcq/100g, K of 0.20 meq/100 and available P of 16.2 ppm.

Sorghum (medium maturing and white seeded variety KSV8) and maize (early maturing, white seeded and streak resistant variety TZESRW) were established as sole crops and mixtures on the same date (25 June 1986, 16 June 1987 and 3 June 1988) on ridges spaced 75 cm apart. Stand spacing within the ridges was 25 cm. At two weeks after planting, the crop plants were thinned to one per stand in sole crop, thus giving plant density of 53,333 plants/ha. For the component crop density treatments, each was maintained at an equivalent of 26,667 plants/ha for the half sole crop treatment and 53,333 plants/ha for the full sole crop treatment. The crop arrangement treatments, alternate double ridges of components, alternate stands along and across ridges and alternate single rows across ridges. The factorial experiment was laid out in a randomized complete block design with four replicates. Each plot had 6 ridges (4.5 m wide) and was 7 m long, i.e. 31.5 m^2 in area. Grain yield from each plot was determined from the four inner ridges using the whole length of the plot (21 m^2).

In the sole crops, fertilizer was applied based on the standard application regime -- i.e. 64 kg N + 32 kg P_2O_5 + 30 kg K_2O/ha for sorghum and 120 kg N + 60 kg P_2O_5 + 60 kg K20/ha for maize. In the mixture, application was based on a rate suggested by Fisher (1984) which was derived from results of multi-location fertilizer trials -- i.e. 90 kg N + 45 kg P_2O5 + 45 kg K_2O/ha for the Northern Guinea savanna. The sources of N, P and K were calcium ammonium nitrate, single superphosphate and muriate of potash, respectively. Half of the N was applied basally while the remainder was applied at 4,6 and 8 weeks after sowing for maize, mixture and sorghum, respectively.

Premergence application of Gardoprim-A at the rate of 5 litres/ha was sprayed immediately after planting. Supplementary hoe-weeding and remoulding of the ridges were carried out twice at 5 and 10 weeks after planting.

Results

a) ***Crop mixture.*** Component crop density showed no effect on maize grain yield (Table 1). Only in 1987 did crop arrangement in alternate stand along and across ridges and the alternate single rows across ridges produce significantly higher grain yield than the alternate single and double ridges. While no treatment effect was significant for cob weight per plant and 100-grain weight in 1986, significantly higher values were obtained at half sole crop density than at full density in both 1987 and 88. Alternating the components in single ridges significantly reduced the cob weight in 1987 while no difference was observed in 1988. Influence of crop arrangement on 100-grain weight was not consistent. For stover yield, full sole crop density produced higher than the half in the three years (Table 1). However, crop arrangement effect was not significant. None of these parameters showed significant interaction effect between component crop density and arrangement. The treatment effects on maize shelling percentage, plant and ear heights and days to 50% silk were not significant.

Table 1. Maize (cv. TZESRW) grain yield, cob weight per plant, stover yield and 100-grain weight as influenced by component crop density and crop arrangement in mixture with sorghum (cv. KSV8) at Samaru, Nigeria.

Treatment	Maize grain (kg/ha)			Maize cob (g/plant)			Maize stover (kg/ha)			Maize 100-grain wt (g)		
	1986	1987	1988	1986	1987	1988	1986	1987	1988	1986	1987	1988
Component crop density												
Half sole crop	880	1440	1188	82	94a	93a	2950b	3829b	2228b	16.8	20.3a	18.7a
Full sole crop	890	1357	1101	66	70b	65b	5088a	5306a	3087a	15.5	18.4b	16.9b
SE ±	63.7	106.9	72.0	5.9	3.9	6.8	199.9	207.5	172.9	0.51	0.37	0.23
LSD (5%)	ns	ns	ns	ns	8.0	20.1	587.9	610.4	508.5	ns	1.09	0.68
Crop arrangement												
Alternate single ridges	952	1150b	1172	76	70b	89	3945	4477	2689	16.5	18.0c	17.9a
Alternate double ridges	1006	1079b	1303	81	77a	82	4258	4184	2494	16.5	18.8bc	17.6a
Alternate stands along and across ridges	876	1664a	1081	80	88a	74	4174	5141	2807	15.3	20.1ab	17.0b
Alternate single rows across ridges	705	1700a	1023	59	93a	73	3699	4470	2641	16.3	20.5a	18.5a
SE ±	90.1	151.2	101.8	8.4	5.5	9.6	282.6	293.5	244.5	0.72	0.52	0.33
LSD (5%)	ns	444.7	ns	ns	16.3	ns	ns	ns	ns	ns	1.54	0.96
Interaction												
Mixing technique x crop arrangement	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

ns = not significant

For sorghum, the full sole crop produced significantly higher grain yield than the half sole crop in both 1986 and 88 (Table 2). In 1987, however, the reverse was the case, possibly because of stem borer damage. Alternate double ridges resulted into significantly lower sorghum yields than the alternate single rows across ridges in both 1987 and 88. In 1986, the crop arrangement effect was not significant. Similarly for the three years, the crop arrangement effect was not significant for the sorghum panicle weight per plant and stover yield (Table 2). Although significantly heavier panicles were produced at half sole crop density, the stover yields were significantly lower. Component crop density effect was not significant for the sorghum grain size, but the crop arrangement effect was significant only in 1987 when alternating component stands along and across ridges gave higher values than in alternate single or double ridges. Again, no interaction effect was significant for the parameters measured. Similarly, treatment effects on plant height, panicle length, threshing percentage and days to 50% bloom were not significant.

Table 3 presents the land equivalent ratio values for the components and their combinations. The treatment effects were not significant for maize, except in 1987 when alternating the components in single or double ridges produced significantly lower yield advantage.

Table 2. Sorghum (cv. KSV8) grain yield, panicle weight per plant, stover yield and 1000-grain weight as influenced by component crop density and crop arrangement in mixture with maize (cv. TZESRW) at Samaru, Nigeria.

Treatment	Sorghum grain (kg/ha)			Sorghum panicle (g/plant)			Sorghum stover (kg/ha)			Sorghum 1000-grain wt (g)		
	1986	1987	1988	1986	1987	1988	1986	1987	1988	1986	1987	1988
Component crop density												
Half sole crop	1194b	1584a	1165b	104a	88a	61	5466b	5442b	5750b	35.0	38.0	26.6
Full sole crop	1411a	1370b	1578a	79b	70b	56	8974a	9302a	10490a	34.5	35.5	27.4
SE ±	70.3	64.5	51.1	4.0	4.2	3.1	473.0	315.1	539.7	0.96	0.96	0.72
LSD (5%)	206.9	268.3	150.2	11.7	12.4	ns	1392.5	926.5	1587.5	ns	ns	ns
Crop arrangement												
Alternate single ridges	1255	1463ab	1425a	87	77	65	6808	7636	7935	36.4	34.8bc	26.1
Alternate double ridges	1128	1248b	1148b	86	70	51	6198	6976	9475	35.7	34.0c	27.8
Alternate stands along and across ridges	1497	1488ab	1447a	100	76	57	7593	7649	7225	32.5	39.8a	26.8
Alternate single rows across ridges	1331	1708a	1466a	93	94	63	8281	7406	7682	34.6	38.4ab	27.2
SE ±	99.5	91.2	72.2	5.6	6.0	4.4	669.0	445.6	763.2	1.35	1.36	1.83
LSD (5%)	ns	268.3	212.5	ns	ns	ns	ns	ns	ns	ns	4.00	ns
Interaction												
Mixing technique x crop arrangement	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

ns = not significant

Table 3. Maize (cv. TZESRW) and sorghum (cv. KSV8) land equivalent ratio (LER) and their combined effect at Samaru, Nigeria.

Treatment	Maize LER			Sorghum LER			Combined LER		
	1986	1987	1988	1986	1987	1988	1986	1987	1988
Component crop density									
Half sole crop	0.43	0.33	0.33	0.88	0.88a	0.70b	1.31	1.21a	1.03b
Full sole crop	0.42	0.31	0.31	1.04	0.76b	0.95a	1.46	1.07b	1.261
SE ±	0.031	0.022	0.020	0.055	0.035	0.031	0.072	0.044	0.033
LSD (5%)	ns	ns	ns	ns	0.102	0.092	ns	0.129	0.098
Crop arrangement									
Alternate single ridges	0.45	0.27b	0.33	0.92	0.81a	0.86a	1.37	1.08bc	1.18
Alternate double ridges	0.48	0.25b	0.37	0.83	0.70b	0.69b	1.31	0.95c	1.06
Alternate stands along and across ridges	0.42	0.38a	0.31	1.11	0.83a	0.871	1.53	1.21ab	1.17
Alternate single rows across ridges	0.34	0.38a	0.29	1.00	0.84a	0.88a	1.33	1.33a	1.17
SE ±	0.044	0.031a	0.028	0.078	0.049	0.044	0.102	0.062	0.047
LSD (5%)	ns	0.092	ns	ns	0.144	0.131	ns	0.183	ns
Interaction									
Mixing technique x crop arrangement	ns	ns	ns	ns	ns	ns	ns	ns	ns

ns = not significant

Generally, mixture maize produced yield that was less than 50% of the sole crop while mixture sorghum produced grain yields that was at least 70% of the sole crop. For sorghum and the combined land equivalent ratio, the treatment effects were not significant in 1986. Yield advantage tended to be higher in a full sole crop in both 1986 and 88 while the reverse was true for 1987 when yield advantage was generally lower as components were alternated in single or double ridges. No interaction effect was significant for the land equivalent ratio of a component or the combined.

b) ***Crop Mixture Relative to Sole Crop.*** Table 4 shows the maize and sorghum grain yield of the mixture relative to their respective sole crop and the combined land equivalent ratio. Maize in sole crop consistently outyielded maize in mixture while sorghum in sole crop did not significantly outyield all those in mixture. Mixture treatments of alternate stands along and across ridges and alternate single rows across ridges established at full sole crop density produced grain yields that were most consistently comparable to sole crop sorghum. This trend was reflected in the combined land equivalent ratio.

The mixture treatment of alternate stands along and across ridges established at full sole crop density gave yield advantages of 59, 21 and 25% in 1986, 87 and 88, respectively. Similarly, the alternate single rows across ridges established at full sole crop density gave yield advantages of 41, 19 and 33% in 1986, 87 and 88, respectively.

Table 4. Grain yield of maize (cv. TZESRW) and sorghum (CV KSV8) in sole and mixed crop at different component density and crop arrangement and the combined land equivalent ratio at Samaru, Nigeria.

Treatment	Maize grain (kg/ha)*			Sorghum grain (kg/ha)*			Land equivalent ratio* for maize and sorghum combined		
	1986	1987	1988	1986	1987	1988	1986**	1987	1988
$C_1 R_1$	894 bc	1262 bcd	1281 b	1120 ab	1548 abc	1274 cd	1.26	1.14 bc	1.12 bc
$C_2 R_1$	1010 bc	1038 cd	1062 b	1390 ab	1378 c	1576 abc	1.49	1.01 bc	1.24 ab
$C_1 R_2$	1092 b	1288 bcd	1327 b	995 b	1289 c	869 e	1.26	1.02 bc	0.90 d
$C_2 R_2$	921 bc	871 d	1280 b	1262 ab	120 bc	1428 bc	1.27	0.88 c	1.23 ab
$C_1 R_3$	966 bc	1506 bcd	1064 b	1359 ab	1555 abc	1341 cd	1.46	1.22 ab	1.10 bc
$C_2 R_3$	787 bc	1822 b	1099 b	1635 a	1421 bc	1554 abc	1.59	1.21 ab	1.25 ab
$C_1 R_4$	568 c	1702 bc	1081 b	1304 ab	1943 a	1178 d	1.25	1.46 a	1.01 cd
$C_2 R_4$	841 b	1697 bc	964 b	1359 ab	1474 bc	1754 a	1.41	1.19 bc	1.33 a
Sole Maize	2130 a	4404 a	3602 a	-	-	-	1.00	1.00 bc	1.00 c
Sole Sorghum	-	-	-	1450 ab	1805 ab	1668 ab	1.00	1.00 bc	1.00 c
SE ±	135.0	215.0	147.7	121.9	153.8	96.5	0.135	0.078	0.059

C1 = Components at half sole crop density; R1 = alternate single ridges; R3 = alternate stands along and across ridges.

C2 = Components at full sole crop density; R2 = alternate double ridges; R4 = alternate single rows across ridges.

* In a colunm means followed by same letter are not significantly different at 5% level of probability.

In both 1986 and 88, maize cob weight per plant in sole crop was statistically at par with weights obtained in some of the mixtures (Table 5). The same was true for stover yield in 1987 and 100-grain weight of maize which showed this trend consistently from 1986 through 88.

Table 6 shows the panicle weight per plant, stover yield and 1000-grain weight of sorghum in mixture relative to the sole crop. In both 1986 and 87, some mixture of sorghum produced heavier panicle weight per plant than in sole crop. In both 1986 and 88, there was no significant difference in 1000-grain weight between sorghum in mixture and sole. However, in 1987 some mixture treatments gave heavier 100-grain weight than in sole crop.

Discussion

The lack of interaction effect of component crop density and arrangement observed in this study suggests that these treatment components are independent of each other.

Generally, the grain and stover yields of components in the mixture tended to be higher at full sole crop density than at half density. The need for higher plant density in mixture than for the sole crop equivalent has been stressed by Willey and Osiru (1972).

Table 5. Cob weight per plant, stover yield and 100 - grain weight of maize (cv. TZSRW) in sole crop and mixture with sorghum (cv. KSV8) at different components and crop arrangement at Samaru, Nigeria.

Treatment	Maize cob (g/plant)*			Maize stover (kg/ha)*			Maize 100-grain wt (g)*		
	1986	1987	1988	1986	1987	1988	1986	1987	1988
$C_1 R_1$	78.3 abc	782. bc	102.4 ab	2910 c	3906 c	2679 bcd	15. abc	18.1 bcd	18.4 bad
$C_2 R_1$	73.2 bc	61.6 c	74.7 bc	4930 b	5047 bcd	2699 bcd	17.4 ab	17.8 cd	17.4 de
$C_1 R_2$	95.0 ab	97.0 b	85.4 bc	3158 c	3454 d	1920 d	17.3 ab	20.7 a	18.9 bc
$C_2 R_2$	67.4 bc	57.8 c	78.4 bc	5358 b	4914 bcd	3068 bcd	15.4 bc	16.8 d	16.4 e
$C_1 R_3$	83.2 abc	97.2 b	93.5 a	2890 c	4399 bcd	2348 bc	16.8 abc	20.9 ab	17.6 cde
$C_2 R_3$	75.9 abc	79.5 bc	54.1 c	5458 b	5882 ab	3267 bc	13.8 c	19.2 abcd	16.5 e
$C_1 R_4$	70.0 bc	104.4 b	91.2 abc	2841 c	3559 d	1967 cd	17.3 ab	21.4 a	19.7 ab
$C_2 R_4$	47.3 c	81.7 bc	54.1 c	4557 b	5382 bc	3315 b	15.3 bc	19.7 abc	17.2 de
Sole Maize	111.9 a	146.9 a	133.5 a	6921 a	7064 a	5530 a	18.8 a	21.6 a	20.5 a
SE ±	11.27	8.49	13.04	379.7	460.0	396.4	0.96	0.87	0.44

C_1 = components at half sole crop density; R_1 = alternate single ridges; R_3 = alternate stands along and across ridges.

C_2 = components at full sole crop density; R_2 = alternate double ridges; R_4 = alternate single rows across ridges.

* In a column means followed by same letter are not significantly different at 5% level of probability.

Table 6. Panicle weight per plant, stover yield and 1000-grain weight of sorghum (cv. KSV8) in sole crop and mixture with maize (cv.TZESRW) at different component density and crop arrangement at Samaru, Nigeria.

Treatment	Sorghum panicle (g/plant)*			Sorghum stover (kg/ha)*			Sorghum 1000-grain wt (g)		
	1986	1987	1988	1986	1987	1988	1986**	1987	1988
$C_1 R_1$	1041	80 a	76 a	4608 d	4916 b	6375 cd	37.4	35.2 bc	26.0
$C_2 R_1$	91 b	74 b	54 ab	9009 ab	1039 a	9493 bc	35.5	34.3 bc	26.2
$C_1 R_2$	97 ab	83 ab	44 b	5540 cd	5034 b	5256 d	35.9	36.1 ab	26.5
$C_2 R_2$	75 b	57 b	57 ab	6855 bcd	8918 a	13695 a	35.5	31.9 c	29.2
$C_1 R_3$	106 a	83 ab	61 ab	6085 cd	6014 b	5380 cd	31.1	39.0 ab	27.9
$C_2 R_3$	94 a	69 b	53 ab	9101 ab	9284 a	8869 bcd	33.9	40.5 a	25.7
$C_1 R_4$	108 a	107 a	65 ab	5630 cd	6203 b	5789 cd	35.8	41.5 a	26.1
$C_2 R_4$	77 b	80 b	60 ab	10932 a	8609 a	9577 bc	33.3	35.3 abc	28.4
Sole Sorghum	93 b	60 b	68 a	7800 bc	8910 a	12302 ab	28.4	34.2 bc	26.2
SE ±	7.9	7.9	6.6	780.3	656.6	1218.1	1.94	1.85	1.39

C_1 = components at half sole crop density; R_1 = alternate single ridges; R_3 = alternate stands along and across ridges.

C_2 = components at full sole crop density; R_2 = alternate double ridges; R_4 = alternate single rows across ridges.

* In a column means followed by the same letter are not significantly different at 5% level of propability.

This is partly because mixtures require higher population pressure to produce maximum yields. Nevertheless, in this study maize did not respond dramatically to increase in plant density. This could be attributed to the fertilizer regime applied. While the rate of 90 kg N + 45 kg °205 + 45 kg K_20/ha has been suggested for the mixture by Fisher (1984), higher levels of N are considered necessary to satisfy crop requirement at high population levels. This is particularly so as the sole crop requirement of maize is 120 kg N + 60 kg P_20_5 + 60 kg K_20/ha. Perhaps, Fisher's suggestion could be appropriate for situations where maize crop density in mixture is less than in sole crop. Competition among maize plants which starts in the early vegetative phase could be postponed by nitrogen application supplied in sufficient quantity (Eddowes, 1969). The need for this higher N dosage was corroborated by the lower yields of maize in mixture than in sole crop. Obviously, maize contribution to yield advantage could be improved by increased N rate.

Unlike maize, sorghum mixture yields outstripped those in the sole crop, suggesting more access to N than in sole crop where only 60 kg N/ha was applied. The sorghum variety matured in about 135 days while the maize matured in only 90 days. Higher sorghum yields in treatments like alternate single rows across ridges than in alternate double ridges was likely due to the availability to sorghum of fertilizer applied to maize as the sorghum remained on the field much longer than maize. Therefore, sorghum appeared to be more competitive than maize in this mixture as significantly higher grain yields were obtained in the mixture than in sole crop. This explains why it is the sorghum component that contributed more to the total yield advantage obtained.

In a similar study where only half of the full sole crop density (replacement series) was used to establish the mixture, Haizel and Twumasi-Afriyie (1977) observed no yield advantage in maize-sorghum mixture. This could be attributed to the fact that the sorghum and maize varieties used matured at about the same time. For yield advantage in crop mixture to be easily obtainable, the need for a wide overlap in crop maturity of the components has been stressed (Baker and Yusuf, 1976; Willey, 1979).

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Research Towards Integrated Control of *Striga* In West and Central Africa.

A.M. EMECHEBE, S.T.O. LAGOKE and J.K. ADU.

Institute for Agricultural Research, Samaru, Ahmadu Bello University, Zaria, Nigeria.

Introduction

About 23 out of about 30 species of *Striga* and related species constitute immediate or/and imminent threat to food grain production in West and Central Africa (Lagoke, 1989). It has been estimated that about two-thirds of the 73 million hectares of land devoted to cereals in sub-Saharan Africa are in ecological zones where their production may be seriously reduced by parasitic flowering plants (FAO, 1989). *Striga* spp. are widely distributed root parasites that derive their mineral nutrients, water and carbohydrates from their multitude of host plants, including such major staple crops as maize, sorghum, pearl millet, finger millet, hungry rice, rice, cowpea, sugar cane and other industrial crops. Because of their soil-borne nature, their highly specialized parasitic relationships with their hosts and their wide genetic variability, *Striga* spp. constitute very serious but peculiar constraints to crop production, both in terms of the yield losses they cause and the difficulties encountered in their control.

An estimated 7 billion US dollars worth of food is reportedly lost annually in sub-Saharan Africa due to *Striga* and related weed species (FAO, 1989). The greatest damage occurs in the savanna and Sahelian zones which constitute the major areas of food grain production in the sub-region. In addition, these areas are affected by several other crop production constraints, both physical (especially drought and low, erratic rainfall) and biotic (other pests and diseases). The *Striga* problem threatens the livelihood of the small-scale and resource-poor farmers who constitute 80% of the farming population.

Status of *Striga* Problem

a) ***Incidence and Distribution of Striga.*** *Striga* spp. are widely distributed in many countries of West and Central Africa. In the Republic of Benin, 70% and 20-40% of the land area in the north and south, respectively, are infested by *Striga* (Favi, 1989). A recent report indicated severe infection of cowpea and some wild legumes by *S. gesnerioides* in the coastal area of Grand Popo (Gbehounon, 1990). Both farmers' fields and those of research stations are infested by *Striga* at varying levels in Burkina Faso. In Cameroon, *Striga* species occur in areas between latitudes 8° N and 12° 30 'N, an area of about 102,053 km^2. In a recent survey, 88 and 94% of the farm units in 1987 and 1988, respectively, had *Striga* (Asiribo, 1990). In Côte d'Ivoire, about 40% of the arable land, including some areas south of latitude 8° N, have *Striga*. The magnitude of the problem is more apparent in the northern parts of the country where many farms have been abandoned (Kouassi, 1989). In the Gambia, 75% of the fields surveyed were infested by *Striga* (Carson, 1989a)

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while in Senegal 24-76% of the farms were infested, the problem being more serious in the eastern, central and northern regions (Diallo, 1989).

Ghana is no exception; *Striga* constitutes a serious problem in the northern parts of the country, from about latitude 8° N northwards. In that region, about 66% of all the farms and 83% of cereal fields are infested by *Striga*. In the Upper West Region, infestation was as high as 86 *Striga* plants/m^2 (Bolfrey et al., 1990). *Striga*, first reported in Guinea in the Kindia district in 1952, is now regarded as a major problem to the inhabitants of Kindia, Dabola, Dinguiraye, Gaoual, Koudara and Siguiri (Camara, 1989).

In Mali, 26-100% of the farm units in the *Striga* zone are infested. Up to 147 *Striga* shoots/m2 of land were observed at Kaporo (Carson, 1989b). In Niger, 12-78%, 4-37% and 0-100% of fields of millet, sorghum, and cowpea, respectively, were infested by *Striga* in various locations, with higher incidence being observed on millet and cowpea than on sorghum (Laycock, 1989).

A recent survey in the Nigerian savanna revealed that *Striga* infested 96% of the total farm units in the area lying between latitudes 8° N and 13°N, or about 67% of the total area of the country (Lagoke *et al.*, 1990). Finally, in Togo about 100,000 ha each of maize and sorghum are being threatened by S. asiatica and *S. hermonthica.*

b) ***Species of Striga Attacking Crops.*** Between 4 and 17 species of *Striga* have been identified in various countries in West and Central Africa on a wide range of hosts, including cereals and legume food grains, wild hosts and pasture crops (Lagoke, 1989). *S. hermonthica* is the most ubiquitous, being present in all the countries in which it attacks cereal crops and wild grasses. *S. gesnerioides* is also present in all cowpea growing countries and wild legumes. Details of the distribution of the *Striga* spp., together with their crop hosts and an indication of their economic importance are given in Table 1.

In Nigeria, *S. hermonthica* is severe on sorghum, maize and millet, while *S. aspera* causes serious damage to maize, sorghum, and millet in the wetter parts of the Sudan savanna ecology. Also *S. asiatica* and *S. forbesii* parasitize maize in the wetter parts of the country (including the highland plateaux); *S. forbesii* has also been reported on hungry rice *(Digitaria exilis)* (Lagoke, 1989). *S. gesnerioides* in cowpea is particularly destructive.

In Cameroon, *S. hermonthica* is by far the most important, attacking maize, sorghum, and pearl millet. *S. gesnerioides* attacks cowpea, while *S. asiatica* attacks maize on land adjoining river banks (Lagoke, 1989). The same three species have been reported in Ghana: *S. hermonthica* and *S. asiatica* on maize and sorghum and *S. gesnerioides* on cowpea (Bolfrey et al., 1989). The important species in Côte d'Ivoire are *S. hermonthica* on maize, sorghum, millet and rice and *S. asiatica* on maize and upland rice (Lagoke, 1989). The situation in Benin is similar to that of Côte d'Ivoire (Gbehounon, 1990).

Table 1. Distribution of *Striga* and related parasitic weed species in West and Central Africa.

Country	Species	Crops parasitized
Cameroon	S. hermonthica	Maize, sorghum, millet and natural waste land grasses and fallows.
	S. aspera	Maize sorghum millet and natural waste land grasses and follows.
	S. gesnerioides	Cowpea and wild legumes
	S. asiatica	Natural waste land grasses
	S. forbesii	Natural grasslands on river and stream banks
	S. passergei	Natural grasslands
	S. Klingii	Natural grasslands
	S. macrantha	Natural grasslands
Nigeria	S. hermonthica	Maize, sorghum, millet, uplandrice, natural grassland
	S. aspera	Maize, sorghum, millet, upland rice, hungry rice, natural grassland.
	S. gesnerioides	Cowpea and wild legumes
	S. forbesii	Maize, natural grassland around stream and river bank
	S. asiatica	Maize on plateau along stream and river bank
	S. brachycalyx	Natural grassland
	S. passargei	Natural grassland
Benin	S. hermonthica	Maize, sorghum, millet and wild grasses
	S. aspera	Irrigated rice, maize, sorghum, millet
	S. gesnerioides	Cowpea and wild legumes
	S. asiatica (yellow)	Maize, sorghum, millet wild grasses
Burkina Faso	S. hermonthica	Maize, sorghum, millet wild grasses
	S. asiatica	Maize, wild grasses
	S. aspera	Maize, sorghum, millet, wild grasses, fallow land
	S. aeguinoctialis	Fallow land and natural grassland
	S. gesnerioides	Cowpea
	S. klingii	Sorghum and millet and wild grasses
Ghana	S. hermonthica	Maize, sorghum, millet, rice and wild grasses
	S. asiatica (yellow)	Maize, sorghum and grasses
	S. gesnerioides	Cowpea and Indigofera, hirsutum
Gambia	S. hermonthica	Maize, sorghum, millet and wild grasses
	S. aspera	Wild grasses
	S. gesnerioides	Wild legumes
Chad	S. hermonthica	Maize sorghum millet, wild grasses
	S. gesnerioides	Cowpea
Senegal	S. hermonthica	Millet, sorghum, maize, grasse
	S. asiatica	Late millet and sorghum
	S. gesnerioides	Cowpea, soyabean?, Wild legumes and Ipomea sp
	S. aspera	Grasses in waste lands and fallows
	S. brach calyx	Grasses in waste lands and fallows
	S. bilabiata	Grasses in waste lands and fallows
	S. forbesii	Grasses in waste lands and fallows
Mali	S. hermonthica	Maize, sorghum, millet, rice, grasses
	S. aspera	Maize, sorghum, rainfed rice, hungry rice, grasses
	S. asiatica (yellow and red)	Grasses
	S. grachycalyx	Sorghum and grasses
	S. bumanii	Natural grassland
	S. bilabiata	Natural grassland
	S. dalziali	Natural grassland
	S. forbesii	Stream and river banks on grasses
	S. linearifolia	Native grassland
	S. macrantha	Native grassland
	S. passergei	Wild grasses
	S. gesnerioides	Cowpea, wild legumes and Ipomea
Côte d'Ivoire	S. hermonthica	Maize, sorghum, millet and upland rice
	S. asiatica	Rice, maize
	S. aspera	Millet, grasses
	S. gesnerioides	Cowpeas

Table 1. Contd.

Country	Species	Crops parasitized
Niger	S. hermonthica	Sorghum, millet and grasses
	S. gesnerioides	Cowpea, wild legumes, Ipomoea sp Merrimia sp
	S. aspera	Millet and grasses
Togo	S. asiatica (mainly red flowered)	Maize
	S. hermonthica	Maize, sorghum, millet and hungry rice
	S. aspera	Lowland rice
	S. forbesii	Maize, sorghum and lowland rice
	S. baumanii	Grasses
	S. bilabiata	Grasses
	S. brachycalyx	Grasses
	S. klingii	Grasses
	S. linearifolia	Grasses
	S. macrantha	Grasses
	S. passergei	Grasses
	S. gesnerioides	Cowpea and wild legumes

However, in Togo *S. asiatica* (red flowered morphotype) is more widely distributed and apparently more damaging on millet than *S. hermonthica*; the yellow flowered type of *S. asiatica* attacks maize and sorghum. *S. aspera* attacks lowland rice, while *S. forbesii* is less commonly found in the Sudan savanna where it affects maize and sorghum (Lagoke, 1989).

The important species reported in Mali include *S. hermonthica, S aspera* and *S. gesnerioides*, but *S. asiatica* has not been found on any cultivated crop plant (Carson, 1989a; Hoffmann, 1990).

By contrast, only *S. hermonthica* constitutes a threat to millet, sorghum, maize and upland rice in Gambia, although *S. aspera* also infects maize (Carson, 1989). Only three species are important in Senegal, namely *S. hermonthica* on maize, millet and sorghum; *S. asiatica* on late millet and sorghum; and *S. gesnerioides* on cowpea (Carson, 1989b; Diallo, 1989; Lagoke, 1989). In Niger, in addition to the serious attack of pearl millet by *S. hermonthica* in the Maradi and Zinder divisions, millet and sorghum are also severely affected in Dosso division; *S. gesnerioides* devastates cowpea throughout the country (Hassan Hamma, 1989; Laycock, 1989). The two most common species in Chad are *S. hermonthica* in maize, sorghum and millet and *S. gesnerioides* in cowpea (Garouang, 1989).

c) ***Crop Yield Losses Caused by Striga*** A conservative estimate of crop losses due to *Striga* in Africa is about 40% (FAO, 1989). The range of yield losses, however, varies from one country to another, depending on the crops attacked and the ecological zones in which the affected crops are produced. Usually, higher yield losses occur in countries situated mostly in the Sudan savanna and/or the Sahel, compared to losses in countries located in the *Guinea* savanna and/or wetter ecologies. It is believed that certain factors (e.g., drought, low and erratic rainfall, and intensive production of crops in marginal environments) have exacerbated yield losses caused by *Striga* damage.

As expected, the magnitude of yield losses is partly dependent on the susceptibility of the crop variety to *Striga* damage. For example, Obilana reported yield losses of 5%, 43-63%, and 95% for the resistant, tolerant and susceptible varieties of sorghum, respectively. While Ramaiah (1984) reported yield loss estimates of 10-35% on experimental fields, crop losses of up to 100% are common on severely affected farmers fields' grown to susceptible crop varieties.

With respect to losses reported in various countries of West and Central Africa, 30% yield loss in cereals, on the average, has been reported in The Gambia (Carson, 1989). Lagoke (1989) reported average yield loss of 39% in Nigeria, with a range of 10-95%, but later estimated a range of 40-100% (Lagoke *et al.*, 1990). A similar range, 50-100%, has been reported in Togo. Also in Mali, preliminary surveys of farmers' field crop yield losses of between 25 and 100% have been reported (Carson, 1989). Ghana has reported one of the highest yield losses of 78 to 100% in sorghum, maize and millet (Bolfrey *et al.*, 1989).

d) ***Factors Affecting Incidence and Severity of Striga Attack.*** Several factors, other than the inherent susceptibility of the host to infection by *Striga*, have been associated with high incidence and/or severity of *Striga* damage in crops (Lagoke, *et al.*, 1988; Emechebe, unpublished report). In general, the intensity of *Striga* damage is exacerbated in plants grown in degraded soils of poor or marginal fertility and low moisture retention capacity. Being a highly adapted parasite, *Striga* relies on its host for water, mineral nutrients and carbohydrates, regardless of the host's nutritional status and provided the latter does not die prematurely (Emechebe, unpublished report). Many *Striga* plants have also been observed to survive and mature on stumps and roots of harvested hosts, a characteristic that apparently enables *Striga* to survive drought conditions.

The successive cultivation of susceptible hosts, in monocrop or in mixtures, is a major factor that increases the incidence of *Striga* in the sub-region, especially as the major cereals are susceptible to more than one species. Multiple infections of cereals and cowpea grown on the same piece of land by *Striga* spp. has made the use of crop rotation untenable in such fields. Any advantages of land fallowing are no longer available to farmers in semi-arid regions because of heavy population pressure on the land. Indeed, land is cultivated and grown to susceptible crops successively. The effect is the build-up of *Striga* seed population in the soil (Emechebe, unpublished report).

As a parasite, *Striga* is very prolific. Thus, a single plant of *S. forbesii* produces up to 25,000 seeds, while *S. asiatica* produces as many as 500,000 seeds per plant. It is clear that an improper management that allows *Striga* to produce mature seeds will increase attack in a subsequent crop.

The very small, light seeds of *Striga* are capable of dissemination over long distances by sand storms and on the hoofs of animals, in addition to short distance disperal through several activities of man, e.g. land preparation. The rapid dissemination of *Striga* throughout most of West and Central Africa has been difficult to explain but at the moment it is postulated that *Striga* seeds have moved long distances inadvertently as contaminants of seed. (Lagoke, 1989; Lagoke *et. al.*,

1990). On the other hand, the wide occurrence of Striga in Côte d'Ivoire has been attributed to the *Striga* seeds present in the dung of cattle that emigrated from *Striga*-infested neighbouring countries, such as Burkina Faso (Kouassi, 1989).

The wide host range of *Striga* is a major factor in its survivability, perpetuation and dissemination through seeds. Most of the cereals *Striga* parasitize many crop plants as well as wild or pasture grasses, even on fallow and roadsides. These parasites, which survive conditions that are unfavourable for good food grain crop production, survive and produce seeds which serve as inoculum for spread to other farms on these wild hosts. Most of the cereal *Striga* species were parasites of wild grasses before they were recognized as parasites of cereal crops.

The inherent ability of the *Striga* seed to survive unfavourable conditions for up to 15 years is a major factor on survival of *Striga* species and it has complicated the problem of control. Subsequent to the after-ripening dormancy, seeds of most *Striga* species require pre-conditioning and adequate chemical stimuli, usually from roots of suscepts, for germination. If, for various reasons the pre-conditioned seed does not germinate, it becomes dormant (wet dormancy) but remains viable until the next crop season; the process can be repeated for up to 20 years.

Possible Methods of Controlling *Striga*

In view of the wide-scale damage done to grain crops by *Striga*, especially in Africa and Asia, a lot of attention has been given to meaningful and economic methods of control. In the context of Africa, control measures within the reach of the peasant farmer have been the obvious choice (Musselana, 1980). The various methods of *Striga* control are discussed briefly below:

a) *Destruction of Striga Plant.* Two main methods have been employed for destruction of *Striga* plants: physical and chemical.

i. ***Physical Destruction.*** Physical destruction of the *Striga* plant by hand-pulling, hoe-weeding or uprooting of the whole plant (haustorium plus shoot) has been the most common practice adopted by peasant, small-scale farmers. Most farmers in The Gambia, for example, control *Striga* by late hoe-weeding or by hand-pulling of plants close to the time of crop harvest (Carson, 1983). Similarly, Bolfrey *et al.* (1990) reported that 90% of farmers in heavily infested areas of Ghana practise hand-pulling of *Striga*, although hoe-weeding is also practised by many. Also, in Nigeria, hand pulling and hoe-weeding are practised in 79-82% of the farms (Lagoke *et al.*, 1988). In contrast, in Burkina Faso experiments have shown that hand weeding of *Striga* in millet fields only once in the season, just before harvesting of the millet, gave encouraging results.

Despite its frequent use by resource-poor farmers, physical destruction of *Striga* plants has some drawbacks. In the first place, *Striga* plants may produce ripe capsules before they are uprooted; such capsules subsequently dehisce to release large numbers of seeds. Secondly, hand-pulling of emerged *Striga* plants, especially at the very early growth stages, often permits the emergence of even more shoots because of removal of apical dominance and reduced competition for

nutrients (Last, 1960; Ishaq, 1968) Thirdly, hand-pulling (apart from being tedious, labour intensive and expensive) is ineffective for preventing loss in yield in the very season it is effected, since most of the damage to the host is done before the *Striga* emerges above soil level, (Lagoke *et al.*, 1988). Thus, Carson (1986) reported that in The Gambia, hand-pulling resulted only in a slight yield increase of grain sorghum but it reduced net income. On the other hand, Doggett (1965) reported that hand-pulling of *Striga* plants under rainfed conditions every two weeks resulted in greater yields of sorghum than pulling every six weeks. Beneficial yield increase due to hand-pulling has also been reported. Indeed, hand-pulling of *Striga* plants could be effective in controlling light infection and could serve as a control measure supplementary to growing of resistant varieties.

ii. ***Chemical Destruction***. Foliar application of herbicides to emerged *Striga* plants has been the main method of destruction of *Striga* plants, the most commonly used herbicide being 2,4-D, one of the most selective and cheapest (Yaduarjrut and Hosmani, 1979). A related compound to 2,4-D (MCPA) has also been effective, especially when it is mixed with bromoxynil to enhance contact (Lagoke *et al.*, 1988). Other chemicals which have been effective as foliar herbicides for *Striga* control are oil-based ametryne and linuron Eplee *et al.*, 1987).

Post-emergence application of foliar herbicides with the conventional knapsack sprayer has reportedly given effective reduction of *Striga* especially when combined with other control measures such as resistant/tolerant crop varieties and a high nitrogen level (Lagoke et al., 1988). Also directed application of paraquat has been effective in selectively killing *Striga* plants in tall growing crops like maize, sorghum and pearl-millet (Eplee and Langston, 1970). Spot spraying of *Striga* shoots with a 2% solution of paraquat using a small hand-sprayer resulted in effective reduction of *Striga* populations and increased income Other chemical compounds like the diphenyl ether compounds, oxyfluorfen, lactofen and acifluofen had excellent post-emergent effect against *Striga*, in addition to being pre-emergence herbicides (Eplee, 1981).

In Nigeria, 2,4-D alone at 2 kg a.i./ha and its mixture with diflufenican (among others) as components of *Striga* control packages resulted in effective control of *S. hermonthica* and other weeds with consequent increase in grain yields of maize and sorghum (Lagoke *et al.*, 1990).

Although chemicals have been effective in controlling emerged *Striga*, they have limitations. For example, phenoxy materials cannot be applied to crop mixtures containing susceptible broadleaf crops such as cowpea. Damage to plants outside the target area may be a problem where the ester formulation is used (Eplee and Norris, 1983). Similarly, ametryne and linuron can damage other crops, such as cowpea. Moreover, the post-emergent herbicides are only beneficial in stopping *Striga* seed production and have minimum yield benefits on the crops in the very season of application. Finally, at present, most chemicals are beyond the economic reach of the ordinary, small-scale farmer.

b) ***Host-Plant Resistance***. The use of varieties resistant to *Striga* is perhaps the safest as well as most promising and economical control method. Although there

were initial attempts at selecting resistant sorghum varieties elsewhere, the first effort in this respect in West and Central Africa was the screening work carried out on sorghum since 1970 by the Institute for Agricultural Research (IAR), Samaru, Nigeria. After screening over 200 lines, SRN 4841 was reported to be resistant. However, Doggett (1954, 1970) had earlier reported *Striga* resistance in two varieties ("Dobbs" and P. 41) from Tanzania and in Framida from Chad.

Among the varieties evaluated in Nigeria, SPV 103 and IS 6961 exhibited the highest level of resistance to *S. hermonthica* (Ramaiah, 1986). Other promising ICRISAT selections with good levels or resistance to *S. hermonthica* in Burkina Faso include: ICSV 1005, ICSV 1006, and ICSV 1007 BF. Unfortunately, grain yields of some of the resistant lines are low and efforts have been to transfer the resistance genes into high-yielding and acceptable background. However, one other promising cultivar, ICSV 1002 BF, had additional good characters (e.g., white grain, resistance to lodging and to important leaf diseases) and was released to farmers in Burkina Faso and the Gambia.

Strenuous effort at IITA identified *Striga*-tolerant, inbred maize lines and hybrids such as 8322-13 and 8321-18 (Kim, 1989). Further work resulted in the development of other hybrid varieties and two open-pollinated varieties which exhibit *Striga* tolerance under moderate levels of infection. Similarly, a hybrid maize variety, NG 3 WC-2, developed by the National Cereals Research Institute, Badeggi, Nigeria, exhibited a higher level of tolerance than 8322-13 at a site in the Southern Guinea savanna of Nigeria (Lagoke *et al.*, 1988). Among open-pollinated varieties of maize tested in a field heavily infested by *S. asiatica*, variety TIBD was the most outstanding.

Initially, identification of *Striga* resistant varieties in millet was difficult, although a selection from a local variety, 3/AHK, was less susceptible than others tested (Ramaiah, 1986). Recently, two millet lines (S-87-122 and S-87-121) from Niger had the lowest *Striga* shoot counts of 2-3 plants/pot, compared with 20-38 plants/pot for susceptible entries (Werder *et al.*, 1989).

Screening of elite cowpea lines under artificial infestation in pots and the field at Kamboinse (Burkina Faso) in 1981 identified two varieties, SUVITA-2 and 58-57; of these, SUVITA-2 had high level of resistance to the *Striga* strain in Burkina Faso and Mali, but was only moderately resistant or susceptible to the strain in Nigeria and parts of Niger (IITA, 1982 and 1986). In 1987, two other varieties, B-301 (from Botswana) and IT82D-849 (an advanced breeding line from IITA) with high levels of resistance across the sub-region were identified (Aggarwal, 1988; Emechebe *et al.*, 1988). The resistance to *Striga* in B-301 has now been shown to be controlled by a single dominant gene (Singh and Emechebe, 1990). Because of the relatively poor seed characteristics of B-301, its gene for *Striga* resistance is being transferred to varieties with desirable agronomic traits by cowpea workers in Burkina Faso and Nigeria.

c) ***Cultural Practices.*** Various cultural control measures for *Striga* control have been reviewed recently by Bebawi (1987) and include the use of fertilizers, crop rotation, land preparation, date of sowing and biological control.

i. ***Fertilizer Application.*** The main form of fertilizer which has been commonly used has been the nitrogenous formulations, except when N is applied as a compound (NPK) fertilizer. Organic manure has also been used by peasant farmers who regard it as a cheaper source of nitrogen.

The applications of N fertilizer and/or manuring have given some control of cereal *Striga*. Egley (1971) in pot trials obtained 45% reduction yield at high nutrient level compared to 70% reduction at low nutrient level; sorghum produced seeds only at the highest nutrient level, indicating some level of protection from the *Striga* attack. By contrast, a trial was reported in Nigeria where the recommended rate of nitrogen did not increase sorghum yield but rather increased the number of seed-forming *Striga* shoots. Only application of four and six times the recommended rate (i.e. 103 kg and 155 kg N/ha) gave economic responses per unit of applied N and reduced the amount of flowering *Striga* shoots to a level which could be controlled by supplementary hand-pulling.

Elsewhere, grain yields of sorghum were increased by 14, 25 and 45% while *Striga* shoot yields were reduced by 14, 21 and 35% with addition of 43, 86 and 172 kg N/ha as urea, respectively (Bebawi and Abdulaziz, 1983). On the other hand, application of 90 kg N/ha resulted in increased grain yield of sorghum in the Southern Guinea savanna zone of Nigeria, but *Striga* count at harvest was increased in fertilized plots compared to unfertilized plots, although there were no significant differences in the incidence of infection (Lagoke *et al.*, 1990).

Fertilizer use as a strategy in the control of *Striga* in maize has received little attention. Preliminary studies in Ghana indicated that ammonium sulphate fertilizer was better than urea in reducing *Striga* count at tasselling, at harvest, or at 10 days after harvest (Bolfrey *et al.*, 1990). *Striga* incidence was only reduced by application of 150 kg N/ha which also reduced yield reduction caused by *Striga*.

The use of nitrogen fertilizer in controlling *S. gesnerioides* in cowpea has not been practised much due to the fact that cowpea obtains most of its N requirement from biological N-fixation which is adversely affected by high doses of applied N. However, studies in potted sand culture showed that 140 ppm N applied continuously as $NaNO_3$ solution completely prevented infection by *S. gesnerioides*, with a drastic decrease in nodule numbers (Emechebe *et al.*, 1988). Adu *et al.* (1989) reported about 76% reduction in *Striga* infection of cowpea with application of 120 kg N/ha at a site in the Sudan savanna zone of Nigeria. At another site within the same zone, application of 30 kg N/ha gave about 37% reduction in *Striga* infection. Although there was no corresponding significant increase in cowpea grain yield, recent studies have indicated some benefit from N application to cowpea in a field heavily infested by *Striga* (Adu and Emechebe, 1991).

The use of fertilizers containing nutrient elements other than N has received little attention; however, a study in India indicated no beneficial effect. For example, while N application to pearl millet in fields heavily infested by *Striga* reduced the incidence of *Striga* and doubled the yield of the crop, neither P nor K had any significant effect on either *Striga* incidence or on yield of pearl-millet (Marthur and Marthur, 1967). In some other studies, P has been combined with N and it has not been possible to separate the effect of the two nutrient elements (Ogunlela, 1983).

Despite the reported cases of N fertilization in either improving the cereal yields or in reducing *Striga* incidence, its use has not been widely accepted. One probable reason is that rates required for effective control of *Striga* are more than those usually applied by the farmers. Furthermore, in heavily infested fields, nitrogen may increase the incidence of infection (Bebawi, 1987). For example, *Striga* counts on sorghum plots treated with manure in northern Nigeria showed that manured plots had about 40% more emerged *Striga* plants than unmanured plots (Butler, 1957). The high cost of fertilizers and their unavailability to farmers also pose a major constraint to the use of fertilizers for *Striga* control.

ii. ***Crop Rotation*** involving the use of non-susceptible trap crops, has been practised by peasant farmers for a long time. A recent survey has shown that about 25% of farmers in *Striga* infested areas of Ghana practise crop rotation (Bolfrey *et al.*, 1989). In The Gambia, alternating sorghum or millet with groundnut results in a low *Striga* infection, while growing three crops of groundnut as a trap crop before a cereal resulted in further reduction of incidence of infection (Lagoke *et al.*, 1988). In contrast, *Striga* population was not reduced in sorghum fields intercropped with multiple rows of groundnut (Carson, 1985). However, in Cameroon, many farmers rotate sorghum with groundnut (Lagoke *et al.*, 1988).

While there is little evidence that groundnut induces the germination of cereal *Striga* seeds, it appears that soyabean, cotton and bambara nut, when grown in rotation with a susceptible cereal host or as intercrops, induce abortive germination of *Striga* seeds with a consequent reduction in incidence of infection.

iii) ***Land Preparation***. Although deep cultivation is tedious and expensive, it has been used to control *Striga* in some places. For example, deep cultivation to bury *Striga* seeds has been effectively used to control the parasite in Mali (Konate, 1986). By contrast, Carson (1986) has suggested using zero or minimum tillage so that crop seed is planted with little soil disturbance. This practice does not appear feasible, since it implies the use of contact herbicides (such as paraquat) which are not only too expensive for use by peasant farmers, but their application also requires a lot of skill and care (Lagoke, *et al.*, 1988).

iv) ***Date of Sowing***. Incidence of *Striga* infection was found to be closely correlated with date of planting of host crops. In the Sudan, for example, late sown sorghum was less attacked than the early sown crop sorghum (Bebawi, 1984). These results have been attributed to cooler soil temperature regimes of the early sown crop. In contrast, late sowing had no influence on incidence of *Striga* infection on sorghum in the Southern Guinea savanna zone of Nigeria; indeed grain yields were better with early sowing (23 June) than with late sowing 14 July) (Lagoke *et al.*, 1990). Similar observations were earlier made by Ramaiah (1987).

v) ***Biological Control*** of *Striga* is an important area that has, at least theoretically, the potential of providing long-term solution to the *Striga* problem, given the achievements obtained with cassava mealybug, cassava mosaic virus disease and other biological control successes in West and Central Africa. Various insects and pathogens have been tried in this method of *Striga* control.

Among the insects identified to be effective in destroying *Striga* are *Steneptilodes taprebanes* (plum moth) which is the most prevalent insect on *S. hermonthica* and *S. asiatica* in East Africa. It can prevent *Striga* seed formation. *Eulocastra* spp. have also been reported on *Striga* species in various parts of the world; *E. argentisparsa* was observed to feed only on *Striga* spp. with one insect consuming about 100 capsules within its life cycle (Lagoke, 1989).

However, *Smicronyx* weevils are the most favoured insects for biological control of *Striga* spp. The weevil occurs in many countries of West Africa (Nigeria, Mali, Guinea, Côte d'Ivoire, Burkina Faso and Niger) as well as in Central, Southern and Eastern Africa (Cameroon, Sudan, Uganda, Kenya and Zambia). Appearance of the adult *Smicronyx* weevil synchronizes with the presence of *Striga* plants, but adult feeding does not seriously affect *Striga*. Galls are formed on the *Striga* by the larval stage, but in the humid savanna zones of Nigeria, the galls appear to have little overall effect on *Striga* seed production. However, in the Sahel, 80% of *Striga* plants can be galled and seed production severely affected.

Amongst the *Striga* pathogens are *Sphaerotheca fuligines* (powdery mildew) reported from India and Africa. It causes premature drying of *S. densiflora* and is more virulent under conditions of low moisture; hence it has potential in the semi-arid regions. *Phema* spp. cause leaf and stem lession in *Striga* spp. in Zimbabwe and stunting in Nigeria. *Cercospora* spp. have been reported in India and in some African countries. In Nigeria, for example, heavily infected *Striga* plants do not produce seeds.

Not much work has been done to effect release of *Striga* bio-control agents. In Ethiopia *Smicronyx albovariegatus* and *Eulocastra argentiparsa*, obtained from India, were released into Humera on the Setit River close to the Sudan border through CIBC, but no recovery survey was done because of the prolonged civil unrest in that area. Another release was made in Kobo in Welo Province but recovery survey made in 1979 provided no information (Lagoke, 1989).

Striga Researchable Issues

A discussion of the researchable issues is clearly heavily biased towards integrated control of *Striga* or, at least, towards the use of several components of integrated pest control in *Striga* control. The essential features of integrated pest management (IPM) comprise three basic principles: firstly, wherever possible, control should rely on natural enemies of pests; secondly, natural enemies should be enhanced (directly or indirectly) and host plant resistance used to reduce the necessity for expensive chemical control; and, thirdly, chemical control should be selective and should only be used as an when pest population increases to a level above which significant economic damage occurs, i.e., above the economic threshold.

The actual application of the IPM principles by the farmer involves four components, namely biological control, cultural control, host plant resistance and selective use of pesticides. Biological control involves the introduction or re-introduction of natural enemies (predators, parasites or diseases), although for some pests, enhancement of existing natural enemies may be a more sensible alternative.

Cultural control as an IPM component basically involves manipulation of the crop and its environment with a view to increasing the chances of survival of natural enemies and/or reducing the chances of survival of the pest. It has been suggested that these can be achieved by mixed cropping rather than monoculture, thereby reducing the size of pest populations by reducing the food resources available to the pest while at the same time providing alternative refuges for the natural enemies. Another example is destruction of crop residues containing resting stages of the parasite.

Host plant resistance has in the past played major roles in the control of crop disease; for some crops such as cowpea and maize, successes have been recorded with respect to plant diseases compared to insect pests. Selective pesticide use is the fourth component of IPM, the concept of economic threshold being used to limit the amount of pesticides to be applied. Fortunately, some available pesticides have some degree of selectivity, while certain application techniques (e.g., ULV and electrodyne spraying) can reduce the amounts of pesticides required to achieve effective control.

With this background, the question is which of the four IPM components should be developed and packaged for *Striga* control in West and Central Africa ? It is our belief that biological control of *Striga*, through the use of parasites and diseases of *Striga* spp., is a distinctly remote possibility. Given this situation, a semblance of integrated control of *Striga* is pivoted on maximum use of host plant resistance which is augmented by various cultural practices and, where necessary, judicious use of herbicides. The expectations of research in these three areas are the subject of the remaining part of this paper and especially focussed on the four SAFGRAD mandated crops - maize, sorghum, millet and cowpea.

a) **Host Plant Resistance.**

i. ***Sorghum***. The efforts to develop sorghum varieties resistant to different species of *Striga* have been reviewed recently by Ramaiah (1986 and 1987). It is obvious that there are several sources of moderate to high levels of resistance in sorghum to individual species of *Striga*, while a few lines have combined resistance to two or more species. The first problem is to determine the relative distribution of the important species of *Striga* attacking sorghum. At the moment, *S. hermonthica* is the most important, being more widely distributed and destructive. However, other potentially destructive species (namely, *S. aspera, S. forbesii* and *S. asiatica*) are beginning to appear at some locations in the sub-region.

There is also some evidence of pathogenic variation within *S. hermonthica*. This, and the distribution of different *Striga* species inflicting severe damage on sorghum, should receive concurrent research attention. This will facilitate the development and screening of varieties for resistance to species for pathotypes important in different locations. A case in point is the recent report that one "seguetana" sorghum variety was highly resistant to *S. hermonthica* in northern Mali but completely susceptible in southern Mali (Ramaiah, personal communication). This suggests a location specific resistance (probably attributable to edaphic factors) or the existence of two different pathotypes in the two parts of Mali.

The EARSAM network has recently confirmed the combined resistance to *S. hermonthica* and *S. asiatica* in Gambella-1107, N-13, ICSV-1006 and ICSV-1007, the last two being white derivatives of Framida. What is now urgently needed is a comprehensive screening of the entire sorghum germplasm of ICRISAT and other organizations, for single and multiple resistance to *S. hermonthica, S. aspera, S. forbesii* and *S. asiatica*. At the same time, work on the genetics of resistance in the available resistant lines should continue, regardless of the mechanism of resistance, to facilitate the breeder's work of incorporating more genes for resistance into the already resistant varieties.

In furtherance of the need to increase the levels of resistance in cultivated sorghum, the wild relatives of sorghum should be screened for resistance to different species of *Striga*. Any genes for high resistance to *Striga* spp. should then be transferred to cultivated sorghum through wide crosses with or without the aid of biotechnology; any heritable tolerance to *Striga* should be transferred to commercial varieties. The overall objective is to produce varieties with the widest resistance base as well as tolerance, as an insurance against the emergence of new, dominant races of the *Striga* spp.

ii. ***Millet.*** For pearl millet, the situation in respect of availability of varieties resistant to *Striga* spp. is a direct contrast to the situation in sorghum. There is virtually no cultivated variety with high level of resistance to *S. hermonthica*. Indeed, only "promising" or "less susceptible" lines have so far been identified. The report that Ex-Bornu millet was highly resistant to *S. hermonthica* at Samaru (Nigeria) in the Northern Guinea savanna, but highly susceptible at Gwoza in the Sudan savanna (also in Nigeria) is illustrative of the existence of pathogenic variation in millet *S. hermonthica*. In Nigeria, at least, millet is not affected by *S. hermonthica* in the Northern Guinea savanna, although it devastates the crop in the Sudan zone, regardless of the planting date. In the Southern Guinea zone, only the late-sown crop is attacked. This type of observation has been reported in other parts of West Africa by Ramaiah (1986). In pearl millet, resistance is probably ecologically specific on account of specific environmental factors. This has important implications in deciding sites at which to screen for resistance to millet *Striga*. Another explanation is that different pathotypes of millet *S. hermonthica* occur in the different ecologies. The implication here is that such apparent ecological differences will become indistinct with the dispersal of the strains across the ecologies.

Nevertheless, it is perfectly reasonable to expect a wide variability of response to *Striga* in pearl millet, given the long association between the suscept and the pathogen in West and Central Africa. Yet, there is no millet variety with high level of "true" resistance to *S. hermonthica* and other important *Striga* species. What could be the reason? Is it because the available germplasm has not been properly and thoroughly screened for their reaction to *Striga* spp? Or is it that germplasm in the present collections does not include materials with high resistance to *Striga*? Are highly resistant materials available in nature and only awaiting collection and evaluation? These and similar questions should receive priority research attention, as should the collection and screening of all available wild and semi-wild relatives of pearl millet. Another aspect of *Striga* millet that requires detailed studies relates

to the apparent absence of cereal *Striga* problem in Somalia despite the overwhelming importance of sorghum and millet as staple food crops in that country. Could the land races of sorghum and/or millet there be highly resistant to *Striga*?

iii. ***Maize***. Whereas *Striga* is mostly an indigenous scourge of Africa, maize is a relatively new crop. Although both *S. asiatica* and *S. hermonthica* had been recognized as major constraints to maize production in Eastern and Southern Africa since the 1930s, *Striga* did not become a serious problem on maize in West Africa until the crop was moved from the rainforest zone to the savanna in the 1970s. It is not surprising, therefore, that there has been no reliable report of "true" resistance to *Striga* spp. in maize until recently when IITA scientists have developed *Striga*-tolerant, open-pollinated, synthetic and hybrid varieties. While the effort is highly commendable, the concern is the reported increase in *Striga* seed population in the soil by these tolerant varieties. For example, at low *Striga* seed population, the hybrids 8322-13 (tolerant) and 8338-1 (susceptible) yielded 7.5 and 5.5 ton of maize grains, compared to 7.6 and 7.5 ton in *Striga*-free soil and 2.7 and 0.0 ton/ha at high *Striga* seed densities, respectively. There is, therefore, a need to continue the search for resistance among the available germplasm of CIMMYT and IITA as well as in all the distant and close relatives of maize.

iv. ***Cowpea***. *Striga* scientists appear to be the happiest, at the moment, with the several sources of moderate to high levels of resistance to *S. gesnerioides*. The work that has already begun towards incorporating the genes for *Striga* resistance in some of these resistant lines (B-301, SUVITA-2, etc) into agronomically acceptable and locally adapted cowpea varieties should continue with the highest priority. In addition, work should also continue in the screening of available germplasm for *Striga* resistance, including such wild relatives as *Vigna radiata* and *V. vexillata*.

b) **Cultural Practices**

i. ***Application of Fertilizers***. More critical and intensive work needs to be done relating to nitrogenous fertilizer effects on cereal *Striga*. The present descrepancies between the results of various workers are probably attributable to differences between soil N status of experimental sites. In this regard, areas that would require research attention should include determining the levels of available N in the experimental site and the crop's optimum fertilizer requirement for that level of available N; the effect of different sources of N; the effect of other nutrient elements and notably P and its interactive effect with N especially on the reaction of cowpea to *Striga*.

ii. ***Crop Rotation***. Crop rotation involving trap crops would help to reduce the *Striga* seed soil inoculum density. In this respect, the trap cropping efficiency (i.e. rate of reduction of the *Striga* seed soil inoculum) of various trap crops should be carefully studied. An important corollary of this area of study is to determine an effective method of estimating the density of *Striga* seeds in the soil. The direct extraction of *Striga* seeds from the soil is probably more quantitative than bioassays involving very susceptible varieties of the suscepts, although both can be used where it is necessary to determine the host species susceptible to the *Striga*

population in a specific location or field. Indeed, an integrated *Striga* control package should make provision for pre-growing season advice to farmers about the level of risk from *Striga* attack so that necessary cultural practices can be effected in time.

iii. ***Mixed Cropping***. There have been conflicting reports about the use of mixed cropping as a *Striga* control measure, especially in cereals. What is the scientific basis for any such controls ? It stands to logic that for some benefit to accrue to the crop at risk, the beneficial crop should induce *Striga* seed germination which would then be followed by lysis of the resulting seedlings before roots of the suscept come in contact with them. Such a hypothesis opens up a host of possibilities on mixed cropping which would need to be addressed.

iv. ***Land Preparation.*** Also deserving research attention is the real effect of land preparation (zero or minimum versus conventional tillage; ridges versus flat; deep versus shallow cultivation) on *Striga* seed inoculum and *Striga* control.

v. ***Sowing Date***. Detailed work needs to be undertaken towards explaining the reported observations that early planted cereal crops are less attacked and/or damaged than later sown crops, and vice versa. Among questions to which answers would need to be sought is to determine the basis of reduced attack in early-sowing crops; a lower incidence of *Striga* infection or reduced severity of attack; how is a lower incidence of infection related or not to the wet dormancy of *Striga* seeds in late-planted cereals; is there an implication of soil temperature; does early planting enhance the crop's tolerance to the pathogen; and so on. Since planting date is location specific, it is important that any beneficial effects of "timely" planting for *Striga* control should be determined and utilised for the different sites and ecologies.

vi. ***Chemical Control.*** Following the commendable progress made in evaluating various post-emergence herbicides for *Striga* control in cereals, the emphasis should now be in evaluating the most suitable methods of application, ensuring that they are not only effective, but also cheap and easy. In addition, there is the need to accelerate the work already begun to screen post-emergence herbicides for the control of cowpea *Striga*. Since pre-emergence herbicides are only just beginning to receive research attention, there is the need to accord high priority to this aspect, especially since most of the damage by *Striga* is done at its subterranean phase, both before and after its emergence above soil level.

vii. ***Seed Disinfection***. Also of researchable importance are aspects of *Striga* dispersal that deserve urgent attention, towards developing integrated control packages. Among questions that relate to the dispersal of *Striga* seed are whether or not they are carried with those of their suscepts; what proportion of *Striga* seeds that are consumed inadvertently by ruminants remain viable after passing through their alimentary canals; for how long do seeds in such animal droppings remain viable compared to other *Striga* seeds? And so on.

c) **Concluding Comment on Researchable Issues** Attempts have been made to highlight those issues that are believed to require urgent research attention by

national, regional and international research centres before an integrated package of *Striga* control can be put together for different crops in different ecologies. As earlier indicated, such a package would necessarily be dependent on the use of *Striga* resistant varieties grown under such cultural practices that argument host plant resistance while mechanical and chemical means are used to reduce the population of *Striga* seed inoculum density in the soil. The most important aspect of any control package is that it should be technically and economically feasible at the level of resource-poor farmers.

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Integrated Research Approach to *Striga* Control in Food Grain Production in East Africa.

A.G.T. BABIKER.

Agricultural Research Corporation, Gezira Research Station, Wad Medani, Sudan.

Abstract

In Eastern Africa sorghum, millet and maize are the main staple food. Immigration of people, pressure on land with the attendant reduction of fallows, planting areas of marginal rainfall, continuous monocropping of susceptible crop varieties and lack of soil conservation set the stage for an outbreak of *Striga*. The problem is expected to be compounded further by the introduction of highly susceptible, high-yielding crop varieties and/or hybrids. The huge reserve of seeds in the soil, the special germination requirements, coupled with a variable environment preclude an easy solution for the *Striga* problem and necessitate adoption of an integrated control strategy. Cultural, chemical and biological methods of control as well as the use of resistant varieties are reviewed. No single method can provide adequate answers to the problem. Effects of individual treatments displayed distinct variations with site and season. The observed variabilities, coupled with lack of immediate returns impede adoption of research recommendations. Research proposals based on manipulation of the agricultural system have been made. The objectives of the proposal are to highlight the limitations of available methods and to suggest possible future amendments.

Introduction

The population of Africa is increasing, food shortage is eminent, agriculture in most countries is traditional and inefficient. Increasing quantities of grains have to be imported. Prices of grains, however, have increased with rises in production costs and pressure of demand on falling world reserves. It is, therefore, apparent that food production should be the prime concern of all African governments.

In East Africa, sorghum, millet and maize constitute the main staple food. The production of these crops, however, is devastated by the parasitic weed, *Striga hermonthica* (Del.) Benth. (Ramaiah and Parker, 1982). *In :* infested areas, yield losses ranged from 40 to 100% (Bebawi, 1987). The parasite is a difficult-to-control weed. It is very versatile and adapted to traditional practices (Ogborn, 1983). It produces large numbers of seeds with prolonged viability and special germination requirements (Andrews, 1945; Eplee, 1975).

Immigration of people as a result of drought conditions and/or civil unrest, pressure on land with attendant reduction of fallows, planting of areas of marginal rainfall, continuous monocropping of susceptible varieties and lack of soil conservation set the stage for an outbreak of *Striga*. The problem, as noted elsewhere (House and Rao, 1982) is expected to be compounded further by the introduction of the highly susceptible, high yielding crop varieties and hybrids.

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Several methods of control, including cultural, chemical and the use of resistant varieties have been tried; and yet the problem, today, remains as serious and insoluble as ever (Parker, 1983).

This paper reviews the main methods of Striga control, together with limitations and future research needs.

Cultural Practices

Cultural practices include crop rotation, trap and catch croppings, mixed cropping and hand-pulling.

a) ***Trap and Catch Cropping***. Trap and catch croppings are the foundation of a cultural strategy for reducing *Striga* seed reserves in soils (Bebawi, 1987). Trap crops (false hosts) are those plants which stimulate the germination of *Striga* seeds without being parasitized. They include cotton (*Gossypium* spp.), sunflower (*Helianthus annus* L.), sesamum (*Sesamum orientale* L.), soybean (*Glycine max* L.), dolichos bean (*Dolichos lablab* L.), groundnut (*Arachis hypogaea* L.) and cowpea (*Vigna unguiculata* Walp) (Andrews, 1945). Planting trap crops and keeping them free of grassy weeds was claimed to cause drastic reduction of *Striga* seeds in soils (Sand, 1987). Cotton preceding sorghum was reported to reduce *Striga* infestation by about four folds (Doggett, 1952 and 1953). In West Africa, trap cropping with cotton, soybean and bambara groundnut *(Voandzeia subtranea)* reduced *Striga* infestation in subsequent maize (Parkinson *et al.*, 1987). Early work at the Gezira Research Station (GRS), Sudan, showed that sowing of groundnut, cowpea and Dolichos bean in a *Striga* infested soil did reduce a large proportion of *Striga* seeds (Andrews, 1945; Wilson-Jones, 1953; Last, 1961). However, recent work at GRS has shown that *Striga* infestation in subsequent sorghum was decreased by Dolichos beans, not affected by cotton, but was considerably increased by sunflower (Babiker, A.G.T., unpublished).

Catch crops are true hosts of *Striga*. They induce germination and are parasitized by the weed. The crop is allowed to grow for 6 to 8 weeks and then ploughed into the soil as green manure (Hamdoun and Babiker, 1978). In South Africa, two years of double catch cropping with Sudan grass *(Sorghum sudanense)* resulted in almost complete control of *Striga* (Saunders, 1933). At GRS, catch cropping with Sudan grass reduced *Striga* in subsequent sorghum by 50% and increased sorghum yield by 524 kg/ha (Last, 1960a and 1961).

b) ***Mixed Cropping***. Mixed cropping sustained less *Striga* than sole sorghum crop. Emergent *Striga* plants were ill-nourished, less vigorous, and had less seed capsules than those emerging on sole sorghum crop. Mixed cropping alleviated the adverse effects of *Striga* on sorghum. Among the companion crops, Dolichos bean was the most suppressive while groundnut was the least. The effect of the companion crop on sorghum growth varied with the latter variety. Sorghum varieties SRN-39, and IS-9830, were the most responsive while Dabar and N-13 were the least (Babiker, A.G.T., unpublished).

c) ***Hand-Pulling.*** Hand-pulling is almost the only universally practised control technique for *Striga* species (Ogborn, 1983). However, effects of hand-pulling on

grain yield, especially on highly infested fields are disputable. Hand-pulling early in the season is labour intensive and has to be repeated several times.

d) ***Land Preparation.*** Mode of land preparation has been reported to contribute to control of parasitic weeds. No-till was found to reduce *Striga* infestation in Niger (Hess and Ejeta, 1987), while deep ploughing was reported to be effective in reducing *Orobanche* infestation in New Zealand (Frater, 1975).

Resistant Crop Varieties

Resistance, in its strict sense, absence of sustained witchweed haustoria attachment (Langston and English, 1990), does not exist. With reference to *Striga*, resistance implies the ability to resist and reduce the number of successful parasitic connections (Ogborn, 1983). Three different host resistance mechanisms to *Striga* have been identified:

a) Low stimulant production (Kumar, 1940; Rao, 1948; Williams 1959),
b) Mechanical barriers (Saunders, 1933) and
c) Antibiosis or physiological obstructions (Saunders, 1942).

Dixon and Parker (1984) have suggested additional resistance mechanisms based on root morphology, differential stimulation of chemotropism and influence of root exudates on rhizosphere microflora.

In theory, resistant varieties should provide the simplest, the best and the cheapest solution (Rao, *et al.*, 1982). However, resistant varieties take many years to develop and need to be adapted to locality (Parker, 1983). Out of 16,000 lines screened in India, only nine were reported to be resistant (Ramaiah, 1988). King (1975) screened 8,000 lines in Nigeria and of these, only 1% displayed high level of resistance. Recent research in Ethiopia identified several lines with good levels of resistance, but none of them was adapted to Ethiopian conditions (Sherif *et al.*, 1987).

Many resistant varieties were reported to lose their resistance after repeated planting (Parker, 1983; Ogborn, 1983). Furthermore, a resistant plant in one location may be susceptible in another (Nkouka, 1988). The problem of resistant varieties is further compounded by their vulnerability to diseases and insects, poor agronomic qualities and low yields (Nkouka, 1988; Ramaiah, 1988).

Fertilizers.

Low soil fertility, particularly low nitrogen status, is conducive to *Striga* parasitism (Doggett, 1965). Sorghum resists infestation when conditions favouring its growth are improved by addition of nitrogenous fertilizers (Bebawi, 1984). In general, very high nitrogen levels are needed for adequate suppression of the parasite (Last, 1960). The influence of nitrogen on *Striga* parasitism varied with rate, soil fertility, the crop and crop variety. Low levels of nitrogen increased *Striga* emergence on infertile soils, but decreased it on fertile ones (Patterson, 1990). Nitrogen is less suppressive to *Striga* on maize than on sorghum or millet (Robinson

and Dowler, 1990). With respect to sorghum varieties, nitrogen decreased *Striga* emergence on Feterita, IS-9830, Gambella-1107 and N-13, had negligible effects on *Striga* population on SRN-39, and stimulated emergence on Debakrie, Hageen Dura-1 and Dabar (Last, 1960; Babiker A.G.T., unpublished).

Herbicides

Many herbicides, including phenoxy and propionic acids amides, acetamides, acetanilides, urea and carbamates were evaluated for their potential use, but many were discarded for lack of efficacy and/or selectivity (Dowler and Robinson, 1990). Fenac, as a pre-plant soil incorporated treatment in sorghum or maize, gave adequate *Striga* control early in the season but displayed moderate residual activity (Hosmani, 1982). Chlorsulfuron, at very low rates (1-4 g/ha), applied at sowing gave and maintained excellent control of *Striga* in Sudan. However, it displayed considerable toxicity to sorghum. In Ethiopia, the product was ineffective against *Striga* and it has no adverse effects on sorghum (Babiker A.G.T. and Ridda, F., unpublished). Atrazine at 0.5 to 1.2 kg/ha gave adequate and persistent control of *Striga*, but it did not improve crop yield (Hamdoun and Babiker, 1978; Ranganadhacharyulu, 1982).

Oxyfluorfen, as directed post emergence treatment in Ethiopia and Sudan, effected satisfactory and persistent control of *Striga*. Furthermore, it improved sorghum growth and yield (Babiker, A.G.T. and Ridda, F., unpublished). Results with 2,4-D were erratic. Work at GRS (Sudan) and India indicated that application of 2,4-D at 4 weeks after planting resulted in excellent control of *Striga* and improved crop yield. Delayed applications reduced efficacy (Last, 1960a and 1960b; Korwar, 1982; Khade, 1982). Results obtained from Ethiopia and USA indicated that 2,4-D delayed *Striga* emergence. Plants emerging after treatment were not affected and that for effective suppression of the parasite, repeated applications were necessary (Ridda, F., unpublished).

Dicamba at 0.3 to 0.6 kg/ha applied 2 to 4 weeks after planting as a directed spray or over the top of the host plant gave and maintained excellent control of *Striga* in both sorghum and maize. *Striga* plants emerging in dicamba-treated plots were deformed, some died before flowering, others formed small deformed flowers while a few succeeded in producing seeds. Early application of the product increased crop growth and yield while delayed applications were harmful to crops, specially maize (Eplee and Norris, 1987).

Herbicides/Fertilizer Combination

Combinations of nitrogenous fertilizers with herbicides viz. 2,4-D, 2,3,6-TBA, fenac, atrazine, dicamba, linuron, oxyfluorfen and chlorsulfuron gave and maintained excellent suppression of *Striga* in both sorghum and maize (Wilson-Jones, 1953; Last, 1960a; Ogborn, 1987; Robinson and Dowler, 1990; Babiker, A.G.T., unpublished). The performance of the combinations was invariably superior to that of the individual components (Last 1960a; Babiker, A.G.T., unpublished).

Germination Stimulants

Several natural and synthetic compounds have been reported to induce germination of *Striga* seeds (Brown, 1965; Egley, 1972; Johnson *et al.*, 1976; Lynn and Chang, 1990). Of these compounds, ethylene, ethephon, strigol and strigol analogues have received most attention. Ethylene and ethephon were quite effective in inducing *Striga* seed germination under both laboratory and field conditions. Ethylene is largely used in USA where thousands of hectares are treated annually with the gas (Eplee, 1975). Field applications of ethephon at GRS was found to decrease *Striga* emergence and increase the number of sorghum heads (Babiker and Hamdoun, 1983). Strigol and strigol analogues were very active under laboratory conditions, but were less effective under field conditions (Babiker and Hamdoun, 1982).

Biological Control

Biological control is an established viable method of weed control (Greathead, 1983). It is relatively less costly and once established, it is self-prepetuating and can be made use of as a component of an integrated control strategy.

Numerous insects feeding on *Striga* have been collected in India and East Africa. Most of these insects, viz: *Heliothis armigera* and *Spodoptera* species, are polyphagous and are important pests of crops (Greathead, 1983). Other insects associated with *Striga* and which seem to have a narrow host range include *Smicronyx* spp., *Eurytoma* spp. and *Ophiomyia strigalis* (Bashir, 1987). These insects were reported to cause significant reduction in seed production (Ramaiah and Parker, 1982). However, the efficacy and spread of these insects is limited by parasites (Greathead, 1983; Bashir, 1987).

Fungi, mostly plurivorous or weak pathogens and saprophytes, were isolated from *Striga* but their significance as agents for biological control has not been assessed (Greathead, 1983).

Discussion

It is, thus, evident that none of the treatments, if adopted alone, can provide adequate answers to the *Striga* problem. The effects of individual treatments on *Striga* have generally displayed distinct variations with season and site. The observed variability, coupled with lack of immediate economic returns and unawareness of farmers and policy makers of the seriousness of the problem, impede adoption of research recommendations.

The variability in treatment effects is a logical consequence of the complex nature of the *Striga* problem. The response to a given treatment is governed by a multitude of interacting variables, including the parasitic nature of the weed, size of the seed bank, seed distribution in the soil and the attendant variability of seed environment with respect to soil moisture, temperature, atmosphere and soil composition. The problem is compounded further by the subterranean nature of the early developmental stages of *Striga* seedlings and by variations in intrinsic susceptibility

of crop varieties, soil fertility and the possibility of existence of *Striga* strains and physiological variants.

Striga eradication in Africa is an impractical approach. The parasite is widely spread and is hosted by many wild grasses in addition to cultivated crops. So far, very expensive and sophisticated methods (soil fumigation with methyl bromide or repeated injections of ethylene) proved widely effective. In Africa, socio-economic factors preclude adoption of expensive and/or sophisticated methods of control. Furthermore, it is noteworthy that in the USA, despite all efforts and facilities, *Striga* still infests 90,000 ha of land (Nkouka, 1989).

Striga Control Methods and Research Needs

In the light of the above discussion, the following groups of methods are to be considered in the campaign against *Striga* and in future research.

a) ***Preventive Methods/Phytosanitary Measures.*** In Africa, preventive methods of control have been totally neglected. Measures should be taken to avoid the movement of *Striga* seeds within a farm and between farms, by machinery, animals and crop residues. In addition, planting susceptible crop cultivars on infested fields should also be avoided. Generally, local varieties are more tolerant to *Striga* than exotic ones (Ogborn, 1983). Introduction of high-yielding sorghum varieties and hybrids led to outbreak of *Striga* infestation in several localities in the world (House and Rao, 1982). A susceptibility chart for crop varieties should be worked out and made available to producers and policy makers. Each recommended and popular variety is to be rated on *Striga* emergence and yield.

b) ***Cultural Practices.*** Plants common to the infested area should be tested for host specificity and host grouping (non-hosts, true hosts or false hosts). The annual depletion rate of *Striga* seeds should be determined for individual species. Plants possessing high depletion capacities can be manipulated for maximum benefits in *Striga* control.

Existing crop rotations, within the area, should be evaluated for their ability to enhance *Striga* seed demise. Rotations comprising one or two trap crops, should be promoted. Inclusion of leguminous crops in the rotation should be encouraged. Legumes, in addition to stimulation of *Striga* seed germination, increase the level of nitrogen in soils. Trap crops should be kept free from grassy weeds. Individual trap crop cultivars should be evaluated for their ability to induce *Striga* seed germination.

Planting sorghum in a mixture with a trap crop, a legume, reduced *Striga* incidence and seed production and improved sorghum growth. Legumes induce *Striga* seed germination. Moreover, their roots may compete with the host for haustorium attachment. The high humidity associated with the legume cover may reduce *Striga* transpiration and hence its ability to withdraw nutrients from the host.

Planting trap crops in mixtures with tolerant and/or resistant crops, especially low stimulant producers may enhance rate of *Striga* seed depletion in soils and may be very effective in case of localized infestations.

Hand-pulling is expensive and has no immediate impact on *Striga* infestation or grain yield. It is feasible under light or localized infestations. In case of heavy infestations, only 10 to 30% of the parasite seedlings appear above ground (Andrews, 1945, Doggett, 1965). Furthermore, re-sprouting of cut shoots from crown buds located beneath the soil surface often occurs. Hand-pulling at flowering is less expensive and may curtail seed replenishment specially if coupled with crop stubble removal.

Seed burial in soil at 50 cm depth led to complete loss of viability within three months (Mazlum, 1983). Work at the Gezira Research Station indicated that during burial, seeds may acquire a form of dormancy which is not broken by the usual pre-conditioning and stimulant treatments. Furthermore, seeds placed on the surface soil (0-5 cm) or those buried at 24 cm depth displayed variable and slow conditioning. Seeds placed at 5 to 20 cm depth were the most responsive to germination stimulants).

Taking the effects of burial on seed behaviour in conjunction with the finding that light inhibits germination (Worsham and Egley, 1990), it could be concluded that in the field, it is unlikely for *Striga* seeds to germinate on or near the soil surface. It is, therefore, imperative that the effects of land preparation on *Striga* infestation should be studied in detail. Deep ploughing during land preparation, for crops preceding susceptible hosts, should provide for deep burial and high rates of seed demise and/or dormancy. Minimum tillage or no-till, when planting host plants, should have the least impact on seed distribution within the soil profile. Furthermore, tillage systems could have indirect influence on *Striga* parasitism through their effects on host root development and distribution within the soil.

Striga seed germination is poor in wet soils (Saunders, 1933). Recent research results have indicated that stimulant production, activity and persistence decreased with increasing soil moisture content. However, high soil moisture delays conditioning and is conducive to wet dormancy (Babiker *et. al.*, 1987). Furthermore, the development of *Striga* following germination and host parasitization is favoured by light-textured, well-drained soil with low moisture content (Saunders, 1933). Flooding might serve probably in limited situations, where water is available. However, proper understanding of the factors involved may enable their simulation.

c) ***Resistant Varieties***. Many resistant varieties have been developed, yet their adoption rates have been very low. Resistant varieties, as they stand today, should never be looked upon as a permanent solution to the problem. It is difficult to convince farmers to plant resistant varieties and to ignore the new high yielding ones and hybrids. Nevertheless, breeding for *Striga* resistance has to continue. Rapid and simple techniques which encompass testing for most resistant mechanisms has to be developed. Resistance has to be broadened and established. Efforts have to be intensified to develop hihg-yielding varieties, each with more than one resistance mechanism. Understanding of the mechanism(s) by which resistance breaks should be given top priority. In this respect, the role of soil and environmental conditions as well as size of *Striga* seed reserves in soils has to be determined.

d) ***Nitrogen Fertilizers***. Generally, the use of nitrogenous fertilizers should be promoted. The relationship between *Striga* infestation and soil fertility has to be elucidated. High levels of soil fertility were reported to decrease stimulant production (Raju *et al.*, 1990) and to increase innate resistance of sorghum (Andrews, 1945).

e) ***Herbicides***. To alleviate the damage caused by *Striga*, the life cycle of the parasite must be disrupted prior to or immediately after attachment to the host root. This entails availability of herbicides within the rhizosphere of host plants. However, availability of herbicides is governed by a multitude of variables, including herbicides' physico-chemical properties, soil and environmental factors (Bailey and White, 1970). To control *Striga*, herbicide treatments are made as either pre-planting soil incorporated, pre-emergence, or post-emergence.

i. ***Pre-plant soil incorporated herbicides.*** Soil incorporation reduces dependence on irrigation and/or heavy rainfall to bring the herbicide within the rhizospheres of host plants. Furthermore, it reduces herbicide losses through volatilization and/or photo decomposition. However, it may reduce selectivity and jeopardize crop safety. Selectivity may be restored by decreasing herbicide rate or by using herbicide antidotes.

ii. ***Pre-emergence herbicides.*** Pre-emergence herbicides kill *Striga* when it emerges through the treated soil. Limited soil moisture and mobility decrease the availability of the product in the vicinity of *Striga* seedlings and may be conducive to erratic performance. Pre-emergence herbicides may have no effect on *Striga* during the early stages of establishment and, hence, may not affect early crop damage.

iii. ***Post-emergence herbicides.*** Post-emergence herbicides with contact action or those with restricted soil mobility or persistence may have no effect on *Striga* during early stages of parasitism. Furthermore, they may not kill *Striga* seedlings emerging after treatment and repeated application may be necessary. Such herbicides may have limited effects on grain yield.

Systemic herbicides, which translocate to the root system and kill *Striga* during early stages of growth, should be promoted as they may result in appreciable increase in crop yield. In general, application of foliar systemic herbicides to control localized infestation should be encouraged. In this respect, the application technique (IDFOLA) described by Ogborn (1983) may be quite useful, easy and safe.

f) ***Fertilizers/Herbicides Combinations***. Use of fertilizers and herbicide combinations should be promoted. However, effects of crop variety, application time, soil placement, soil type and environmental conditions on performance and persistence have to be studied.

g) ***Germination Stimulants and Haustorium Inducers.*** Germination and haustorium induction are two separate developmental events which are coordinated in time and space. They involve an orderly series of successive changes which are

controlled by signal molecules exuded from roots of hosts and non-host plants (Lynn and Chang, 1990). The active compounds are phenolic and allelopathic in nature (Riopel *et al.*, 1990).

i. ***Germination Stimulants.*** Use of germination stimulants, apart from ethylene, has met with little success (Babiker and Hamdoun 1982; Babiker, *et al.*, 1987). Most of the compounds have restricted mobility (Egley, 1990) and very limited stability in soils (Babiker, *et al.*, 1987). For maximum response, seeds have to be conditioned. Treatments made prior to conditioning are ineffective. Furthermore, they delay the conditioning process (Ramaiah and Parker, 1981; Parker, 1983). Restricted mobility and unstability of germination stimulants and lack of even conditioning in the field pose serious limitations on practical use of available germination stimulants, including ethylene. For practical utilization of the concept of suicidal germination, compounds with prolonged persistence and no adverse effects on the conditioning process are required. In this respect, the recent report of Fischer *et al.*, (1990) on active and stable germination stimulants should be of prime concern.

ii. ***Haustorium initiation.*** Many synthetic and natural compounds can induce haustorium initiation. Haustorium initiation occurs in close proximity to the host root and involves cessation of radicle growth, enzymatic degradation of surface components of the host root and cell division (Riopel, *et al.*, 1990). It is, thus, apparent that haustorium initiation, by its very nature, offers many intriguing possibilities for *Striga* control. Inhibition of cell division and/or the enzyme involved in the bio-synthesis of the haustorium factor, will curtail induction of haustoria and hence seedling establishment. Pre-mature or concurrent induction of haustoria together with germination may lessen contact with the host root and/or promote abortive attachment to soil particles.

h) ***Biological Control.*** *Striga* species and short-lived annuals that produce enormous number of seeds are not ideal targets for biological control (Greathead, 1983, Bashir, 1987). However, because of the seriousness of the problem and the low input needed, exploitation of biological control option could be considered as a component of an integrated control strategy. Much work is needed on surveys of natural enemies, their parasites and predatôrs. Adequate information on biology, host specificity and quantitative damage assessments is required. In this respect, the inhibition of *Striga* seed germination reported by Dixon and Parker (1984) in association with the rhizosphere microflora of the sorghum variety N-13 needs special consideration.

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Interactions Between Some Cowpea Lines and Two Parasitic Higher Plants-*Striga Gesnerioides* and *Alectra Vogelii.*

A.M. EMECHEBE and B.B. SINGH.

Institute for Agricultural Research, Samaru, Ahmadu Bello University, Zaria, Nigeria,
and
IITA/IAR Kano Sub-Station, Kano, Nigeria.

Abstract

Two higher plants parasitic in cowpea, *Striga gesnerioides* and *Alectra vogelii*, have become yield-reducing factors in the semi-arid zones of West and Central Africa. In Nigeria, *Striga* is particularly devastating in the drier Sudano-Sahelian zone while *Alectra* is more destructive in the more humid, Northern Guinea savanna. Pot culture techniques were used to evaluate 14 cowpea varieties/lines for their reactions to *Striga* and *Alectra* in the glasshouse (temperatures, 25-45°C) and the screenhouse (temperatures, 25-35°C), respectively. In addition, the interaction between 10 cowpea lines of varying susceptibility to *Striga* and 11 populations of *Striga* were studied in pot culture in the screenhouse, using approximately similar *Striga* seed densities.

The results showed that *Striga* plants emerged above soil level from susceptible potted cowpea plants 28 days after sowing (DAS), while Alectra emerged 35 DAS. As a consequence of differences in the expression of resistance/susceptibility to *Striga* and *Alectra*, the 14 cowpea varieties/lines were grouped into five classes: those with very high resistance to both parasitic plants (exemplified by B-301); those having very high resistance to *Striga* combined with high susceptibility to *Alectra* (e.g. IT82D-849); high resistance to *Alectra* combined with fairly moderate susceptibility to *Striga* (e.g. IT86D-843); moderate to high resistance to both *Striga* and *Alectra* (e.g. TN93-80), and those highly susceptible to both parasites (e.g. TVx 3236, VITA-3 and SUVITA-2). The results suggest that resistance to both parasites should be combined in cowpea varieties intended for production in the semi-arid parts of West and Central Africa. There was some evidence to the effect that *Striga* seed populations collected from various sites varied in their pathogenicities on 10 cowpea lines under pot culture conditions.

Introduction

In the semi-arid zones of West and Central Africa, cowpea is severely affected by *Striga gesnerioides* and *Alectra vogelii*. In Nigeria, *Alectra vogelii* is more prevalent and destructive in the Northern Guinea savanna; although it is also fairly prevalent in the Sudan savanna, it is less destructive (Emechebe *et al.*, 1988). On the other hand, *S. gesnerioides* is far more prevalent in the Sudan than in the Guinea savanna. *Striga* causes severe damage to cowpea in all heavily infested sites. At present, the combined damage caused by *Alectra* and *Striga* is regarded as the single

most important biotic constraint to cowpea production in the dry savanna zones of Nigeria, especially as there is no way to control crop damage once the plants are severely infected (Emechebe et al., 1988).

Host plant resistance is potentially the most feasible method of controlling *Striga* and *Alectra*. Through the effort of SAFGRAD/IITA, SUVITA-2 (Gorom Local) was found to be resistant to cowpea *Striga* in Burkina Faso and Mali but susceptible in Nigeria and most of Niger (IITA, 1984), indicating the existence of, at least, two strains of *S. gesnerioides* in West Africa. Efforts to find new sources of resistance to *S. gesnerioides* paid off in 1987 with the identification of cowpea varieties B-301 and IT82D-849, both of which were subsequently shown to be resistant in Burkina Faso, Niger, Nigeria and Mali (Aggarwal, 1988; Emechebe *et al.*, 1988).

Cowpea line B-301 was initially identified in Botswana for its resistance to *A. vogelii* (C. Riches, personal communication) and Emechebe and Singh (1989) have confirmed that it is resistant to *A. vogelii* in Nigeria. However, these workers have reported that the other two sources of resistance to *S. gesnerioides* (SUVITA-2 and IT82D-849) are susceptible to cowpea *Alectra*. This has necessitated the search for other sources of resistance to *A. vogelii*. Consequently, part of the study reported in this paper was aimed at evaluating a number of cowpea lines with varying degrees of resistance to *S. gesnerioides* to determine if any of them is also resistant to *A. vogelii*.

Previous attempts to screen cowpea lines in the field in different locations in Nigeria have yielded inconsistent results (Emechebe *et al.*, 1988). For example, a variety could show apparent resistance at Kano (Kano State) and high susceptibility at Bakura (Sokoto State) and vice-versa for another variety. It was postulated that since Kano and Bakura, for examples, are in the same ecological zone, such observed differences could be attributed to availability of different strains of *S. gesnerioides* at these sites (Emechebe *et al.*, 1988). The study reported in the second part of this paper was, thus, undertaken to find out if there is variation in the pathogenicity of *S. gesnerioides* at the different sites.

Materials and Methods

a) *Reactions of Cowpea lines to Striga and Alectra*

The 14 cowpea lines used in the study are listed in Table 1. The reaction of the 14 lines to *S. gesnerioides* was evaluated in the glasshouse (temperatures, 25-45°) in potted soil according to the method described by Emechebe *et al.*, 1988). Each 5-inch pot contained about 800 *Striga* seeds collected from Bakura in 1987.

Table 1. Reactions of 14 cowpea lines to *Striga gesnerioides* in pot culture in the glasshouse at Samaru, 1989.

Cowpea line	Number of emerged *Striga*/pot	Number of attached *Striga*/pot
IT86D-531	2.75 ef*	14.87 defg*
IT81D-994	20.0 b	31.13 c
IT84S-2246-4	28.25 a	85.5 a
IT87S-1643	5.15 e	12.87 efg
IT87S-1252	11.87 d	35.13 bc
IT86D-371	14.5 cd	29.13 cd
IT82D-849	0.38 ef	2.75 g
B-301	0.0 f	0.0 g
SUVITA-2 (Gorom Local)	17.63 bc	26.87 cde
IT86D-534	13.0 cd	24.37 cde
TN93-80	2.63 ef	6.50 fg
IT86D-472	13.50 cd	23.0 cde
VITA-3	15.87 bcd	46.25 b
IT86D-843	3.13 ef	20.63 cdef

* Means followed by the same letter in the same column are not significantly different at P = 0.05.

The experiment was planted in July 1989 and terminated 70 days after sowing as earlier described (Emechebe and Singh, 1989).

The experimental design was randomized complete block, with eight replicates (one pot served as a replicate). The numbers of *Striga* plants that emerged above soil level as well as the number attached to the roots of the cowpea plants, were determined.

A similar experiment was done to study the reaction of the same 14 cowpea lines to *A. vogelii*. The trial was planted in the screenhouse (temperatures, 25-35°C) in August 1989 and also terminated 70 days later. The numbers of emerged and attached *Alectra* plants were determined as was done for the experiment on *Striga*.

b) **Reactions of Cowpea Lines to 11 Populations of *S. gesnerioides***

Seeds of *S. gesnerioides* were collected in 1988 from 11 locations - eight from Kano, two from Sokoto and one from Kaduna States. Seeds of each population were used to inoculate potted soil in 5-inch pots containing about 800 *Striga* seeds each. Three pots of each population of *Striga* were sown in August 1989 with seeds of one of 10 cowpea lines of varying susceptibility to *Striga*. The numbers of *Striga* plants that emerged above soil level as well as the numbers attached to the roots, were determined 70 days after sowing.

Table 2. Reactions of 14 cowpea lines to *Alectra vogelii* in pot culture in the screenhouse at Samaru in 1989.

Cowpea line	Number of Emerged *Alectra*/pot	Number of attached *Alectra*/pot
IT86D-531	6.25 e*	17.25 de*
IT81D-994	2.50 ef	26.38 cd
IT84S-2246-4	28.87 ab	34.37 bc
IT87S-1643	5.87 ef	11.50 ef
IT87S-1252	18.13 cd	38.87 b
IT86D-371	0.38 ef	3.25 f
IT82D-849	30.13 a	66.13 a
B-301	0.00 f	0.00 f
Gorom Local (SUVITA-2)	22.75 bc	25.50 cd
IT86D-534	0.75 ef	1.38 f
TN93-80	5.63 ef	11.38 ef
IT86D-472	0.87 ef	2.13 f
VITA-3	14.87 d	25.63 cd
IT86D-843	0.75 ef	8.25 ef

* Means followed by the same letter in the same column are not significantly different at P = 0.05.

Results and Discussion

The reactions of 14 cowpea lines to *S. gesnerioides* and *A. vogelii* are presented in Tables 1 and 2. The reactions of these lines to the two parasites could be separated into five clases. The first group comprised only B-301 which had very high resistance to both *Alectra* and *Striga*. The second group consisted of only one line (IT82D-849) which was highly resistant to *Striga* but highly susceptible to *Alectra*. In the third group is ITZ86D-843 with high resistance to *Alectra* but moderate resistance/susceptibility to *Striga*. The fourth group consisted of lines that were susceptible to both *Alectra* and *Striga*; the majority of the lines belong to the group. The fifth and final group comprised TN9-80 which had moderate to high resistance to both *Striga* and *Alectra*. The fifth and the third groups (ITZ86D-843 and TN93-80) would be useful in developing lines for resistance to both parasites.

It is cl ar from Tables 1 and 2 that Gorom Local and IT82D-849 are very susceptible to *Alectra* and care is required in using them as sources of resistance to *Striga*, if the varieties are expected to be grown in *Alectra*-infested locations.

The reactions of the 10 cowpea lines to 11 populations of *S. gesnerioides* at Samaru in the screenhouse are summarized in Table 3. The analysis of variance shows that the differences among the reactions of the varieties to *Striga* were highly significant, as were the differences in the reactions of the varieties to *Striga* collected from the different sites (Table 4). This implies that the pathogenicities of the populations are significantly different from each other, a clear suggestion of the existence of different strains. This is supported by the highly significant interaction

between cowpea lines and the sites of collection of *Striga* seeds. The means of the reactions of the lines across the populations of *Striga* are presented in Table 5. It is evident that *Striga* seed population from Bakura was significantly the most virulant while the pathogenicities of the populations from Kano State (second site at Minjibir) and Wailare II (also in Kano) were similar; those of populations from Tomas, Dambata, and Wailare I (Kano) were also similar. While the pathogenicity of the population from Samaru was the lowest, it was not different from the pathogenicities of the populations from Kazaure and the first site in Minjibir; these were not different from the pathogenicity of the population from Ungwar Kusa (Kano). It is clear that the pathogenicities of the populations are not necessarily related to the sites of collection, suggesting that mixtures of different strains may occur at the same site.

Table 3. Reactions of 10 cowpea lines to 11 *Striga* seed populations collected from 11 sites in northern *Guinea* and Sudan savanna zones of Nigeria.

Place of collection of *Striga* seed	B301	IT820 -957	IT83D -534	IT86D -472	IT86D -843	IT82D -849	IT84S -2246	IT84D -666	VITA 3	TVx 3236
Ungwar Kusa	0.0	3.6	3.6	4.6	6.0	0.0	6.0	2.3	3.0	8.0
Wailare I	0.0	10.67	4.67	10.0	3.3	0.0	2.67	7.0	5.5	12.3
Minjibir I	0.0	13.3	4.3	3.3	3.0	0.0	3.0	0.0	2.3	4.0
Kazaure	0.0	4.67	4.3	2.67	4.67	0.0	6.67	2.0	7.0	4.3
Samaru	0.0	8.0	5.67	3.3	0.3	0.0	1.3	2.3	0.67	4.0
Kano	0.0	7.3	6.0	4.67	8.3	0.0	3.0	1.0	4.3	6.0
Wailare II	0.0	12.0	4.0	3.0	9.3	0.0	16.7	5.1	16.3	10.3
Dambata	0.0	4.67	8.67	4.3	3.67	0.0	9.67	4.3	5.67	8.3
Minjibir II	0.0	10.0	11.67	5.3	5.0	0.0	10.0	6.3	22.3	11.67
Tomas	0.0	11.0	7.67	4.67	3.67	0.0	7.67	1.0	12.67	9.0
Bakura	0.0	14.3	12.3	13.67	12.67	0.0	14.0	6.3	29.3	15.67

The high level of resistance of B-301 remained stable in all of the 11 locations. There have been reports of susceptibility of B-301 from various countries of West and Central Africa which could be attributed to outcrossing. But very recently, one replicate of B-301 in a 4-replicated trial near Cotonou (Benin) was reported to have been 'uniformly infected' by *Striga*. A plausible explanation is that there was inadvertent mix-up of seeds. There is the unlikely possibility that the replicate was planted on a piece of land that was uniformly infested by a new, virulent strain of *S. gesnerioides*.

Table 4. Analysis of variance for the reactions of 10 cowpea lines to 11 populations of *S. gesnerioides*

Source of variation	Degrees of freedom	Sum of squares	Mean square	F - Value	Probability
Replication	2	11.661	5.830	1.7419	0.1776
Site of collection of *Striga* seed (A)	10	2230.564	223.056	66.6412	0.0000
Cowpea line (B)	9	3487.988	387.554	115.7873	0.0000
A x B	90	3079.012	34.211	10.2211	0.0000
Error	218	729.673	3.347		

Table 5. Overall means of reactions of 10 cowpea lines to *Striga* seeds obtained from 11 locations.

Site of collection of *Striga* seeds	Mean of ractions of 10 cowpea lines
Ungwar Kusa	3.933 def*
Wailare I	5.567 c
Minjibir I	3.00 fg
Kazaure	3.533 efg
Samaru	2.900 g
Kano	4.067 de
Wailare II	7.700 b
Dambata	4.767 cd
Minjibir II	8.233 b
Tomas	5.733 c
Bakura	11.83 a

* means followed by the same letter are not significantly different at P = 0.05.

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Management of Cowpea Under *Striga* Infestation in the Sudan Savanna of Burkina Faso: Responses of Daylength Sensitive Cultivars

N. MULEBA and E. MOSARWE

IITA/SAFGRAD, 01 BP 1783 Ouagadougou 01, Burkina Faso and Department of Agricultural Research, Gaborone, Botswana.

Abstract

Four daylength sensitive (DS) and two daylength insensitive (DI) cowpea *(Vigna unguiculata* (L.) Walp.) cultivars were compared at three sowing dates in 1982-83 under natural *Striga gesnerioides* (Willd) infestation at Kamboinse, Burkina Faso, in the Sudan savanna zone. In spite of *Striga* seed conditioning, *Striga* emergence appeared to depend on cowpea cultivar and the prevailing climatic conditions. The wetter the conditions, the earlier the emergence of *Striga* and vice-versa. *Striga* emerged 28 days at the earliest and 75 days at the latest, after sowing of cowpea. *Striga* density depends on the time of emergence; the earlier the emergence, the higher the final density of *Striga,* irrespective of the sowing date or cowpea cultivar. Crop damage caused by *Striga* appeared to depend on the time of emergence: the earlier *Striga* emerged before flowering by cowpea, the more the crop was subjected to *Striga* damage manifested by low flowering intensity, low number of pods per unit area and low grain yield. Compared to DI cultivars, the DS types were more vulnerable to *Striga* damage, especially when sown before 50 days of their respective critical photoperiod. The optimum sowing date for DI cultivars was about end of June, compared with mid-July for DS cultivars. The DS cultivars, with their critical photoperiod in late September, were not at all adapted to Kamboinse growth conditions where the *Striga* resistant DI cultivar Suvita-2 yielded best especially when sown early.

Introduction

In addition to insect pests and drought, witchweed (*Striga gesnerioides* (Willd.) Vatke) parasitism constitutes a major cause of cowpea seed yield losses in about 50% of arable lands in the Sahel-Sudanian and the semi-arid coastal zones of West and Central Africa. The physiology of *Striga gesnerioides* has been reported by Parker (1984) and Worsham (1987). Two cowpea cultivars, Suvita-2 and 58-57, were among the first to be identified in the field and confirmed in pot culture as resistant to *Striga* attack at Kamboinse, Burkina Faso (Aggarwal *et al.,* 1984; Aggarwal and Halley, 1988). Later on, additional *Striga* resistant cultivars were identified: B 301 and IT82D-849 (Emechebe *et al.,* 1988). Inheritance studies involving Suvita-2 and B-301 have indicated a monogenic dominant inheritance of resistance to *Striga* (Aggarwal *et al.,* 1984; Singh and Emechebe, 1990).

In field trials conducted by SAFGRAD-IITA at several locations in West and Central Africa towards ascertaining the stability of the cowpea varieties and lines

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identified as resistant to *Striga*, Suvita-2 exhibited good resistance in Burkina Faso, Mali and Senegal but only moderate to low levels of resistance elsewhere, especially in Niger and Nigeria (Aggarwal and Halley, 1988; IITA-SAFGRAD Cowpea Network Report, 1990). Although B-301 and IT82D-849 have exhibited good resistance to *Striga* in the sub-region generally, they and especially B-301, were attacked by *Striga* in some fields in Mali, Nigeria and Senegal (IITA-SAFGRAD Cowpea Network Report, 1990).

Such results, coupled with the monogenic nature of inheritance of *Striga* resistance in cowpea, indicate that the use of *Striga* resistant cultivars alone may not be enough to ensure sustainable cowpea production. Appropriate agronomic production practices need to be developed in order to prevent severe yield losses, should in case the genetic resistance of cultivars break down. To this end, and in the absence of field data on the effect of sowing date on the performance of cowpea under natural *Striga* infestation, the work reported in this paper was undertaken to determine the response of several daylength sensitive cultivars to successive sowings and identify the optimum sowing date towards minimizing cowpea seed yield losses.

Materials and Methods

The experiment was conducted in the 1982 and 83 cropping seasons at Kamboinse, Burkina Faso, to compare the performances of four daylength sensitive (DS) cultivars (Ouahigouya Local, Kaya Local, IAR 1696 and Kamboinse Local Noir) and two daylength insensitive (DI) cultivars (*Striga* resistant Suvita-2 and *Striga* susceptible KN-1) sown at three different dates (18 and 31 July and 10 August, 1982). The field used was on a mid-slope, on an "aquic-oxic" Paleustalfs soil of very deep, slightly gravelly sandy clay loam. The field was heavily infested with *Striga gesneriodes* in the previous year, 1981.

The experiment was a split-plot design, with four replications. Sowing dates were assigned to the main plots and cowpea cultivars as sub-plots. Each plot measured 4.5 x 5 m. After ploughing and harrowing the field in preparation for planting, one year-old *Striga* plant materials (crushed *Striga* seeds and plant debris mixed with wet sand) were broadcast on the field at 10 g/m^2 and ploughed under with a hand hoe to ensure good *Striga* infestation. Single superphosphate at 50 kg P_2O_5/ha was also broadcast on the field and worked under before sowing. Seeds were sown on flat beds at two seeds per hole and later thinned to one plant per hole, 2 weeks after sowing. The spacing was 75 cm between rows and 20 cm between holes in a row. Rows were earthed up 3 weeks after sowing and ridges were tied every 1.5 m to capture and retain rain water.

The crop was uniformly sprayed with the insecticides Monocrotophos (R), at 12 g a.i./ha when aphids *(Aphis craccivora)* were observed; Deltamethrin (R) at 12 g a.i./ha at flower bud formation; and Endosulfan (R) at 400 g a.i./ha every 10 days after flowering for general pest/disease protection. Plots were kept free of weeds by hand-hoeing before *Striga* emerged and elimination by hand pulling after *Striga* emergence. Observations taken included the number of days to 50% flowering, flowering intensity per unit area counted every two days till the end of flowering,

days to *Striga* shoot emergence, *Striga* shoot density per unit area assessed at cowpea ripening, number of pods and grains per unit area, and 100-seed weight. Grain yield was assessed from the four central rows of each plot, leaving 50 cm off the end of each row. Pods were harvested as they matured, air dried to a constant weight for 10 days and threshed. Climatic data were recorded at the Kamboinse meteorological station.

The data were statistically analysed for all characters assessed and the "student" T-test used to establish levels of significance. The experiment was repeated in 1983, but with DS cultivar IAR 1696 replaced by DS Kamboinse Local Rouge. IAR 1696 was a particularly late-maturing variety as compared with Kamboinse Local Rouge whose critical photoperiod is in early September (Table 1). From the experience gained in the previous year, planting dates were adjusted in 1983 to: 12 June, 18 July and 12 August. It should be noted that cowpea is traditionally sown in mid-July in the study area.

Results

A total of 606 and 663 mm rainfall was received in 1982 and 1983, respectivelly. Rainfall was generally poorly distributed in both years and particularly in September - a critical period for flowering and grain filling (Fig. 1).

a) ***Flowering***. Flowering in both DI, Suvita-2 and KN-1, was virtually unaffected by sowing date, both varieties being the earliest to flower in each of the years (Fig. 2). With the exception of IAR 1696, DS cultivars exhibited a trend of hastened flowering as sowing was delayed. The trend was significant in 1982 for cultivars Kaya Local and Kamboinse Local Noir and in 1983 for all DS cultivars, except Kamboinse Local Noir for the 21 June and 18 July sowings.

Both DI cultivars produced the largest flowering intensity for each sowing date (Table 2). Unlike the DS cultivars, their flowering intensity declined with later sowings but this was significant only in 1983 and for Suvita-2. DS cultivars with a critical photoperiod in late September or later (Kaya Local, Kamboinse Local Noir and IAR 1696) produced the lowest flowering intensity which, in 1982, tended to increase with later sowings. In contrast, both DS cultivars Ouahigouya Local and Kamboinse Local Rouge with a critical photoperiod in early September, produced their maximum flowering intensity from mid-July sowings during both years. In general and with the possible exception of Kamboinse Local Noir, the flowering intensity of DS cultivars reached a maximum when the period extending from sowing to the critical photoperiod was less than 50 days.

b) ***Striga* emergence.** *Striga* shoot generally emerged much earlier in 1983 than in 1982 (Fig. 3). In 1982, *Striga* shoots tended to emerge earlier in early than in late sowings for all cultivars, except the *Striga* resistant Suvita-2 (DI). The trend was, however, significant only for cultivars IAR 1696 and KN-1. With the exception of these cultivars in the late sowings, *Striga* emerged about the same time for all *Striga* susceptible cultivars. In 1983, sowing on 18 July appeared to hasten *Striga* emergence in all susceptible cultivars as compared to the earlier and later sowings.

Table 1. Characteristics of cowpea cultivars studied under natural *Striga* infestation at Kamboinse, Burkina Faso in 1982-83.

Cultivars	Critical photoperiod	Habit	Adaptation area (Isohyets mm)	Remarks
		Daylength sensitive		
Ouahigouya local	Early September	Prostrate	600 - 800	Landrace, Burkina
Kaya local	Late September	Prostrate	600 - 800	Landrace, Burkina
IAR 1696	Early October	Prostrate	600 - 800	Introduction from Kano, Nigeria
Kamboinse local noir	Late September	Prostrate	600 - 800	Landrace, Burkina
Kamboinse local rouge	Early September	Prostrate	600 - 800	Landrace, Burkina
		Daylength insensitive		
	Days to maturity			
Suvita-2	75	Spreading	< 600	Landrace, Burkina
KN-1	75	Spreading	< 600	Commercially released in Burkina Faso

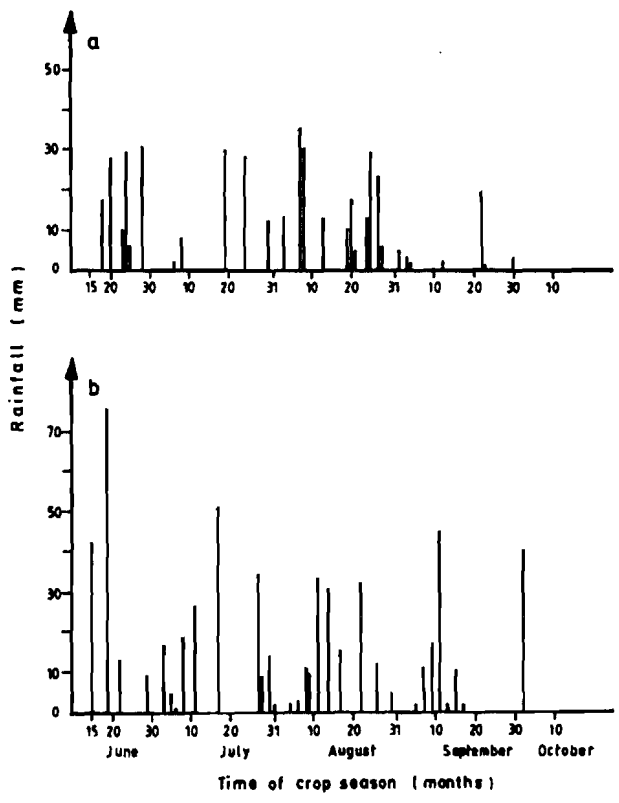

Fig. 1. Rainfall at Kamboinse, Ouagadougou, Burkina Faso in 1982 (a) and 1983 (b).

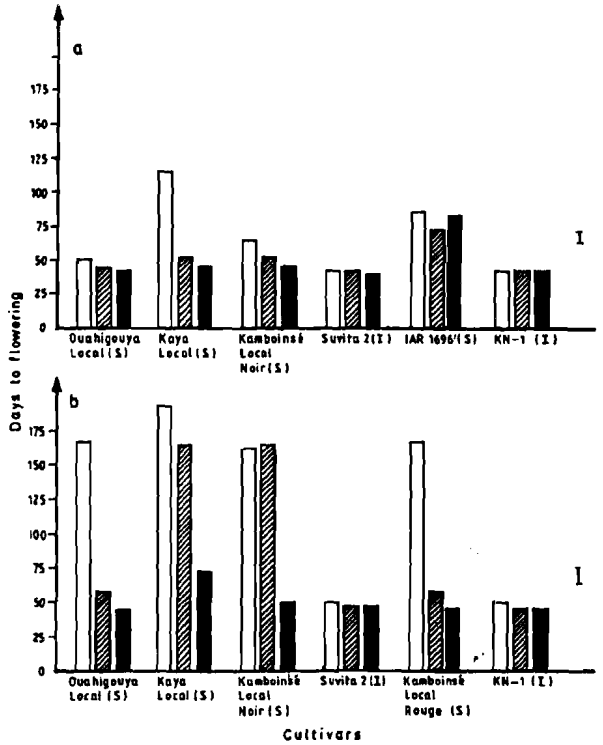

Fig. 2. Days to flowering of daylength-sensitive (S) and insensitive (I) cowpea cultivars as affected by sowing dates : 18 july (□) 31 July (□) and 10 August (■) in (a) 1982 ; and 21 June (▩), 18 July (▩) and 12 August (■) in (b) 1983 in a *Striga* sick plot at Kamboinse, Burkina Faso. Vertical bars represent S.E. with 45 D.F.

Table 2. Flowering intensity of daylength sensitive (S) and insensitive (I) cowpea cultivars as affected by sowing dates under natural *Striga* infestation at Kamboinse, Burkina Faso in 1982-83.

Cultivars	Sowing dates					
	1982			1983		
	19 Jul	31 Jul	10 Aug	21 Jun	18 Jul	12 Jul
	Flowers/m²					
Ouahigouya Local (S)	58	21	41	16	80	35
Kaya Local (S)	0	2	29	6	2	11
Kamboinse Local Noir (S)	0	5	56	27	10	11
Kamboinse Local Rouge (S)	-	-	-	10	62	31
Suvita-2 (I)	191	134	167	312	175	63
IAR 1696 (S)	0	2	6	-	-	-
KN-1 (I)	146	146	102	211	260	97
S.E.	16			17		
D.F.	45			45		

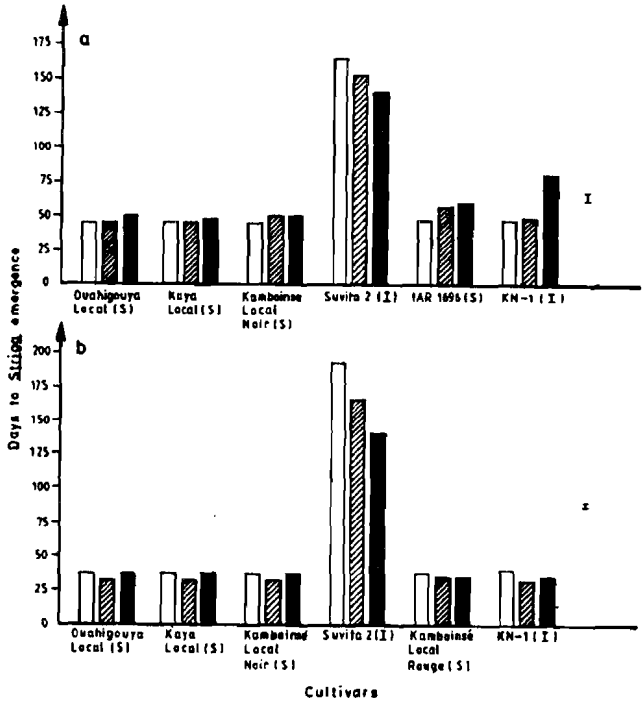

Fig. 3. Days to *Striga* emergence of daylength-sensitive (S) and insensitive cultivars as affected by sowing dates : 18 July (□), 31 July (▨) and 10 August (■) in (a) 1982 ; and 21 June (□), 18 July (▨) and 12 August (■) in (b) 1983 in a *Striga* sick plot at Kamboinse, Burkina Faso. Vertical bars represent S.E. with 45 D.F.

c) ***Striga* density.** *Striga* density was affected significantly by sowing date and cultivar (Table 3). *Striga* density declined with later sowings. With the exception of Suvita-2 which was not infested, all other cultivars were moderately to heavily infested.

d) ***Days to maturity.*** The growth duration of cowpea cultivars was longer in 1983 than in 1982 (Fig. 4). DI cultivars generally matured earlier than DS cowpea for all sowings, except for KN-1 sown on 18 July, 1983. Except for IAR 1696, the growth duration of DS cultivars was significantly reduced with later sowings, particularly in 1983.

e) ***Seed yield.*** Seed yield was generally greater in 1982 than 1983 (Fig. 5). Suvita-2 yielded the highest at all sowings. *Striga* susceptible DI cultivar KN-1 out-yielded, significantly, DS cultivar Ouahigouya Local only for the 21 June sowing in 1983; for all other sowing dates, it yielded either equally or significantly lower. Daylength sensitive cultivars, with a critical photoperiod in early September, yielded the highest from the 18 July sowings during both years. These varieties produced almost no seeds for the 21 June, 1983 sowing and yield declined with later sowings after mid-July. In contrast, those DS cultivars with a critical photoperiod in late September and early October (Kaya Local, Kamboinse Local Noir and IAR-1696), produced either no seed at all or had yield increases with later sowings

Table 3. *Striga* density of daylength sensitive (S) and insensitive (I) cowpea cultivars as affected by sowing dates under natural *Striga* infestation at Kamboinse, Burkina Faso, in 1982-83.

Sowing dates			Cultivars		
	1982[a] (1-5)	1983[b] Vx + 1..		1982[a] (1-5)	1983[b] Vx + 1..
21 June	-	4.5	Ouahigouya local (S)	3.0	3.9
18 July	3.3	4.1	Kaya local (S)	3.5	4.7
31 July	2.7	-	Kamboinse local noir (S)	2.7	4.4
10 August	2.4	-	Kamboinse local rouge (S)	-	4.5
12 August	-	3.1	Suvita-2 (I)	1.0	1.0
S.E.	0.2	0.2	IAR 1696 (S)	2.6	-
D.F.	6	6	KN-1 (I)	2.7	4.9
			S.E.	0.2	0.3
			D.F.	45	45

[a] *Striga* density was rated using a (1-5) scale in 1982, with 1 = plot free from *Striga* infestation and 5 = *Striga* shoots present about every 30 cm and well distributed.

[b] Data on *Striga* density was analysed using square root transformation Vx-1, where x = number of *Striga* shoots per m^2.

(Fig. 5). As was the case for flowering intensity, DS attained maximum yield when the period extending from sowing to their respective critical photoperiod did not exceed 50 days; beyond this period, the yield dropped to nil.

Discussion

Striga emergence appeared to be dependent on the cultivar and/or the prevailing meteorological conditions especially during the first 20-30 days after sowing. In fact, the 10 August sowing in 1982 which received insufficient and scattered rainfall from 28 August to 20 September delayed *Striga* emergence, with cowpea IAR 1696 and KN-1 most affected. In contrast, sowing on 18 July, 1983 benefited from good and well distributed rainfall which hastened *Striga* emergence especially among the *Striga* susceptible cultivars. In general, *Striga* emerged earliest 28 days and latest 75 days after sowing cowpeas in this field study. These results appear to conflict with the earlier findings of Parker (1984) and Worsham (1987) relating to *Striga* conditioning requirement and shoot emergence. Because *Striga* seeds are reported to require a water inhibition period (conditioning) before they can germinate, *Striga* shoots were expected in this study to emerge earlier in the late than in the early sowings. But this was generally the reverse. This apparent discrepancy might be explained in terms of either wet dormancy as reported by the same workers, or as a

result of broken conditioning due to the frequent dry spells preceding the sowing of cowpea and/or *Striga* emergence. A further explanation may also be tenable in the differences among cowpea cultivars in their susceptibility to *Striga*, with the least susceptible delaying *Striga* shoot emergence longer than the most susceptible ones.

Striga density appeared directly related to the time *Striga* shoots emerged in a plot. Irrespective of sowing date or cultivar, early emergence induced denser *Striga* infestation than late emergence (r = 0.75**). Early *Striga* emergence also caused severe damage to the cowpea crop. Other traits that were severely affected by *Striga* damage included reduced cowpea flowering intensity (r = 0.68**), reduced number of pods (r= 0.73**), delayed maturity, reduced grain number per unit area (r = 0.59**) and decreased seed yield (r = 0.66**).

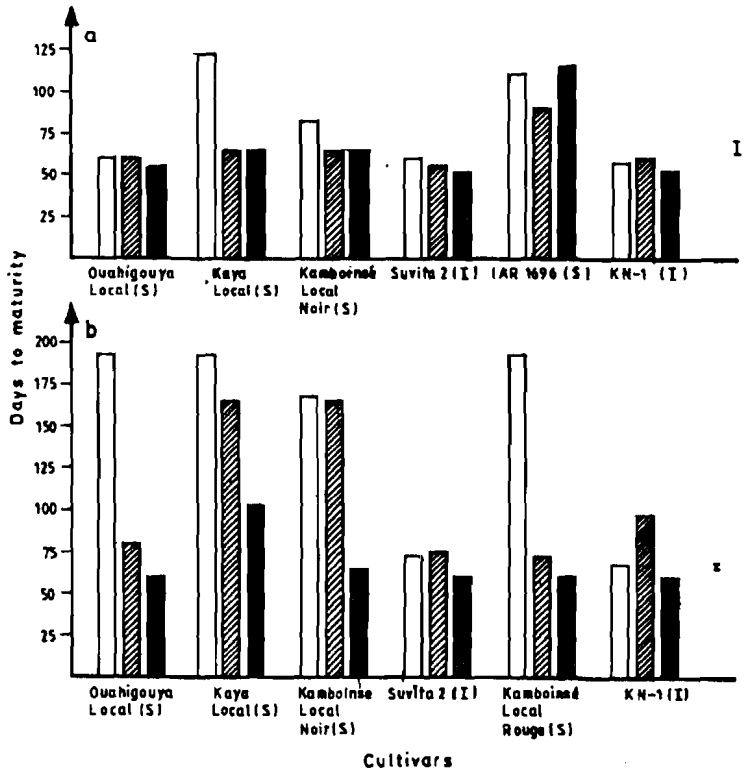

Fig. 4. Days to maturity of daylength-sensitive (S) and insensitive (I) cowpea cultivars as affected by sowing dates : 18 July (□), 31 July (▨) and 10 August ■) in (a) 1982 ; and 21 June (□), 18 July (▨) and 12 August (■) in (b) 1983 in a *Striga* sick plot at Kamboinse, Burkina Faso. Vertical bars represent S.E. with 45 D.F.

Damage to cowpea was much more serious when *Striga* shoots emerged long before flowering. Thus, DS cultivars sown more than 50 days before their critical photoperiod suffered the most *Striga* damage. This explains, at least in part, the high flowering intensity and relatively greater grain yield of DS cultivars

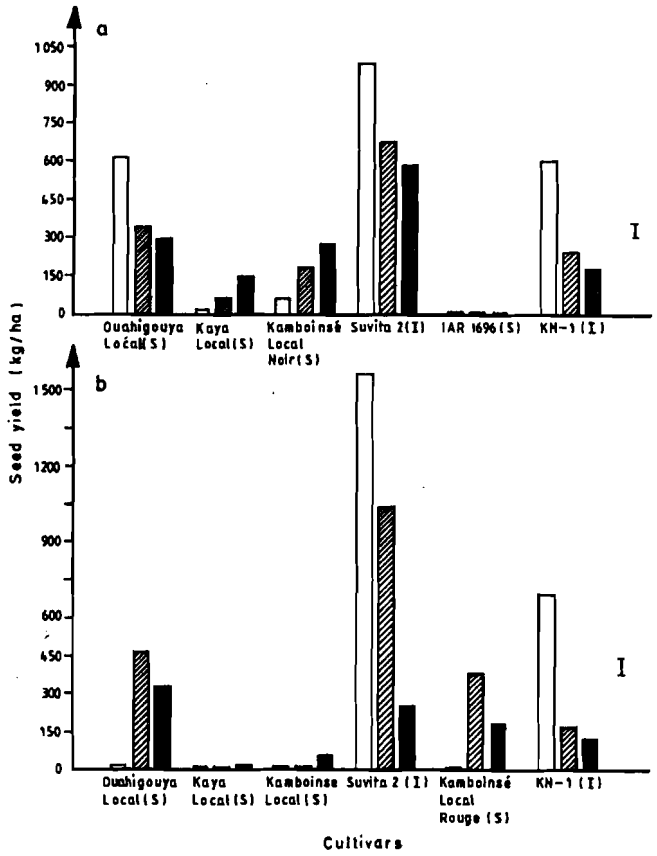

Fig. 5. Seed yield of daylength-sensitive (S) and insensitive (I) cowpea cultivars as affected by sowing dates : 18 July, (□) 31 July (▩) and 10 August (■) in (a) 1982 ; and 21 June (□), 18 July (▩) and 12 August (■) in (b) 1983 in a *Striga* sick plot at Kamboinse, Burkina Faso. Vertical bars represent S.E. with 45 D.F..

(Ouahigouya Local and Kamboinse Local) sown in mid-July. Their relatively decreased flowering intensity and seed yield (in later sowings) could be ascribed to the combination of *Striga* and drought damages. The yield decline of DI cultivar KN-1, when sown late, might also be attributed to negative *Striga* and drought effects - in contrast to Suvita-2 where the reduced yield was probably as a result of drought only, since *Striga* shoots did not emerge at all in plots grown to this variety.

In conclusion, it is evident from the study that under *Striga* infestation it is best to use *Striga* resistant cultivars because of their assured chance of yielding maximally irrespective of sowing date. In the event that such *Striga* resistant cultivars are not available, then any susceptible cowpeas should be sown early in the season, about the end of June for DI cultivars and mid-July for DS cultivars whose critical photoperiod falls in early September. Any DS cultivars whose critical photoperiod is in late September to early October or later are not suitable for Kamboinse conditions.

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Nitrogen Sources and Levels and the Control of *Striga hermonthica* in Sorghum.

NWASIKE, C.C., F. PANCRAS-DEKE, V.O. CHUDE, E.O. ASIRIBO, C.A.KIMBENG and F.A. SOWEMIMO.

Institute for Agricultural Research, Samaru, Ahmadu Bello University, Zaria, Nigeria.

Abstract

Four varieties of sorghum were grown in soil treated with *Striga hermonthica* seeds at different levels of Nitrogen fertilizer to study the effect of these on *Striga* count and other agronomic characters.

Highly significant differences were detected among N levels for plant height, stem girth, dry matter yield and root weight. Plant vigour showed significant differences among N levels. There were highly significant differences among the varieties for plant height, *Striga* count, dry matter yield and root weight. No differences was found between the Nitrogen fertilizers used.

Interaction between N levels x fertilizer x varieties was significant only for *Striga* count. This suggests that the effectiveness of nitrogen in suppressing *Striga* emergence does not depend on either the source or the level but the interaction of the two and the responsiveness of the varieties to both the fertilizer and the *Striga*.

Introduction

The parasitic weed *Striga* has been identified as an important pest hampering high grain yield production of sorghum in Nigeria and elsewhere. Six species of the weed are of common occurrence in the country, among which *S. hermonthica* is the most ubiquitous in the Nigerian savanna (Adeosun, 1990), where most of the sorghum is grown. An estimated $950 million (USA) annual loss in sorghum yield is attributed to *S. hermonthica* (Lagoke *et al.*, 1988).

Even though breeding genotypes resistant to *Striga* is the most economic way of averting losses caused by this parasite, the development and use of an efficient screening system in *Striga* resistance has been slow. The increasing urgency to alleviate *Striga*-caused losses in the savanna zones has increased the emphasis on cultural methods of control especially through fertilizer usage (Pancras-Deke, 1988).

Till date, no single control measure has been able to effectively check the damage done by *S. hermonthica*. The use of fertilizers has been exploited as a possibility in minimizing yield losses due to *Striga* attack. It has been reported that *Striga* infestation is more severe on infertile soils and that application of nitrogen fertilizer to infested land reduces losses caused by this parasitic weed (Pesch and Piertese,

1982; Ogborn, 1983; Piertese, 1985; Hamdoun and Babiker, 1989; Laycock, 1989). Earlier studies in Sudan (Last, 1960) revealed that the application of 60lbs of nitrogen per acre treppled yields of sorghum on highly infested soils and produced up to eight times the yield on heavily infested land. Several authors have indicated that high rates of nitrogen applied as urea or ammonium sulphate affected *Striga* development by inhibiting germination, delaying flower emergence, causing stunting of emerged shoots, reducing flowering and dry matter production (Agabawi and Youmis, 1965; Parker, 1984; Pesch and Piertese, 1982; Laycock, 1988; Hess and Ejeta, 1988). However, the effectiveness of this has been found to depend on the category of crop, dosage of fertilizer, ecological zone and its availability within reasonable economic rates.

There is little information regarding the control of *S. hermonthica* on sorghum using nitrogen fertilizers in the savanna ecological zone of Nigeria. The objective of this investigation was, therefore, to study the effectiveness of two sources of nitrogen at different regimes on the control of *S. hermonthica* on different sorghum varieties.

Materials and Methods

The experiment was conducted in the screenhouse at the Institute for Agricultural Research, Samaru, Nigeria. Soil samples were collected from a previously uninfested sun-dried, crushed to pass through a 2.0 mm sieve. The soil had an initial N content of 5.6% and had earlier been described by Kowal (1968).

Each pot contained 6 kg of soil to which was mixed 500 ml (approximately 0.5 gm) of *Striga* seeds. Single superphosphate and Muriate of Potash at the rate of 8gm and 1.13 gm, respectively, were added to this mixture as basal fertilizers.

Treatments comprised two sources of nitrogen fertilizers (Urea and Calcium Ammonium Nitrate), four levels of N (O, 50, 100 and 150 ppm) and four improved varieties of sorghum (L. 2123 which is susceptible, KSV-4 and NR71150 both resistant and SK-5912 which is tolerant to *Striga* attack). Varieties SK-5912 and L.2123 are long-season sorghums while KSV-4 and NR71150 are short-season. The experiment was a factorial arrangement replicated three times. Ten seeds were planted per pot and later thinned to five seedlings after germination. The pots received equal amounts of water throughout the experiment.

Among data collected from each pot were plant vigour, plant height, stem girth, *Striga* count, dry matter yield of leaves as well as stem and root weight.

Results

Plant Vigour

Highly differential response in plant vigour was shown among the varieties and for different levels of fertilizer application (Tables 1 and 2). Varieties KSV-4 and SK-5912 were significantly more vigorous than the others, the least vigorous being L.2123. Nitrogen application influenced plant vigour, giving an average increase of 24.3% over control at 200 ppm (Table 2). However, C.A.N. was most effective in

increasing plant vigour at 150 ppm, while the response to Urea application was highest at 200 ppm (Fig. 1).

Plant Height.

Highly significant differences were detected in plant height over all varieties and levels of application (Table 1). The tallest plants were reported for KSV-4 and the least for NR71150. Generally, plant height increased with increasing levels of nitrogen and reached a peak at 150 ppm, giving an increase of 45.3% over the control. This was especially true for Urea fertilizer but not for C.A.N. where the greatest height was attained at 200 ppm (Fig. 2).

Stem Girth

Significant difference were observed in stem girth for varieties. Nitrogen levels showed highly significant differences. Stem girth showed significant increase over control at higher levels of nitrogen, reaching a peak at 150 ppm (Table 2). Using C.A.N. fertilizer, varieties L.2123 and SK-5912 (long season) increased in stem girth up to 200 ppm, while the peak for KSV-4 and NR71150 was at 150 ppm. There was no clear pattern in respect of urea fertilizer (Fig. 3).

Table 1. Analysis of variance for host and parasite as affected by two sources of nitrogen at different regimes.

Sources of variation	df	Mean squares					
		Plant vigour yield (shoot)	Plant height	Stem girth	Dry matter yield (shoot)	Root weight	*Striga* count
Replication	2	0.86	1.13	8.49	525.3	29.01	31.91
Fertiliser (F)	1	0.033	7.25	0.51	12.01	0.000	15.41
Levels (a)	4	2.52	577.23*	1.85*	522.1*	40.88*	23.55
f x a	4	0.97	18.43	0.97	14.66	2.02	94.55*
Varieties (v)	3	11.51*	1684.92*	1.12*	524.37*	6273*	226.08*
n x v	12	0.39	68.07	0.45	256.54*	12.20	20.26
f x v	3	1.01	97.34	1.12	18.61	0.40	33.92
n x f x v	12	0.59	95.38	0.24	27.07	4.74	63.99*
Residual	78	0.84	73.73	0.39	114.35	7.44	29.19

* Significant at 5% of probability.

Table 2. Mean values for six characters at different levels of fertilizer treatment, averaged over sources and varieties.

Level of Nitrogen fertilizer (ppm)	Plant vigour	Plant height (cm)	Stem girth (cm)	Dry matter yield (gm) shoot	Root weight (gm)	*Striga* count
200	4.04	36.21	2.87	11.73	5.21	8.46
150	3.92	37.62	2.89	6.38	5.10	8.21
100	3.46	31.32	2.64	5.02	3.13	6.21
50	3.67	31.29	2.47	3.29	3.75	8.21
0	3.25	25.89	2.30	1.83	2.16	7.96
LSD	0.527	4.89	0.353	5.39	1.57	3.11

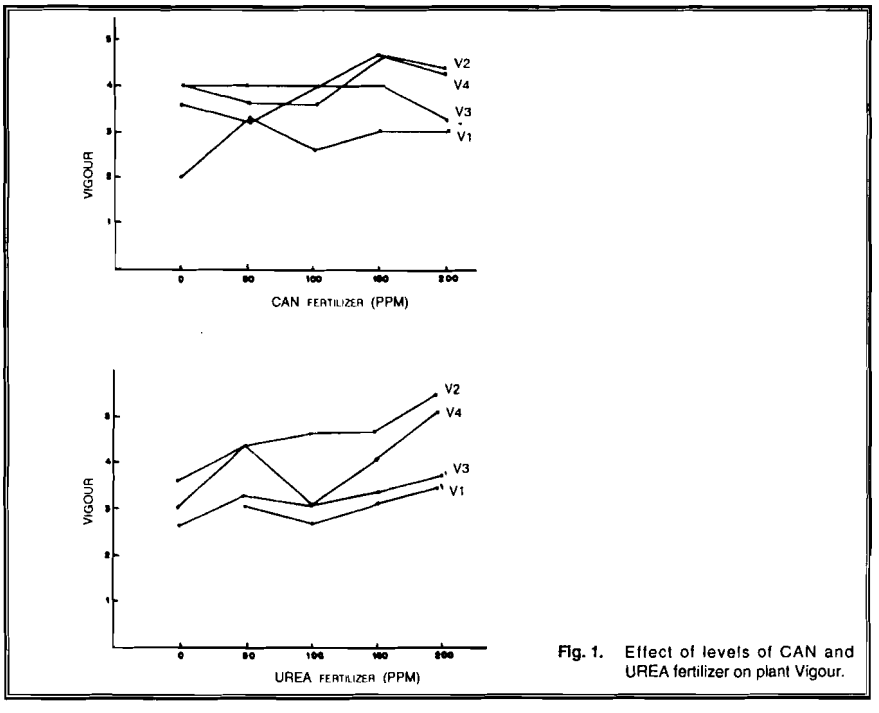

Fig. 1. Effect of levels of CAN and UREA fertilizer on plant Vigour.

Shoot Dry Matter

Overall dry matter yield increased with increasing levels of fertilizer. The variety SK-5912 had the higest dry matter yield with a value of 7.16% over the lowest (Table 3). Nitrogen levels and varieties differed significantly for this character.

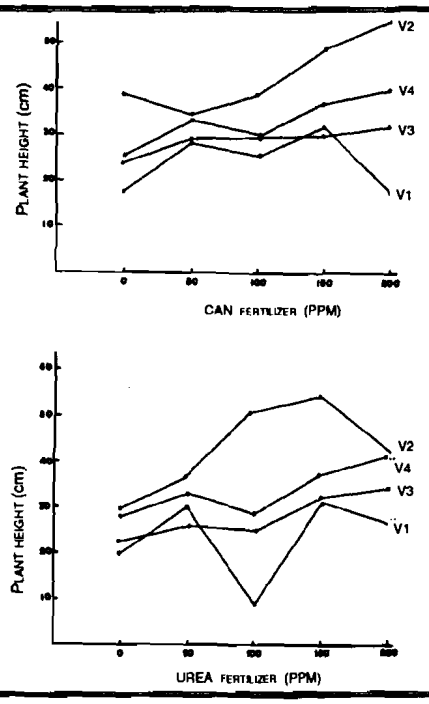

Fig. 2. Effect of levels of CAN and UREA fertilizer on plant height.

Root Dry Matter

There were highly significant differences among varieties and nitrogen levels for root dry matter yield (Table 1 and Fig. 4).

Root weight increased with increasing nitrogen levels, yielding up to 241.2% over the control at 200 ppm (Table 2). The highest response was recorded for SK-5912 (Table 3 and Fig. 4).

Striga Count

Highly significant differences for *Striga* count were found among the varieties (Table 1). Variety L.2123 sustained the highest amount of *Striga* while the lowest was supported by SK-5912, with up to 221.2% difference between the two varieties (Table 3).

There were no significant differences in *Striga* count due to sources of fertilizer or levels of application. However, N levels x fertilizer source x variety interactions were significant. Thus, there was no clear-cut relationship between sources of nitrogen fertilizer or levels of application with *Striga* count (Table 2). However, increasing the application of C.A.N. showed a general decrease in *Striga* count with a 58.9% decrease over control at 200 ppm (Fig. 5). The variety NR71150 was the most responsive, with a decrease of 82.5% *Striga* below control at 200 ppm. On the variety L2123, *Striga* count was reduced by 73.4% relative to the control at 100 ppm of C.A.N. but was increased by the same value (73.4%) at 150 ppm.

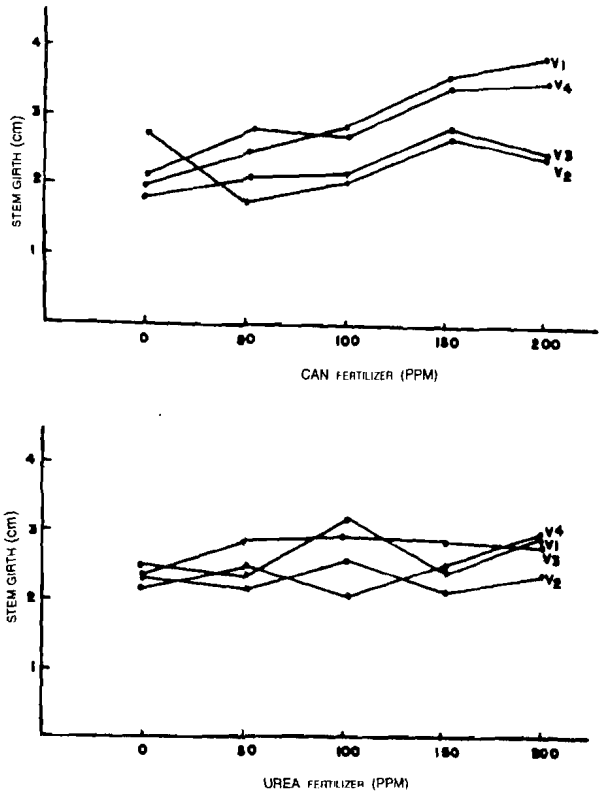

Fig. 3. Effect of levels of CAN and UREA fertilizer on stem girth.

Table 3. Mean values of performance of four varieties of sorghum, averaged over sources of fertilizer and levels of application.

Sorghum variety	Plant vigour	Plant height (cm)	Stem girth (cm)	Dry matter yield (gm)	Root weight (gm)	*Striga* count
SK-5912	4.10	33.78	2.76	10.18	5.46	10.73
KSV-4	4.23	42.04	2.43	6.38	4.83	11.26
NR171150	3.43	26.24	2.55	3.02	2.59	13.54
L.2123	2.90	26.39	2.86	3.02	2.59	23.73
LSD	0.471	4.41	0.32	4.82	1.40	2.78

The response of cultivars to different levels of urea fertilization was inconsistent. At 100 ppm of urea *Striga* count was decreased by 27% relative to the control. Urea application was most effective in reducing *Striga* count on the variety NR71150.

Discussion

Although there was no consistent evidence that most response to nitrogen fertilization would invariably depress *Striga* infestation, it is likely that a well grown crop would resist infestation and support less *Striga* than a poorly grown crop (Last, 1960). The varieties SK-5912 and KSV-4 had significantly low *Striga* counts and these were consistently associated with good agronomic performance. On the other hand, the amount of *Striga* infestation on NR71150 was unusually low compared to its agronomic performance. It is likely that the roots of this variety did not produce enough stimulant for effective germination of the *Striga* seeds (Okonkwo, 1990).

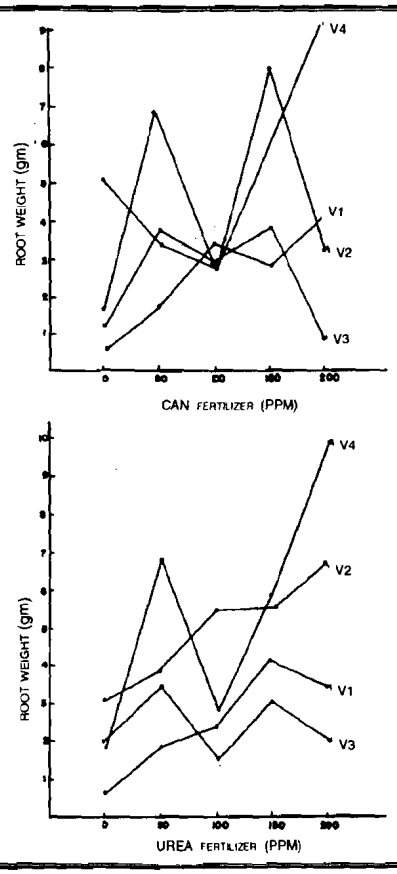

Fig. 4. Effect of levels of CAN and UREA fertilizers on root weight..

There was no direct significant effect to suggest that high levels of nitrogen suppressed *Striga* emergence. Rather, the results showed that the effectiveness of nitrogen in suppressing *Striga* emergence does not depend on either the source or the level but the interaction of the two and the responsiveness of the variety to both

the fertilizer and *Striga*. The existence of some kind of relationship between a variety's degree of response to nitrogen fertilization and its relative resistance to *Striga* infestation has been observed. The failure of high doses of either urea or C.A.N. to suppress *Striga* count on the susceptible variety L.2123 tends to support this suggestion.

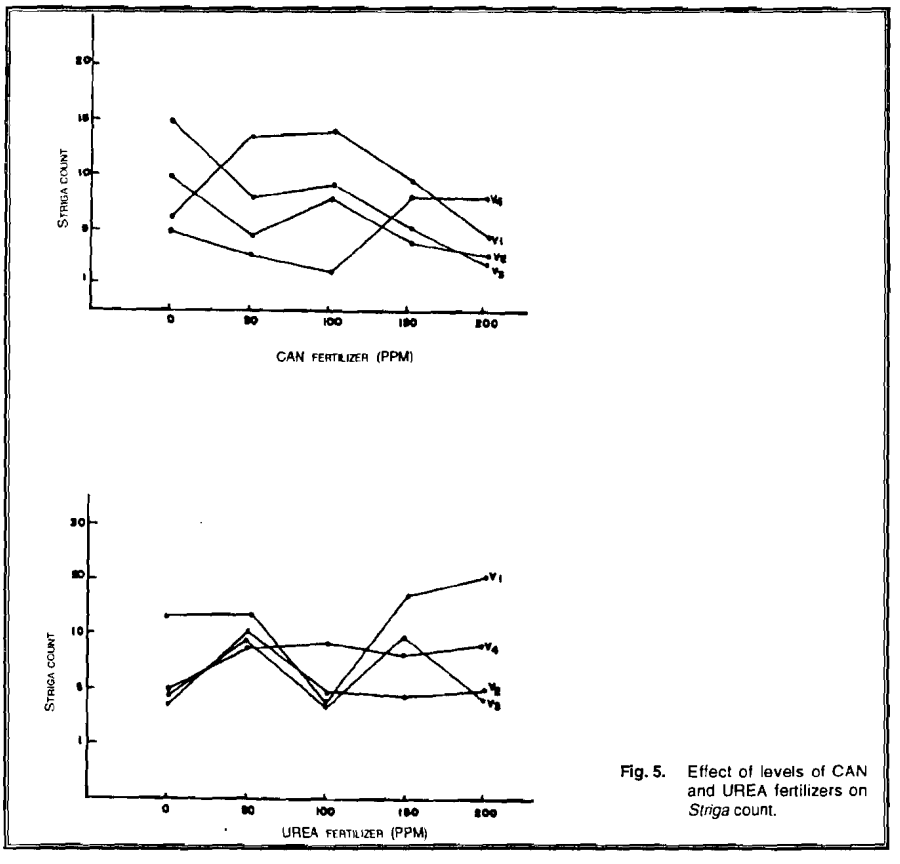

Fig. 5. Effect of levels of CAN and UREA fertilizers on *Striga* count.

Potential varieties must, therefore, possess some level of resistance before they can make use of high doses of nitrogen fertilizers, since according to Ogborn (1979), high levels of nitrogen do not only increase yield of sorghum but also number of emerged *Striga* plants. The cultivation of varieties without a substantial amount of resistance at high nitrogen levels would tend to increase the seed-producing capacity of the pest rather than to control it.

Based on *Striga* count and other agronomic observations, the varieties SK-5912, KSV-4 and NR71150 are suspected to possess a level of resistance to *Striga hermonthica*, while L.2123 is susceptible. The usefulness of SK-5912 and KSV-4 as potential sources of resistance had been identified (Obilana, 1979; Adeoti, 1986); while NR71150 has recently been so identified (Nwasike *et al.*, 1990).

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Etude des Parasites du Niébé en Association avec le Sorgho et le Maïs.

YEHOUENOU A.

INA, N'Dali, Benin.

Résumé

La présente expérimentation a été conduite pendant deux campagnes agricoles, en 1989 et en 1990, à la Station de Recherche sur les Cultures Vivrières d'Ina (Nord Bénin) pour étudier le complexe parasitaire du niébé associé au sorgho et ou maïs. Cinq formes d'association et une culture pure de niébé ont été étudiées. Les résultats indiquent que le niébé a été plus attaqué en culture pure que dans les associations. Cependant, les dégâts causés sur les gousses par *Maruca* et *Cydia* ne présentent pas de différences significatives.

Introduction

L'une des principales causes des faibles rendements du niébé, *Vigna unguiculata* (L) Walp., au Bénin, est l'action néfaste des parasites. En effet, le niébé, comme les autres légumineuses attire un important complexe parasitaire durant la végétation et pendant le stockage (Kyamanywa et Tukahirwa, 1988, Singh 1990). Un bon rendement de niébé en culture pure est impossible sans traitement phytosanitaire. Cependant, l'usage de pesticides, outre la destabilisation des équilibres biologiques naturels, alourdit les charges des paysans, petits exploitants qui ont une pratique séculaire d'association des cultures. Aussi avons-nous entrepris cette étude en vue d'identifier les formes d'association qui réduisent le plus l'effet néfaste des parasites du niébé.

Matériels et Méthodes

Les études ont été réalisées sur les parcelles d'expérimentation de la Division Agronomique au cours des campagnes agricoles 1989 et 1990.

Cinq formes d'association et un traitement en culture pure de niébé (voir annexe) ont été étudiés en bloc de Fisher à quatre répétitions sur des parcelles élémentaires de 20 m^2 (5 m x 4 m). Des observations hebdomadaires ont été faites, de la levée à deux semaines après récolte, sur les principaux ravageurs du niébé : les pucerons, les thrips, les punaises et les lépidoptères.

Pour les pucerons, les poquets attaqués sont comptés sur toute la parcelle et le pourcentage des plants attaqués déterminé. En ce qui concerne les thrips, le niveau de population est évalué par la méthode de " check board drop ", tôt le matin entre 7h00 et 8h00 sur dix plants choisis au hasard par parcelle. Des observations visuelles de punaises sont faites tôt le matin entre 7h00 et 8h00 sur toute la parcelle.

Les différentes espèces sont dénombrées séparément. Les populations de larves de différentes espèces de lépidoptères et leurs dégâts sont déterminés par comptages des gousses perforées.

En 1990, l'attaque massive de *Ootheca mutabilis* 3 semaines après le semis nous a contraint à traiter au FAS-TAC à raison de 2 l/ha toutes les parcelles.

Résultats

L'Association sorgho-niébé. La campagne 1989 a été marquée par l'absence de pucerons et des punaises nombreuses, particulièrement les espèces *Anoplocnemis curviceps* et *Riptortus dentipes*. Malgré l'abondance des populations de thrips il n'y a pas de différence significative entre les attaques des traitements. On peut toutefois remarquer que la culture pure (T1) et l'association T4 ont attiré plus de thrips. Il n'y a pas de différence significative entre les associations et la culture pure quant aux dégâts de *Maruca* et de *Cydia* sur les gousses. Ces résultats sont consignés dans le Tableau 1.

L'entomofaune parasitaire a été plus importante en 1990 que l'année précédente. Les pucerons, les thrips et les lépidoptères notamment ont été plus abondants. Sur 704 punaises dénombrées, il a été identifié 324 *Anoplocnemis curvipes*, 280 *Riptortus dentipes* et 100 *Acanthomia* sp (Tableau 2). On n'a pas observé de pucerons sur les traitements T2 et T6, alors que la culture pure a été cette année encore plus attaquée, les autres traitements restant équivalents. Il n'y a pas de différence significative entre les traitements en ce qui concerne les dégâts de *Maruca* et *Cydia* sur les gousses (Tableau 2).

Tableau 1. Les effets de l'activité parasitaire sur le niébé sous diverses formes d'associations avec le sorgho, campagne 1989.

Traitements	% poq. attaqués par pucerons	Moy. thrip sur 10 plants	Nombre de punaises					Moy. gous. attaquées par *Maruca* et *Cydia* sur 10 plants
			An	Ri	Ac	Ne	Total traitement (toutes espèces confondues)	
T2	0	120*	8	6	0	0	14	9*
T3	0	95	10	2	0	0	12	7
T4	0	103	2	4	0	0	6	8
T5	0	132	1	0	0	0	1	7
T6	0	115	1	0	0	0	1	7
T7	0	125	3	3	0	0	6	12
Total			23	15	0	0		
CV (%)		33.2					32.1	

* les moyennes ne sont pas significativement différentes (P = 0,05)
An = *Anoplocnemis curvipes* ; Ri = *Riptortus dentipes* ; Ac = *Acanthomias* sp
Ne = *Nezara viridula*

Tableau 2. Les effets de l'activité parasitaire sur le niébé sous diverses formes d'association avec le sorgho, campagne 1990.

Traitements	% poq. attaqués par pucerons	Moy. thrips sur 10 plants	Moy. punaise par parcelle	Moy. *Maruca* sur 10 plants	Nbre total *Cydia*	Moyenne gousses perforées par *Maruca* et *Cydia*
T2	1.2	254 a	60 a	76 a	19	50 *
T3	0	104 b	27 b	35 b	0	35
T4	3,6	110 b	23 b	35 b	8	37
T5	1.2	103 b	20 b	39 b	8	31
T6	8,11	128 b	21 b	31 b	9	33
T7	0	108 b	24 b	34 b	7	24,6
CV (%)		19.00	33.7	20,00		

* les moyennes ne sont pas significativement différentes (P = 0,05)

Association maïs-niébé. Le Tableau 3 montre que les thrips ont attaqué plus les traitements T1 et T3. Ces deux traitements ont aussi attiré des punaises, notamment *Anoplocnemis curvipes* et *Riphortus dentipes*. Il n'y a pas de différences significatives entre les traitements quant aux dégâts des lépidoptères et il n'a pas été noté de pucerons.

En 1990, le traitement T6 n'a pas connu de pucerons. On note moins de thrips sur T5 et T6, tandis que la culture pure reste encore la plus infestée. Il n'y a pas de différence significative entre les traitements pour les dégâts de *Maruca* et *Cydia* (Tableau 4).

Discussion

La campagne 1990 montre particulièrement des résultats favorables à l'activité des insectes qui a démarré dès l'émergence des cultures; l'invasion massive des jeunes plants de niébé par *Ootheca mutabilis*, 3 semaines après semis, en est une preuve. Ces résultats peuvent être attribués aux différences de régime pluviométrique entre les deux saisons. En effet, en 1989, 1.217,4 mm de pluie ont été enregistrés en 79 jours tandis que 1990 ne recevait que 874,4 mm en 68 jours, soit un déficit de 343 mm (- 27 %) par rapport à l'année précédente.

Au cours des deux campagnes, la culture pure de niébé a été plus attaquée par les ravageurs que les associations, Ce qui confirme les observations de Singh, (1990) et renforce la thèse de Sterner (1985) selon laquelle l'association culturale réduit les dégâts causés par les ravageurs.

Tableau 3. Les effets de l'activité parasitaire sur le niébé sous diverses formes d'associations avec le maïs, campagne 1989.

Traitements	% poq. attaqués par pucerons	Moy. thrip sur 10 plants	Nombre de punaises					Moy. gons. attaquées par *Maruca* et *Cydia* sur 10 plants
			An	Ri	Ac	Ne	Total traitement (toutes espèces confondues)	
T2	0	105 ab	11	5	0	0	16	11*
T3	0	86 b	0	2	0	0	2	11
T4	0	121 a	6	0	0	0	6	10
T5	0	82 b	3	1	0	0	4	13
T6	0	72 b	2	1	1	1	5	13
T7	0	82 b	4	1	0	0	5	14
Total			26	10	1	1		
CV (%)		19,5					30,9	

* les moyennes ne sont pas significativement différentes (P = 0,05)

An = *Anoplocnemis curvipes* ; Ri = *Riptortus dentipes* ; Ac = *Acanthomias* sp ; Ne = *Nezara viridula*

Tableau 4. Les effets de l'activité parasitaire sur le niébé sous diverses formes d'association avec le maïs, campagne 1990.

Traitements	% poq. attaqués par pucerons	Moy. thrips sur 10 plants	Moy. punaise par parcelle	Moy. *Maruca* sur 10 plants	Nbre total *Cydia*	Moyenne gousses perforées par *Maruca* et *Cydia*
T2	2,7	203 a	57*	55*	9 ab	40*
T3	9	113 ab	32	32	3 b	31
T4	28,81	104 ab	34	34	2 b	33
T5	8	104 ab	42	42	2 b	41
T6	10	84 b	32	32	3 b	31
T7	0	63 b	32	32	6 ab	29
CV (%)		45,7	34,4	39	31,5	42

* Les moyennes ne sont pas significativement différente (P = 0,05)

Nos résultats ont aussi montré que les associations avec 2/3 de population normale de céréales, en lignes jumelées, ont été plus propices aux ravageurs (particulièrement aux thrips) que les autres combinaisons. Ainsi la géométrie de l'association semble jouer un rôle dans l'infestation de la légumineuse.

Nous n'avons observé aucune différence significative en ce qui concerne les dégâts des lépidoptères et cela peut s'expliquer par le fait que l'activité des thrips a laissé peu de gousses suffisamment développées pour être attaquées par les lépidoptères.

Conclusion

L'étude des parasites du niébé en culture pure ou en association avec le maïs ou le sorgho montre que la culture pure de la légumineuse est toujours plus infestée que celle où elle est associée avec une céréale. Dans les deux cas, l'intensité de cette infestation dépend de la pluviométrie. Ainsi en 1990 (874 mm) les parasites sont plus nombreux qu'en 1989 (1274 mm).

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Annexe : Description des traitements

I. Association sorgho-niébé

1. Traitement 1 (T1) : niébé pure. 166.667 plants/ha
2. Traitement 2 (T2) : sorgho-niébé en ligne alternées (1 : 1)
3. Traitement 3 (T3) : sorgho-niébé, 2/3 population normale de sorgho ; S: 41.667 plants/ha, N: 55.556 plants/ha (2 : 2) ; deux lignes N à 0,60 m x 0,20 m.
4. Traitement 4 (T4) : sorgho-niébé, 2/3 population normale de sorgho ; S: 41.667 plants/ha, N: 41.667 plants/ha (2 : 2) ; deux lignes de N à 0,40 m x 0,40 m.
5. Traitement 5 (T5) : sorgho-niébé, 2/3 population normale de sorgho en lignes jumelées ; S: 44.444 plants/ha N: 55.556 plants/ha (2 : 1).
6. Traitement 6 (T6) : sorgho-niébé, même ligne.

II. Association maïs-niébé

1. Traitement 1 (T1) : niébé pure 166.667 plants/ha
2. Traitement 2 (T2) : maïs-niébé, 2/3 population normale de maïs M 41.667 plants/ha, N: 55.556 plants/ha (2 : 2), deux lignes N à 0,60 m x 0,20 m.
3. Traitement 3 (T3) : maïs-niébé, 2/3 population normale de maïs M 41.667 plants/ha, N 41.667 plants/ha (2 : 2) deux lignes N à 0,40 m x 0,40 m.
4. Traitement 4 - T4) : maïs-niébé, 2/3 population normale de maïs en lignes jumelées : M 44.444 plants/ha, N 55.556 plants/ha (2 : 1).
5. Traitement 5 (T5) : maïs-niébé, lignes alternatives (1 : 1).
6. Traitement 6 (T6) : maïs- : TZB
   Sorgho : Toko-bessenou.
   Niébé : TVx 1850-01F.

L'Expérimentation sur le Desherbage Chimique du Maïs en Zone Cotonnière au Nord-Cameroun.

J. MARTIN et E. GERARDEAUX.

IRCT-CIRAD, IRA Maroua et IRCT-CIRAD IRA Garoua, Cameroun.

Résumé

Le programme de criblage d'herbicides lancé par l'Institut de la Recherche Agronomique au Nord-Cameroun comprend quatre phases successives : efficacité, sélectivité, arrière effet, approche économique. Une quinzaine d'herbicides maïs ont ainsi été testés en deux ans. Des résultats intéressants, en particulier sur *Commelina benghalensis*, ont été obtenus avec plusieurs herbicides de pré-levée et de post-levée. Ces résultats contribuent à la définition d'itinéraires techniques mieux adaptés aux conditions locales : par exemple, réduction des doses d'herbicides de pré-levée en cas de buttage 30 jours après semis ; en travail minimum du sol, utilisation d'herbicides de post-levée en relais d'un labour chimique. L'intégration du désherbage chimique du maïs permet une meilleure maîtrise de l'enherbement au niveau du système de culture à base coton.

Introduction

Les herbicides en culture de maïs sont vulgarisés depuis 1977 au Nord-Cameroun. De 1979 à 1983 ils ont été très largement utilisés (70 à 90 % des surfaces intensives). Depuis 1984, ils se maintiennent à environ 3000 ha, soit 40 à 60 % des surfaces intensives. A titre indicatif, les herbicides en culture cotonnière concernent environ 10 à 13.000 ha, soit 10 à 14 % des surfaces. Le traitement consiste en une application d'herbicide de pré-levée à 4 l/ha. Le Gramoxone (paraquat 200 gma/l) a été introduit pour détruire les herbes présentes au moment du semis ; il est utilisé à 1 à 2 l/ha en mélange avec l'herbicide de pré-levée, ou même seul dans certains cas. Les produits utilisés depuis 1987 sont : Bellater (atrazine + cyanazine 250 + 250 gma/l), Primextra (atrazine + métolachlore 170 + 330 gma/l),Lasso GD (atrazine + alachlore 250 + 250 gma/l), Gramoxone ou sepgramox (paraquat à 200 gma/l).

Présentement, les efforts de recherche sur le maïs portent sur l'élaboration d'itinéraires techniques pour la culture du maïs avec un labour minimum dans le but de protèger le sol contre l'érosion. Dans le domaine de la lutte contre les mauvaises herbes, on a entrepris à partir de 1988, d'étudier les effets des herbicides sur cultures vivrières entrant en rotation avec le coton, principalement le maïs. Les résultats présentés ici sont ceux des essais conduits en 1989 et 1990.

Matériels et Méthodes

Schéma de sélection. Un herbicide doit répondre à plusieurs exigences : être efficace vis-à-vis des adventices (limitation de la concurrence), épargner la culture en place et sans présenter d'arrière effet sur les cultures suivantes, être rentable.

Le schéma de sélection des herbicides mis au point par l'IRCT et homologué par la C.E.B. (Commission des Essais Biologiques de la Société Française de Phytiatrie et de Phytopharmacie) en 1981 comprend quatre phases-tests (Deat, 1988) : (i) Efficacité vis-à-vis de la gène adventice, (ii) Selectivité vis-à-vis de la culture, (iii) Arrière effet vis-à-vis de la culture suivante et (iv) approche économique avec les tests en milieu paysan.

L'efficacité globale et spécifique d'un herbicide à une dose donnée est évaluée suivant la méthode du témoin adjacent. Trois doses sont étudiées : la dose proposée par le fournisseur encadrée par les doses 3/4 et 3/2. Les essais ne sont jamais sarclés. Les cotations d'enherbement sont faites jusqu'au 60ème jour.

La sélectivité d'un herbicide reconnu efficace à une dose donnée est étudiée en comparant les doses simple, double et triple à un témoin non traité. L'évaluation porte sur les éventuels effets de phytotoxicité et non sur l'enherbement.

L'évaluation de l'arrière-effet phytotoxique sur la culture suivante de la rotation a pour support les essais de sélectivité et la méthodologie est la même pour les 2 types d'essais. Ainsi, les trois premières phases de sélection comportent des essais en milieu contrôlé. Les sols sont labourés. Les applications d'herbicides sont faites en conventionnel à 250 l de bouillie/ha.

Les herbicides reconnus efficaces, sélectifs et sans arrière effets sont testés pour leur intérêt économique en conditions réelles. Les traitements herbicides en bas volume (20 l/ha) et les entretiens sont réalisés par les paysans, selon leurs propres critères.

Le dispositif expérimental. Pour les trois premières phases, le dispositif expérimental consiste en un réseau d'essais multilocaux comprenant quatre à cinq sites. Les sites sont choisis pour couvrir une variabilité importante à la fois pédologique (sols ferrugineux, fersialitiques, alluviaux et planosols), floristique et climatique (750-1150 mm). Les tests en milieu paysan ont été mis en place dans la région la plus utilisatrice d'herbicides.

La flore de l'étude. Les relevés floristiques réalisés ont identifié plus de 120 espèces réparties comme suit : les Poaceae annuelles dont *Digitaria horizontalis, Pennisetum pedicellatum, Rottboellia cochinchinensis,* les *Commelinaceae* dont *Commelina benghalensis*, les *Asteraceae* et les *Convolvulaceae* et les *Rubiaceae.* Ces familles sont les plus représentées. Les Cyperaceae vivaces (*C. rotondus* et *C. esculentus*), *Imperata cylindrica, Cynodon dactylon* et *Euphorbia heterophylla*) sont par contre peu nombreuses. Les cotations n'espèrant pas aller au-delà du 60ème jour, aucune information n'est disponible sur *Striga hermonthica.*

Les herbicides étudiés. Trois familles d'herbicides représentant 22 spécialités ont été étudiées (Tableaux 1 et 2). Certains de ces herbicides sont déjà vulgarisés au Cameroun, et quelques uns sont nouveaux. Quinze matières actives sont étudiées seules, en association ou en mélange. L'atrazine est la matière active la plus représentée dans les associations ; les anilides substituées sont également très représentées. Dans la suite de la communication, la terminologie suivante sera

Tableau 1. Herbicides testés en 1989 et 90.

Firme	Spécialité	Matières actives et concentration en g/l	Formulation	LPC/HA Dos. de référ.	Efficacité		Sélectivité		Arr Effet	
					89	90	89	90	90	TMP 90
Calliope	Allizine	Atrazine 250 + alachlore 250	SC	4	pré	-	pré	-	*	pré+pp
Ciba-Geigy	Primextra	atrazine 170 + métolachlore 330	SC	4 et 3	pré	pré	-	-	-	pré+pp
	Primagram extra	atrazine + métolachlore + glyphosate 435	SC	4	pp	-	pp	-	*	pré+pp
Dow	(ABIDM-01)	?	EC	1	post	-	post	-	*	-
R.P.A.	Pree	métazachlore 400	EC	2	-	pré	-	-	-	-
	Pree + atrazine	Métasachlore 400 + atrazine 500	SC + SC	2 + 2,4	-	pré	-	-	-	-
	Panter	pendiméthaline 160 + linuron 90	EC	5	-	pré	-	-	-	-
	Challenge	aclonifen 600	SC	2	-	pré	-	-	-	-
	Stomp + Challenge	pendiméthaline 500 + aclonifen 600	EC + SC	2,4 + 2	-	pré	-	-	-	-
	(Exp 04527A)	bromoxyil 120 + atrazine 240	SC	2,5	-	post	-	post	-	-
	Lasso GD	alachlore + atrazine	SC	4	-	-	-	-	-	pré+pp
Monsanto	(Mon 8448	acétochlore 840	EC	1,5	-	pré	-	-	-	-
	(Mon 8448 + atrazine 500)		EC + SC	1,5 + 2	-	pré	-	-	-	-
	(Mon 8484 + Mon 13202)	acétochlore 840 + ? 240	EC +EC	1 + 0,5	-	pré	-	-	-	-
Dupont	(E 9636)	? 25 %	WP	48gpc/ha	-	post	-	-	-	-
I.C.I.	-	acétochlore 768	EC	1,5	-	pré	-	-	-	-
	A 0051	? 300	?	1,3	-	post	-	-	-	-
	A 0051 + atrazine	? 300 + atrazine 500	SC	1,3 + 2	-	post	-	-	-	-
Hoechst	Prado	pyridate 200 + atrazine 160	SC	4	-	post	-	-	-	-
Shell	Prowl	pendiméthaline 330	EC	3	-	-	-	pré	-	-
-	-	atrazine 500	SC	2,4	-	pré/post	-	-	-	-
	Gramoxone	paraquat 200		2,0		-	-	-	-	pp

Légende : pré = prélevée de la culture et des adventices
post = post-levée de la culture et des adventices
pp = post-levée précoce des adventices.

* traitement sur essai sélectivité

utilisée : (i) pré-levée signifie post-semis, pré-levée de la culture et des adventices, (ii) post-levée précoce signifie post-semis, pré-levée de la culture et post-levée précoce des adventices et (iii) post-levée signifie, post-levée de la culture et des adventices.

Environ 2/3 des produits étudiés sont appliqués en prélevée et 1/3 en post-levée. Une seule formulation a été étudiée en post-levée précoce. Dans les tests en milieu paysan, les herbicides de prélevée sont mélangés avec du gramoxone à 0, 1 ou 2 l/ha suivant l'état d'enherbement du champ au moment du semis.

Tableau 2. Familles des herbicides testés.

Principales Familles	Matières Actives Testées
Derivés de l'Urée	Linuron
Anilides substituées	Acétochlore Alachlore Metazachlore Metolachlore
Chloro-triazines	Atrazine
Composés Phenoliques, Toluidines	Pendimethaline
Autres	E 9636 A 0051 Pyridate Mon 13202 Aclonifen Bromoxynil Glyphosate Paraquat

Résultats

Efficacité. Les résultats sont présentés en prenant comme critère d'efficacité globale : la durée pendant laquelle l'enherbement est resté acceptable (note > 7 ; note 10 = enherbement nul, note 0 = enherbement total), la note d'enherbement obtenue 60 jours après le semis.

Les meilleurs herbicides pré-levée (Tableau 3) présentent les caractéristiques communes suivantes : efficacité globale équivalente, présence d'atrazine, forte rémanence (au moins 60 jours), large spectre et faiblesse sur *Rottboellia cochinchinensis* (à l'exception de l'assosiation atrazine + acétochlore qui semble présenter une efficacité moyenne). Ces herbicides, qui comprennent ceux déjà vulgarisés, sont nettement supérieurs aux herbicides coton ; en particulier, ils sont

très efficaces sur *Commelina benghalensis* (Gerardeaux et Martin, 1990 a et b; Martin et Gerardeaux, 1989 a et b). Cette efficacité leur est conférée essentiellement par l'atrazine, qui utilisée seule à 1200 gma/ha s'est très bien comportée. Il conviendra donc de revoir les ratios atrazine/anilides substituées en fonction de leurs prix respectifs. De plus, les doses peuvent certainement être revues à la baisse dans le cas où une moindre rémanence est recherchée. La métazachlore à 1200 gma/ha présente une bonne efficacité globale, mais elle est sans effet sur *Ipomea eriocarpa.*

Tableau 3. Efficacité des herbicides de prélevée.

	J à 7	N 60
atrazine 1800 + métazachlore 1200	60	8,5
atrazine 1200 + métazachlore 800	60	8,5
atrazine 1200	60	8,0
atrazine 680 + métolachlore 1320	60	8,0
atrazine 510 + métolachlore 990	60	8,0
atrazine 510 + métolachlore 990 (1989)	60	8,0
atrazine 1500 + alachlore 1500 (1989)	60	8,0
atrazine 1000 + alachlore 1000 (1989)	60	8,0
atrazine 1000 + acétochlore 1260	60	7,5
atrazine 1020 + métolachlore 1980 (1989)	60	7,5
métazachlore 1200	60	7,0
atrazine 900 = métazachlore 600	60	7,0
atrazine 1000 + acétochlore 1680	60	7,0
atrazine 510 + métolachlore 990 (1989)	60	7,0
atrazine 750 + alachlore 750 (1989)	60	7,0
atrazine 1000 + acétochlore 840	55	6,5
aclonifen 1800	45	6,5
métazachlore 800	45	6,0
métazachlore 600	45	6,0
pendiméthaline 1200 + linuron 675	45	5,0
aclonifen 1200	40	6,0
pendiméthaline 900 + aclonifen 900	40	6,0
pendiméthaline 1200 + aclonifen 1200	40	5,5
pendiméthaline 1800 + aclonifen 1800	40	5,5
acétochlore 840 + M13202 180	40	3,0
aclonifen 900	35	5,5
pendiméthaline 600 + linuron 338	35	5,0
pendiméthaline 800 + linuron 450	35	5,0
acétochlore 1536	35	4,0
acétochlore 840 + M13202 90	35	4,0
acétochlore 840 + M13202 120	35	4,0
acétochlore 1152	30	5,0
acétochlore 768	30	4,0

J à 7 : Durée (en Nb de jours après semis) pendant laquelle l'enherbement est resté correct (> =7)
N 60 : Note d'enherbement obtenue à 60 jours après semis.

Les associations contenant de la pendiméthaline sont moyennement à peu efficaces (Tableau 3). Cela les rend peu intéressantes même si elles sont légèrement efficaces sur *Rottboellia cochinchinensis.*

Les résultats sont présentés dans le tableau 4 pour les herbicides post-levée précoce. Ils se caractérisent par l'adjonction d'une troisième matière active agissant par contact ou par systémie, destinée aux plantules d'adventices présentes au moment du semis (note 8). Cette association est intéressante dans le cas où elle touche des adventices peu sensibles aux herbicides de pré-levée. Par contre les feuilles des adventices constituent un écran diminuant l'efficacité des matières à effet résiduaire.

Les traitements de post-levée ont été effectués environ 20 jours après les semis, avec des enherbements approchant la note 7 (sarclage nécessaire). Les résultats sont présentés dans le Tableau 5. Les meilleurs de ces herbicides (Groupe I) ont en commun : une très bonne efficacité, une forte rémanence et des spectres relativement larges.

Tableau 4. Efficacité des herbicides de post-levée précoce.

	J à 7	N 60
atrazine + métolachlore + glyphosate 2650	60	7,0
atrazine + métolachlore + glyphosate 1740	45	6,0
atrazine + métolachlore + glyphosate 1305	30	5,0

Jà 7 : Durée (en Nb de jours après semis) pendant laquelle l'enherbement est resté correct (> =7).

N 60 : Note d'enherbement obtenue à 60 jours après semis.

Cependant, ils ont une faiblesse sur les Poaceae, en particulier sur *Rottboellia cochinchinensis* ; Toutefois, l'association A0051 + atrazine se distingue par une bonne efficacité sur *Digitaria horizontalis.*

Le deuxième groupe comprend deux herbicides : le bromoxynil + atrazine qui présente des caractéristiques proches des deux herbicides précédents, mais s'est montré moins efficace aux 3 doses étudiées et le A0051 à 400 gma/ha qui présente un spectre assez large mais une efficacité globale insuffisante.

Les trois herbicides du troisième groupe sont d'une efficacité faible ou nulle. Il s'agit de Atrazine + A0051 à 840 + 300 gma/ha et Atrazine + Pyridate à 480 + 600 gma/ha. L'atrazine à 1000 gma/ha est peu efficace en post-levée alors qu'elle est très efficace en pré-levée.

Tableau 5. Efficacité des herbicides de post-levée.

	J à 7	N 60
Groupe I.		
atrazine 960 + pyridate 1200	80	8,0
atrazine 1125 + A0051 400	80	8,0
atrazine 1680 + A0051 600	80	8,0
atrazine 480 + pyridate 600	65	7,0
atrazine 640 + pyridate 900	60	7,0
atrazine 840 + A0051 300	60	7,0
Groupe 2.		
A0051 400	55	6,5
atrazine 450 + bromoxynil 225	50	6,5
atrazine 900 + bromoxynil 450	45	6,0
atrazine 600 + bromoxynil 300	45	5,5
Groupe 3.		
atrazine 1000	0	5,5
E 9636 9	0	4,0
E 9636 12	0	4,0
E 9636 18	0	4,0
ABIDM01 0,75 l/ha	0	3,0
ABIDM01 1,00 l/ha	0	3,0
ABIDM01 1,50 l/ha	0	3,0

Jà 7 : Durée (en Nb de jours après semis) pendant laquelle l'enherbement est resté correct (> =7).
N 60 : Note d'enherbement obtenue à 60 jours après semis.

L'association de l'atrazine avec le A0051 provoque un effet de choc important plus qu'additif : il y aurait donc synergie entre les 2 matières actives. Les associations atrazine + A0051 à 840 + 300 gma/ha et atrazine + pyridate à 480 + 600 gma/ha méritent de passer en expérimentation avancée.

Sélectivité et Arrière-Effet. Parmi les produits de pré-levée et de post-levée précoce, les associations atrazine 1000 + alachlore 1000 gma/ha et atrazine + métolachlore + glyphosate à 1750 gma/ha ont été étudiées. Elles ne présentent pas de phytotoxicité vis-à-vis du maïs ni même d'arrière effets significatifs sur coton. La pendiméthaline en pré-levée à 1000 gma/ha présente des risques de phytotoxicité pour le maïs. Ce risque s'étend donc aux associations contenant de la pendiméthaline.

Tests en Milieu Paysan. Les semis de maïs intensif ont eu lieu fin Juin début Juillet sur des sols encombrés de repousses suite aux labours. Ce sont des touffes d'herbes mal enfouies car déjà trop développées au moment du labour (*Pennisetum pedicellatum, Digitaria horizontalis* et/ou *Tridax procumbens*). Ces tests révèlent que l'efficacité des traitements est fortement conditionnée par l'abondance et la vigueur des repousses de labour. En l'absence de repousses, (en labour motorisé classique bien exécuté par exemple), les herbicides de prélevée testés ont confirmé leur efficacité et leur sélectivité en milieu réel. Ils ont même été suffisamment efficaces lorsque les paysans ont sous-dosé à environ 3 l/ha au lieu de 4 l/ha. En

présence de repousses peu vigoureuses, l'adjonction de gramoxone à l'herbicide de prélevée est efficace et on se retrouve dans le premier cas. En présence de repousses nombreuses et vigoureuses l'addition de gramoxone même à 2 litres/ha s'avère souvent insuffisante. Les feuilles exposées sont brûlées par le paraquat, mais la base des touffes n'étant pas atteinte, ces herbes repoussent vigoureusement à la faveur des pluies suivantes. Aussi le paysan est-il souvent obligé de sarcler 15 jours après le traitement, d'où une réduction de la pellicule d'herbicide de prélevée et une explosion des germinations. L'herbicide de prélevée est donc utilisé à perte dans ces cas-là.

Discussions

Les résultats obtenus soulèvent la question suivante : comment raisonner le désherbage chimique du maïs dans un système de culture coton/céréales ? La réponse dépend de l'importance du labour, d'où l'examen de deux cas : système conventionnel ou minimum tillage.

Système Conventionnel se caractérise par la place importante qu'y occupe le travail du sol qui consiste en labour avec ou sans reprise, sarclage et buttage. Ce système est le plus répandu jusqu'à présent. Le premier problème est celui des repousses de labour. Deux cas peuvent alors se présenter :

a) ***des repousses peu nombreuses et une levée d'adventices au semis :*** le problème peut être résolu par l'emploi d'un herbicide de contact seul ou en mélange avec un herbicide de prélevée. Le recours à une telle combinaison extemporanée est préférable à l'utilisation d'herbicides ternaires préformulés comprenant une matière active agissant par contact ou par systémie. En effet, ces derniers sont plus coûteux et souvent sous-dosés en matières actives à effet résiduaire. Le mélange offre aussi plus de souplesse car il permet de moduler les doses d'herbicide de contact selon la vigueur des repousses. Une autre solution serait les herbicides de post-levée, mais leur efficacité sur ces repousses reste à étudier.

b) ***des repousses abondantes et vigoureuses.*** Les herbicides de contact (type paraquat) peuvent s'avérer insuffisants pour maîtriser les repousses. En l'absence de solution chimique dans l'immédiat, deux voies de recherche peuvent être proposées : le traitement des repousses avec un herbicide systémique mélangé ou non à un herbicide de pré-levée, ou l'intervention au niveau du tapis herbacé avec un herbicide de contact (ou systémique) en plein, 2 à 3 semaines avant le labour, de façon à éviter le problème des repousses (labour chimique).

La deuxième contrainte est celle de la composition de la flore qui va lever. L'intensification a conduit dans de nombreux cas à des modifications de l'enherbement vers des types oligospécifiques dominés par *Commelina benghalensis* (Lebourgeois, 1989). Les explications suivantes peuvent être avancées : des germinations massives provoquées par le labour et les sarclages, une remarquable faculté de régénération après les sarclages, une sélection par les herbicides coton vulgarisés jusqu'à présent qui se sont revelés peu ou pas efficaces sur cette adventice. Dans ces trois cas l'utilisation d'herbicides de prélevée à base d'atrazine

est parfaitement appropriée. Les doses actuellement vulgarisées (4 l/ha), valables si une très forte rémanence est recherchée, peuvent être réduites (3 l/ha) en raison de la pratique systématique du buttage 30 jours après la levée. Cette diminution des doses, en abaissant le coût du traitement herbicide, le rendrait aussi accessible à un plus grand nombre de paysans. Dans ce même contexte, l'utilisation des herbicides de prélevée actuellement disponibles pour le coton est inappropriée. Aussi, en attendant de disposer d'herbicides-coton adaptés, il s'avère indispensable de revoir la stratégie de lutte contre les adventices et en particulier contre *Commelina benghalensis* en privilégiant le désherbage chimique sur le maïs et les entretiens mécaniques ou manuels sur le coton.

La pertinence d'un traitement de post-levée en système conventionnel, doit être aussi raisonnée en fonction du buttage. L'intervalle entre le traitement et le buttage représente environ 20 jours : c'est donc davantage un effet de choc qu'un effet rémanent qui est recherché ici. La composition des herbicides et les doses d'utilisation devront en tenir compte.

Les herbicides maïs de pré ou post-levée étudiés jusqu'à présent ne maîtrisent malheureusement pas tous les enherbements tels ceux de *Rottboellia cochinchinensis* ou des *Cyperacees vivaces.*

Dans le cas du labour minimum, la maîtrise de l'enherbement pose un problème majeur. Les résultats obtenus à ce jour dans ce système permettent d'avancer qu'il est techniquement possible de maîtriser l'enherbement d'une culture de maïs en labour minimum dans le cas où dominent des adventices à feuilles larges. La maîtrise de l'enherbement repose alors sur 2 ou 3 interventions : la destruction du tapis herbacé, avant le semis, par un traitement en plein avec un désherbant total (labour chimique). la limitation de l'enherbement, pendant le cycle, par un traitement de post-levée ayant une action de choc et assurant une rémanence suffisante, le recours à un traitement dirigé sur l'interligne avec un herbicide total, pour pallier une éventuelle faiblesse du traitement de post-levée, voire le remplacer le cas échéant.

La recherche doit se poursuivre dans les directions suivantes : le criblage et les conditions d'utilisation des herbicides totaûx, la détection d'herbicides maïs de post-levée efficaces sur graminées, la mise au point des traitements dirigés. Le problème se pose dans les mêmes termes pour le coton ; cependant, les herbicides de post-levée disponibles ont des spectres d'action très restreints car ils sont uniquement graminicides.

Conclusion

Les résultats de désherbage chimique présentés ici montrent que les alternatives proposées ne sont pas généralisables àtoutes les situations et qu'elles sont à raisonner en fonction des types d'enherbement. Mais le désherbage chimique du maïs offre des possibilités qui permettent d'améliorer la maîtrise de l'enherbement au sein des systèmes de cultures à base coton.

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Evaluation of Plant Products for the Control of Cowpea and Maize Storage Insects.

M. OWUSU-AKYAW.

Ghana Grains Development Project, Crops Research Institute, Kumasi, Ghana.

Cowpea and maize seeds are damaged by the storage beetle *(Callosobruchus maculatus)* and the weevil *(Sitophilus zeamais)*, respectively. An experiment was set up in Kwadaso, Kumasi, Ghana, to assess the effectiveness of 11 locally available plant products in the control of the storage insects. The crop varieties used were cowpea TVx 4678-03D and maize Dorke-SR. The plant products tested were: hot pepper powder, black pepper powder, orange peel powder, eucalyptus leaf powder, jatropha leaf powder, neem leaf powder, ordinary wood ash, neem wood ash, neem seed oil, jatropha seed oil and groundnut oil. Actellic 2% dust was the check insecticide used. Adults of *C. maculatus* and *S. zeamais* from laboratory stock were introduced separately into kilner jars, each containing 500 gm of the treated cowpea and maize seeds, respectively. The results indicated that all the oil products were as effective as the Actellic 2% dust and completely controlled *C. maculatus* and *S. maculatus* for three months and *S. zeamais* for six months while neem wood ash and ordinary wood ash controlled only *S. zeamais* up to five and six months, respectively.

Introduction

Maize and cowpea are important staple crops in Ghana, with annual production of about 750,000 and 30,000 tons, respectively (PPME, 1989). Farmers' efforts to increase production are hampered by insect pests encountered during storage of the harvested produce. While maize grains are damaged in storage by the maize storage weevil *(Sitophilus zeamais* Motsch. - Coleoptera: Curculionidae), cowpea is damaged by the cowpea storage beetle *(Callosobruchus maculatus* F. - Coleoptera: Bruchidae). Grain damage could reach 100% if the insects are not controlled. Grains heavily damaged by storage insect pests will obviously fetch a lower market price or nothing if declared unfit for human and animal consumption, causing the farmer a heavy financial loss.

Although losses caused by storage insects can be drastically reduced by the use of conventional insecticides, peasant farmers who produce the bulk of Ghana's maize and cowpea may have no access to them or are unable and unwilling to use them because of the prohibitive cost and associated health hazards (Taylor and Webley, 1979).

Plant products which are easily available locally, relatively inexpensive, non-toxic to humans and possess insecticidal, antifeedant or repellent properties have been identified. It has been reported that vegetable oils (Mital, 1971; Singh *et al.*, 1978; Messina and Renwick, 1983) and oil extracted from the rind of citrus fruits (Su *et al.*, 1972; Taylor and Vickery, 1974) possess ovicidal and larvicidal properties on *C.*

maculatus eggs and larvae on the surface of treated cowpea seeds. In addition, the oils may act as oviposition deterrents (Su *et al.*, 1972; Messina and Renwick, 1983) and cause adult mortality (Su *et al.*, 1972). Results from Taylor's (1975) experiment on admixture of powdered orange or grape fruit peel with stored cowpea showed that orange peel powder was toxic to *C. maculatus* and significantly depressed oviposition and progeny emergence. Black pepper, *Piper nigrum* L., is present in several African countries where it is used as a condiment and for medicinal purposes. It has, however, been found to be highly toxic to many stored product insects like the rice weevil, *Sitophilus oryzae* (Su, 1977; Gunathilagaraj and Kumaraswami, 1979), the bean weevil, *Acanthoscelides obtectus* (Lathrop and Keinstead, 1946) and *C. maculatus* (Gunathilagaraj and Kumaraswami, 1979. The neem tree, *Azadirachta indica* A. Juss, a native of India and now widely distributed throughout the tropics, has been found useful for ornamental purposes and for the treatment of malaria in Ghana, Nigeria and other West African countries (Irvine, 1961). The insecticidal and antifeedant potencies of *A. indica* against *C. maculatus* have been reported by many researchers, including Ivbijaro (1983) and Sowumi and Akinnusi (1983). Ivbijaro (1983) found that neem seed powder significantly reduced fecundity, prolonged developmental period and decreased adult emergence but did not affect survival of adult *C. maculatus*.

Although plant products have prospects for the control of storage insects in Ghana, little or no research attention has been given to them. This paper describes a study to determine the efficacy of some local plant products for preservation of maize and cowpea seeds.

Materials and Methods

An experiment was set up in the Entomology laboratory of the Crops Research Institute, Kwadaso, Kumasi, Ghana to test the efficacy of locally available plant products for the control of the maize storage weevil *(Sitophilus zeamais)* and the cowpea storage bettle *(Callosobruchus maculatus)*. The mean temperature and relative humidity of the laboratory ranged from 23°-30°C and 66-87%, respectively.

Eleven (11) plant products were used to treat seeds of the test cowpea variety TVx 4678-03E and maize variety Dorke-SR. Both crop varieties are highly susceptible to attack by the respective storage insects. The plant products investigated were: hot pepper (*Capsicum annum* L., Solanaceae) powder; black pepper (*Piper nigrum* L., Piperaceae) powder; orange (*Citrus sinensis* Osbeck, Rutaceae) peel powder; *Eucalyptus tereticornis* Sm. (Myrtaceae) leaf powder; *Jatropha curcas* Linn. (Euphorbiaceae) leaf powder; neem *(Azadirachta indica* A. Juss, Miliaceae) leaf powder; ordinary wood ash; neem wood ash; neem seed oil; jatropha seed oil, and groundnut (*Arachis hypogaea* Linn: Papilionaceae) oil. All or most of these materials are available throughout Ghana. Actellic 2% dust was the insecticide used as a check. The source and method of preparing the plant products are indicated in Table 1.

The maize and cowpea seeds were fumigated with phostoxin tablets in an airtight chamber for three days to kill any insects inside the seeds. The fumigated seeds were aerated outside the chamber to remove the phosphine gas of the fumigant and

then conditioned to the laboratory environment for 14 days before use. The moisture contents of the seeds were 12.6% for the cowpea and 13.5% for the maize.

Five hundred (500) grams each of the seeds were weighed into separate 750 ml kilner jars which had been previously cleaned and sterilized with 98% ethanol. Twelve such set-ups were made for each of the cowpea and maize varieties. Seeds in each of the 12 jars of a test variety were thoroughly admixed with one of the 12 products above. The quantities of the materials used were 10 gm each of the eight powdery plant products, 5 ml each of the 3 oil products and 0.25 gm of the Actellic 2% dust. Each of the treatments of the cowpea was replicated three times whereas there were four replicates for each of the maize treatments. Two pairs (2 males and 2 females) of 0-1 day adult *C. maculatus* and 10 pairs of *S. zeamais* were selected at random from laboratory breeding stocks and introduced into each of the treated cowpea and maize seeds, respectively. Each jar was covered with a lid lined with a metal mesh consisting of 400 square holes/cm2. The mesh allowed air into the jar, protected the seeds from rodent attack and prevented the introduced insects from escaping. A control consisting of seeds untreated with any product but containing insects was set up as above. The jars were arranged on shelves which had been disinfected with Kelthane (acaricide) against infestation of the test materials by mites.

Table 1. Source and method of preparing plant products.

Product	Source	Method of preparation
Hot pepper powder	Fresh ripe fruits bought from Kumasi Central Market	Fresh fruits air dried in the laboratory for 1 month and ground in a hammer mill through 1 mm sieve.
Black pepper powder	Dry seeds bought from Kumasi Central Market	Dry seeds ground in a hammer mill through 1 mm sieve.
Neem leaf powder	Fresh leaves collected from plants near Crops Research Institute (CRI), Kwadaso.	Fresh leaves air dried in the laboratory for 1 month and ground in a hammer mill through 1 mm sieve.
Jatropha leaf powder	- do -	- do -
Eucalyptus leaf powder	Fresh leaves collected from plants at the University of Science and Technology campus, Kumasi.	- do -
Ordinary wood ash	Ash collected from a house at CRI workers' quarters. Type of wood unknown	Ash sieved through 1 mm sieve
Neem wood ash	Dry wood collected from plants near CRI compound.	Wood burnt and ash sieved through 1 mm sieve.
Neem seed oil	Fresh seeds collected from Volta Region, Ghana.	Seed coat removed, kernel dried in the oven at 40°C for 2 weeks, ground in a mill and oil extracted by pressing paste mechanically.
Jatropha seed oil	Fresh seeds collected from different areas in Ashanti Region, Ghana.	Same as for neem seed oil or oil obtained by boiling paste mixed with water and collecting oil settling on the surface of the water.
Groundnut oil	Already bottled oil bought from Kumasi Central Market.	Dry seeds fried on fire, testa removed, kernel ground in a mill and oil extracted by pressing paste mechanically.

Two weeks after introducing the insects into the treated seeds, 33 ml volume of the cowpea seeds was taken with a plastic cylindrical vial. The number of eggs laid on the seeds by the insects, number of hatched eggs and number of hatched larvae penetrating the seeds were recorded. Since eggs of *S. zeamais* are laid inside the seed, these records were not taken for the maize treatments.

Monthly records were taken for six months for all the treatments on the number of damaged seeds, number of holes per unit damaged seed, weight of seeds and number of insects per 33 ml volume of seeds. Samples of the seeds were also taken, planted on moist filter papers in petri dishes before and after the experiment; the number which germinated and/or became mouldy were counted.

Results and Discussion

The mean number of eggs laid by *C. maculatus* on the cowpea seeds two weeks after setting up the experiment is presented in Table 2. The results showed that the insect laid some eggs on seeds of all the treatments except those treated with Actellic 2% dust and jatropha seed oil. The number of eggs laid was highest on seeds treated with eucalyptus leaf powder and lowest on those treated with groundnut oil. This observation might be due to the insecticidal activity of the Actellic dust which caused mortality of the insects introduced into the samples. In addition, oil products have been found by several workers to be toxic or to cause osmotic tension and, consequently, coagulation of protoplasm and mortality of eggs (Mital, 1971; Su *et al.*, 1972; Messina and Vickery, 1974., Singh *et al.*, 1978., Messina and Renwick, 1983). In the medium in which eggs were laid, the products used to treat the seeds do not perhaps deter oviposition or have non insecticidal constituent which could cause mortality of the insects before oviposition (Su *et al.*, 1972., Messina and Renwick, 1983).

Where the highest number of eggs were laid, the admixed product probably stimulated oviposition. None of the eggs laid on the seeds treated with neem seed oil and groundnut oil hatched. This could be attributed to the ovicidal properties possessed by the oil products (Mital, 1971; Singh *et al;* 1978., Messina and Renwick, 1983). The proportion of hatched eggs and hatched larvae penetrating seeds on which eggs were laid were lowest for the seeds treated with black pepper powder (Table 2). Perhaps the insecticidal property of piperine in black pepper might have caused some egg and larval mortalities (Su, 1977).

Table 2. Mean number of eggs laid by *C. maculatus* on treated cowpea seeds two weeks after introducing insects.

Treatments	N° of eggs laid/33 ml volume of seed	% seeds with eggs	% hatched eggs	% hatched larvae penetrating seed
Hot pepper powder	8	1.9	95.9	100.0
Black pepper powder	4	1.9	38.9	66.7
Orange peel powder	5	2.5	91.7	100.0
Eucalyptus leaf powder	13	4.0	97.6	100.0
Jatropha leaf powder	8	3.7	91.9	98.1
Neem leaf powder	8	3.6	93.5	100.0
Ordinary wood ash	5	2.5	74.7	100.0
Neem wood ash	6	2.5	82.2	91.7
Neem seed oil	5	2.5	0	0
Jatropha seed oil	0	0.0	0	0
Groundnut oil	1	0.8	0	0
Actellic 2% dust	0	0.0	0	0
Control (untreated)	6	3.0	97.0	100.0
Mean	5	2.2	58.7	65.9
CC (%)	34	42	21.3	24.7
LSD (5%)	1	ns	20.5	26.7

Figures 1 and 2 show the mean per cent damage and number of insects/33 ml volume of seeds of the test cowpea and maize seeds infested with the respective storage insects and stored from 1-6 months. The mean per cent loss in seed weight and number of holes per unit damaged seed of the treated cowpea and maize seeds are also indicated in Figures 3 and 4. The results showed that throughout the storage period, no damage was caused by either *C. maculatus* or *S. zeamais* to the respective test materials treated with neem seed oil, jatropha seed oil, groundnut oil and Actellic dust. Thus, the oil products were as effective as Actellic dust in controlling the cowpea and maize storage insects. Consequently, there was insignificant loss in the weight of the cowpea and maize seeds treated with these four products. The observations in the cowpea were obvious, since no eggs were laid on the seeds treated with Actellic dust and jatropha seed oil, and none of the eggs laid on seeds treated with neem seed oil and groundnut oil hatched. The products might have also acted similarly on the maize storage insect.

Except black pepper powder, neem wood ash and ordinary wood ash, none of the other plant products could control any of the storage insects. Black pepper powder controlled *C. maculatus* for three months and *S. zeamais* for six months due, perhaps, to the piperine in the product (Su, 1977) which probably had longer term effect on *S. zeamais* than on *C. maculatus*. On the other hand, neem wood ash and ordinary wood ash controlled only *S. zeamais* for 5 and 6 months, respectively. The ash products might have reduced the integranary spaces of the maize causing obstruction to free movement of the insects in search of mating partners and thereby retarding their multiplication. The ash particles might have also caused abrasions on the body of the insects as they move over them and causing adult mortality. The ash products were, however, only effective against *S. zeamais*, apparently because

of the indentations on the maize seeds which could hold more of the applied material onto the surface. The slippery and non-dented surface of the cowpea seeds caused the ash to settle at the bottom of the kilner jar with minimum or no contact with the insects and exposing the seeds to the insects for infestation. Since the type of ordinary wood ash was unknown, it cannot be explained why it was more effective than neem wood ash.

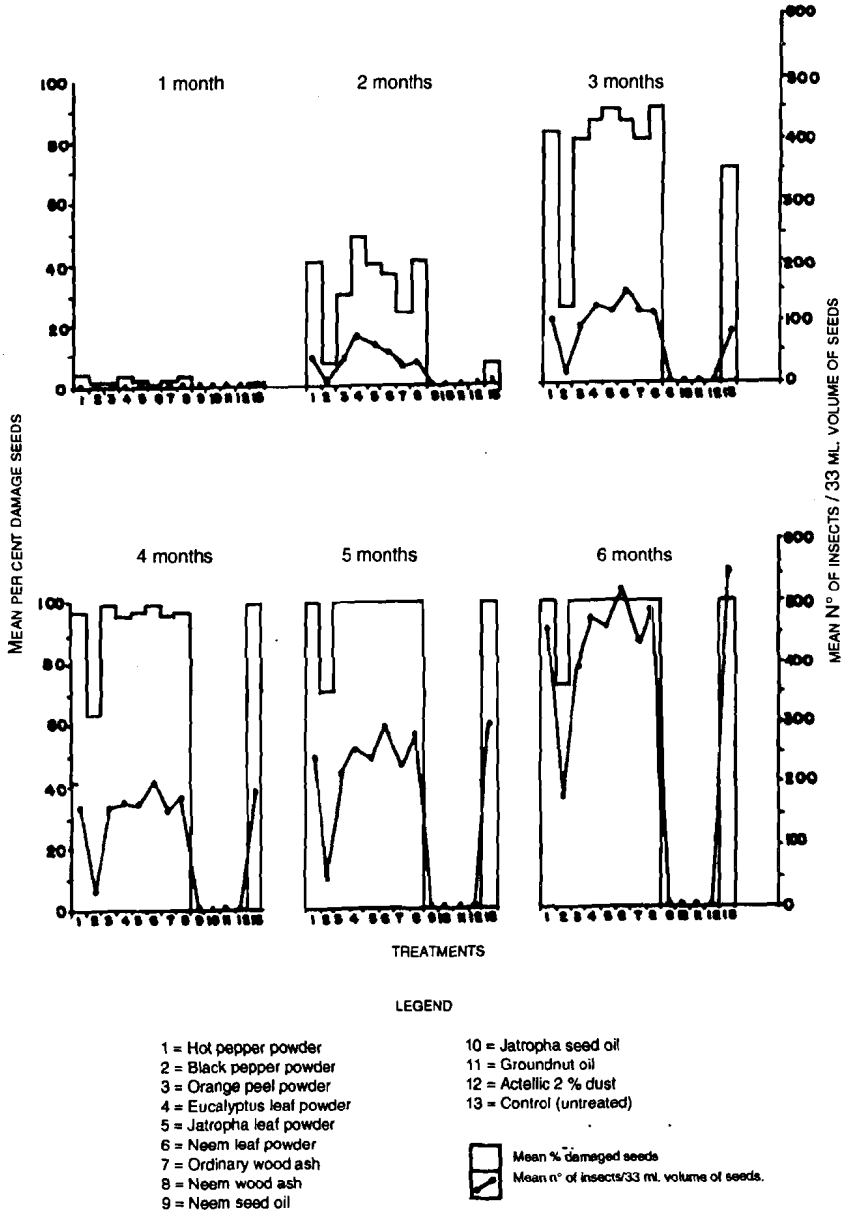

Fig. 1. Mean percent damage, and number of insects/33 ml volume of seeds of treated cowpea infested with *C. maculatus* and stored from 1-6 months.

Unexpectedly, insect damage and loss in weight were higher in some of the treated seeds than seeds in the untreated control stored for two and three months for the cowpea (Fig. 1 and 3) and from the second to the fifth month for the maize (Fig. 2 and 4). These were observed in the cowpea seeds treated with hot pepper powder, orange peel powder, eucalyptus leaf powder, ordinary wood ash and neem wood ash. For the maize, the products were hot pepper powder, orange peel powder, eucalyptus leaf powder, jatropha leaf powder and neem leaf powder. Presumably, the insects laid quite a high number of eggs on both the cowpea and maize seeds treated with these products as demonstrated in Table 2 for the cowpea. Since the products might have also acted as feeding stimulants and probably had no lethal effect on the respective insects, this enhanced population build-up (Fig. 1 and 2). Consequently, damage and loss in weight of seeds treated with these products were higher than those of seeds of the untreated control.

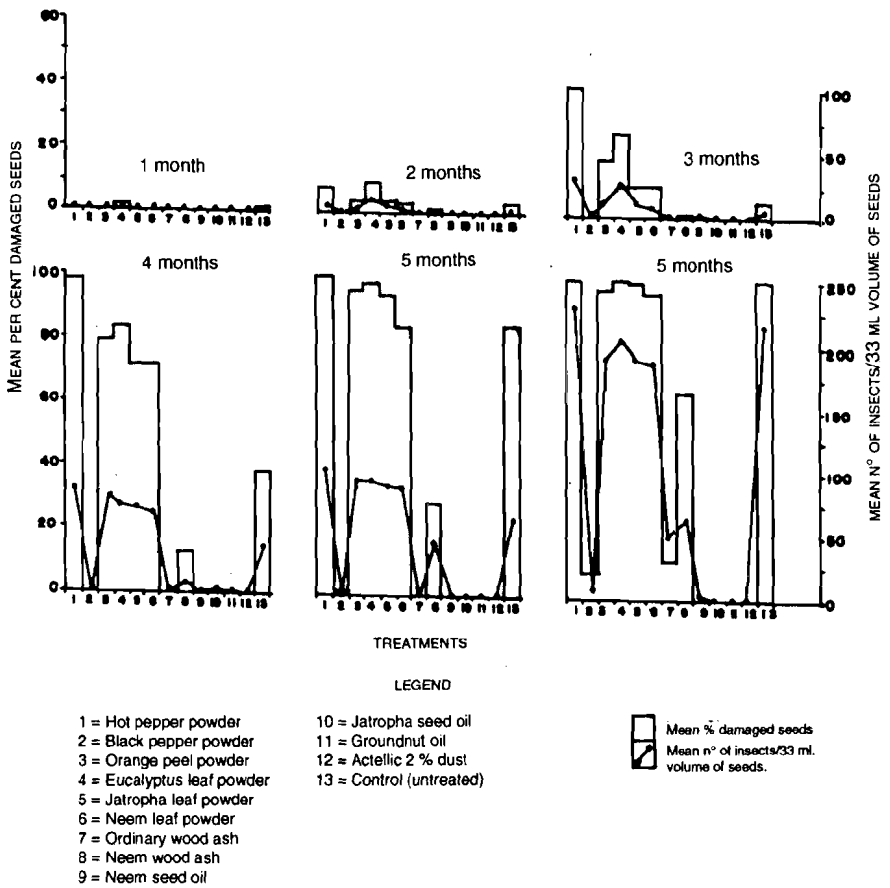

Fig. 2. Mean percent damage, and number of insects/33 ml volume of seeds of treated maize infested with *S. zeamais* and stored from 1-6 months.

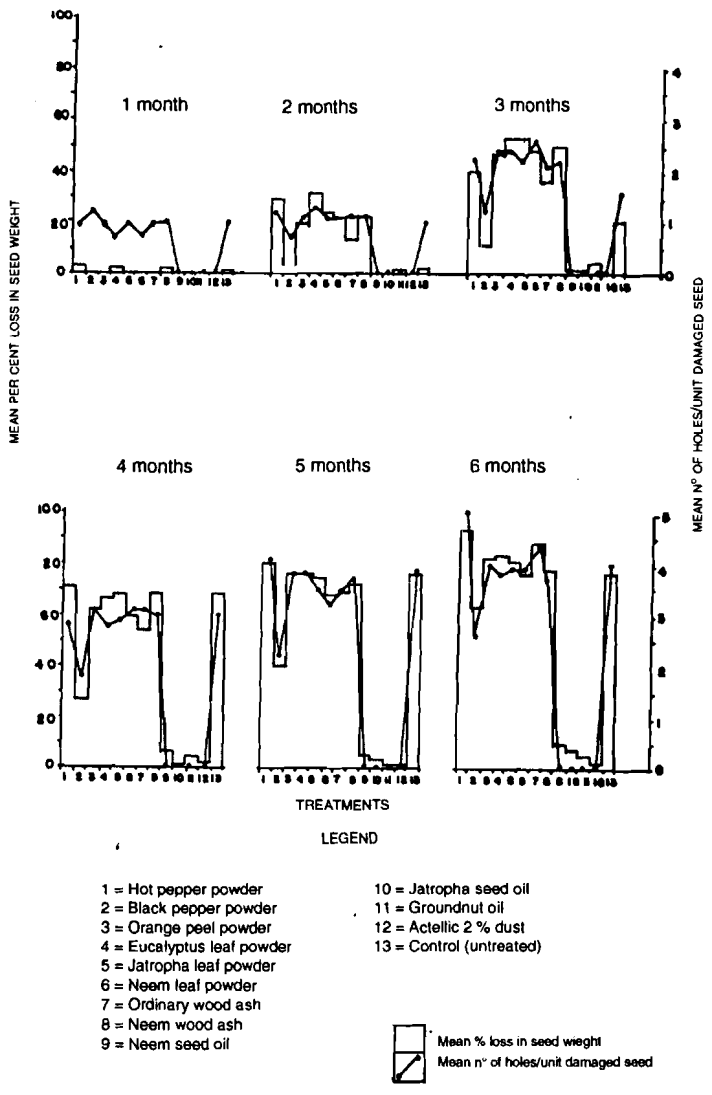

Fig. 3. Mean percent loss in seed weight and number of holes/unit damaged seed of treated cowpea infested with *C. maculatus* and stored from 1-6 months

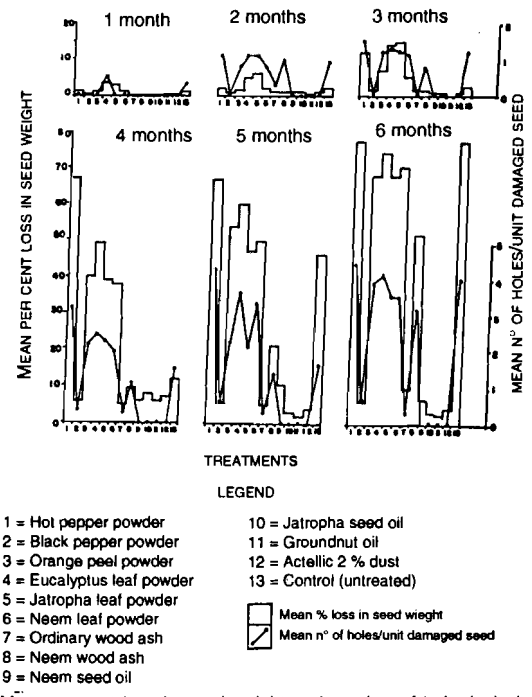

Fig. 4. Mean percent loss in seed weight and number of holes/unit damaged seed of treated maize seeds infested with *S. zeamais* and stored from 1-6 months

Table 3. Mean seed germination, mouldy seeds and number of insects/bulk of treated cowpea seed infested with *C. maculatus* and stored for 6 months.

Treatments	Initial % seed germination	Final % seed germination	Final % mouldy seeds	Insects/ bulk of seeds
Hot pepper powder	98	0	100	3776
Black pepper powder	97	0	100	841
Orange peel powder	97	0	100	3969
Eucalyptus leaf powder	98	0	100	4660
Jatropha leaf powder	97	0	100	4479
Neem leaf powder	97	0	100	5161
Ordinary wood ash	97	0	100	4067
Neem wood ash	99	0	100	4317
Neem seed oil	98	94	8	4[a]
Jatropha seed oil	99	95	7	4[a]
Groundnut oil	98	92	12	4[a]
Actellic 2% dust	97	95	7	4[a]
Control (untreated)	96	0	100	5453
Mean	98	29	72	2826
CV (%)	2	5	3	24
LSD (5%)	NS	2	4	1136

[a] Values are original insects introduced into the seeds.

After six months in storage, per cent germination of the seeds treated with the oil products and Actellic dust ranged from 92-95 for the cowpea (Table 3) and 81-89 for the maize (Table 4). Expectedly, values of the per cent mouldy seeds after the six months of storage the seeds were very low and ranged from 7-12 for the cowpea (Table 3) and 11-13 for the maize (Table 4). For the other treatments, 100% of the cowpea and 99% of the maize seeds became mouldy and as a result none of them germinated. These observations were so since in both the cowpea (Tables 3 and 5) and maize (Tables 4 and 6) seed germination negatively and significantly correlated with seed mouldiness and insect population and damage. Therefore, the properties possessed by the oil products make them as effective as Actellic 2% dust for the preservation of maize and cowpea seeds intended for planting in one to six months time. In addition, since values of the per cent germination of the maize seeds treated with black pepper powder (76%) and ordinary wood ash (80%) were quite high after six months in storage, these products could also be used for preservation of seed maize from one to six months.

From the study, it may be concluded that the following plant products, available throughout Ghana, have the potential for the preservation of cowpea and maize seeds for varying periods of time:

Table 4. Mean seed germination, mouldy seeds and number of insects/bulk of treated maize seeds infested with *S. zeamais* and stored for 6 months.

Treatments	Initial % germination	Final % germination	Final mouldiness	Insects/bulk of seeds
Hot pepper	98	0	99	3690
Black pepper powder	95	76	12	41
Orange peel powder	96	0	99	3528
Eucalyptus leaf powder	97	0	99	3394
Jatropha leaf powder	96	0	99	3195
Neem leaf powder	98	0	99	3343
Ordinary wood ash	98	80	10	83
Neem wood ash	98	0	99	2837
Neem seed oil	97	82	12	20[a]
Jatropha seed oil	97	81	13	20[a]
Groundnut oil	98	85	11	20[a]
Actellic 2% dust	96	89	13	20[a]
Control (untreated)	98	0	99	3816
Mean	97	38	59	1847
CV (%)	3	43	11	15
LSD (5%)	NS	19	10	398

[a] Values are original insects introduced into the seeds.

Table 5. Correlation among parameters tested in the storage of treated cowpea seeds infested with *C. maculatus* and stored for 6 months.

	Initial n° of eggs/ 33ml vol of seed	Initial % seeds with eggs	Initial % hatched eggs on seeds	Initial % hatched larvae pene-trating seeds	% da-maged seeds	N° of hole/ da-maged seed	% loss in seed weight	N° of insect/ 33ml vol of seeds	N° of insect/ bulk of seeds	Final % of seed germi-nation
Initial % seeds with eggs	0.83**									
Initial % hatched eggs on seeds	0.59**	0.54**								
Initial % hatched larvae penetrating seeds	0.57**	0.54**	0.96**							
% damaged seeds	0.55**	0.51**	0.90**	0.91**						
N° of holes/damaged seed	0.52**	0.49**	0.90**	0.91**	0.97**					
% loss in seed weight	0.58**	0.53**	0.91**	0.91**	0.98**	0.96**				
N° of insects/33 ml vol. of seeds	0.57**	0.52**	0.90**	0.88**	0.95**	0.91**	0.94**			
N° of insects/bulk of seeds	0.57**	0.57**	0.91**	0.87**	0.90**	0.87**	0.89**	0.96**		
Final % seed germination	-0.53**	-0.50**	-0.91**	-0.94**	-0.97**	-0.94**	-0.97**	-0.90**	-0.86**	
% mouldy seeds	0.53**	0.50**	0.91**	0.94**	0.97**	0.94**	0.94**	0.90**	0.85**	- 0.99**

In/parameter = 39 ** Significant at the 1% level

Table 6. Correlation among parameters (1) tested in the storage of treated cowpea seeds infested with *S. zeamais* and stored for 6 months.

	N° damaged seeds	N° of holes/damaged seed	% loss in seed weight	N° of insects/ 33 ml vol. of seeds	N° of insects/ bulk of seeds	Final % seed germina-tion
N° of holes/damaged seed	0.97**					
% loss in seed weight	0.97**	0.94**				
N° of insects/33ml vol. of seeds	0.93**	0.91**	0.93**			
N° of insects/bulk of seeds	0.97**	0.96**	0.96**	0.91**		
Final % seed germination	-0.90**	-0.89**	-0.88**	-0.80**	-0.89**	
Final % mouldy seeds	0.95**	0.94**	0.94**	0.86**	0.97**	-0.95**

In/parameter = 52 ** Significant at the 1% level.

a) Neem seed oil, jatropha seed oil and groundnut oil which were as effective as Actellic 2% dust in the control of both cowpea and maize storage insects for six months.

b) Black pepper powder which could control the cowpea storage beetle for three months and the maize storage weevil for 6 months.

c) Neem wood ash and ordinary wood ash which could preserve only the maize seeds for 5 and 6 months, respectively.

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Evaluation of Cowpea and Pearl Millet Cultivation to Improve and Sustain Yield of the Intercrops.

B.R. NTARE, and L.K. FUSSEL *

ICRISAT Sahelian Centre, Niamey, Niger.

Abstract

Cowpea (*Vigna unguiculata* (L.) Walp) and pearl millet (*Pennisetum glaucum* (L.) R. Br.) are two of the predominant food crops in the semi-arid zone of West Africa. Intercropping millet and cowpea is a popular practice in the region. A review of research conducted at the ICRISAT Sahelian Centre in Niamey, Niger, indicates the importance of plant cowpea type in the system. Early-maturing cultivars (60-70 days) reduce millet yields less than do the medium to late-maturing cultivars. Indeterminate, spreading cultivars produce higher grain and fodder yield than determinate cultivars. Late and photoperiod sensitive types produce more fodder than grain and have a more pronounced negative effect on millet yields. On the other hand, there was a tendency for cowpea to perform better when intercropped with short, early-maturing millet cultivars than with the tall and late-maturing traditional types. Sowing date of cowpea relative to pearl millet is a critical factor in the millet/cowpea intercropping system. Cowpea cultivars suited for intercropping with millet are those that are less competitive with millet while maintaining acceptable yields of both grain and fodder in the system. Research findings demonstrate that millet/cowpea intercropping systems can be made more productive by modifying agronomic factors such as sowing dates, plant densities and planting patterns as well as the choice of appropriate cultivars of both millet and cowpea. Crop rotations are seen as a promising adjunct to further intensification of the cropping system.

Introduction

Cowpea, (*Vigna unguiculata* (L.) Walp.) and pearl millet (*Pennisetum glaucum* (L) R.BR.) are two of the predominant food crops in the semi-arid zone of West Africa. The two crops are generally grown together in mixtures.

Of all the regions of sub-Saharan Africa, West Africa has shown the slowest growth rate for total food production, mainly due to the low production of the main staples (Spencer and Sivakumar, 1987). Production of pearl millet has shown a slow production rate of only 1% and for cowpea, production has been rather static. Average grain yields of both crops are uniformly low.

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* Present address: 21, Naroom Road, Niagra Park, N.S.W. 225, Australia.

The poor production performance of the millet/cowpea production system can be attributed to the fact that both crops are grown under harsh dryland conditions characterized by poor soils and erratic rainfall. Few inputs are used.

An array of crop management options which can improve the production system are available (Fussel *et al.*, 1989). This paper will limit itself to a review of research results of experiments conducted at the ICRISAT Sahelian Centre (ISC) in an attempt to improve the productivity of the millet/cowpea cropping system.

Traditional Pearl Millet/Cowpea Cropping Systems

Cowpea grains offer nutritious food and the haulms (harvested stems and leaves) serve as fodder for livestock. The superiority of intercropping in terms of insurance from risk, higher returns and better resource use has been reviewed (Fussel and Serafini, 1985; Ntare *et al.*, 1989). Although, there are no clearly defined patterns that can be said to exist in any ecology in which pearl millet and cowpea are grown, millet/cowpea is the most predominant in the Sahel. The traditional pearl millet/cowpea intercropping systems have been developed through man's interaction with an environment that involves a high degree of risk due to the inherent poverty and variability of the cropping ecology.

Planting dates vary from simultaneous planting of millet and cowpea to various relay plantings. Planting patterns vary from systematic inter-row planting to random mixtures.

The major yield reducing factors for intercropped cowpea are low cowpea plant density, shading by the cereal crop, pests and diseases, drought stress and low fertility of the soils. Therefore, a programme aimed at improving cowpea yields under intercropping was designed to minimize these constraints in such a way as to increase cowpea yield without reducing cereal yields.

Research has been conducted on various factors that affect millet/cowpea intercrop performance. These include choice of cowpea cultivars (Ntare, 1989), the effect of fertilizer (Fussel and Serafini, 1985) planting date of cowpea in relation to millet and cowpea density (Ntare, 1990).

Varietal Screening for Intercropping

i. ***Cultivar Choice.*** In the Sahelian zone, traditional millets and cowpea are adapted to flower and fill their grain during September-October. This period often coincides with the average end of the rainy season. In years when rains stop early, both crops are severely affected by drought.

With the increasing availability of new cultivars, often with different plant types and maturity cycles, there is scope for developing more productive and stable millet/cowpea cropping systems. Such systems should, however, have the stability typical of the traditional systems. Appropriate maturity of cultivars selected for both crops is very important. In the short season environment of the Sahel, cultivars should reach maturity before moisture is exhausted. Therefore, breeding for

earliness is a pre-requisite in this case. Early maturity is desirable for two reasons. First, with a shorter growing season, early varieties avoid unpredictable moisture stress, both at the start and end of the rainy season. Secondly, there is much more flexibility in selecting a more favourable planting time. Both of these advantages result in a much lower risk of crop failure and thus, a more stable cropping system.

ii. ***Effect of Cowpea Plant Type.*** Millet/cowpea intercropping trials conducted at ISC have demonstrated the importance of cowpea plant type in the system (Ntare, 1989). Early maturing (60-70 days) and determinate cultivars reduce millet yield less than the medium (75 days) to late maturing (90 days) cultivars (Table 1). Indeterminate cultivars produce higher grain and fodder yields than indeterminate cultivars. On the other hand, late and photoperiod sensitive cultivars produce more fodder than grain and have a more negative effect on millet yields.

iii. ***Sole Crop vs Intercrop***: Intercropping reduces legume yields and in the case of millet/cowpea, this depends on the cultivar (Table 2). It is generally believed that a significant, positive correlation of yields between two planting systems suggest a minimal genotype by cropping system interaction and, thus, a minimal need for separate breeding strategies for the two systems (Smith and Francis, 1986). In a study involving 300 cowpea cultivars in sole and intercropping, linear correlation between grain and fodder yields of cowpea in sole and intercrop were positive and significant, with r values ranging from 0.45 to 0.91 (Ntare, 1989) indicating that it was possible to select high-yielding cultivars of cowpea for intercropping based on their sole crop rejected, respectively, on the basis of sole-crop grain yield. Therefore, selection of cowpea cultivars for intercropping based on their grain yield in sole crop may have limited success. On the other hand, selection based on fodder yield favoured late-maturing types.

iv. ***Effect of Millet Cultivars.*** In an experiment to study the effect of different millet cultivars, cowpea grain and fodder yields were greatly affected by the local millet cultivar (Table 3). The early-maturing millet had less effect on cowpea yields than the late-maturing cultivar. Similar results were reported by Reddy *et al.* (1990). They further reported that intercropped cowpea performed better when intercropped with a dwarf millet cultivar than the tall traditional one. In spite of these effects, there has been no evidence of a significant millet x cowpea cultivar interaction. This shows that one could use either of the millet varieties for screening cowpeas in intercropping.

Table 1. Effect of cowpea plant type on grain and fodder yields (t ha^{-1}) in an intercrop of cowpea and pearl millet, ISC, Sadore, Niger, rainy seasons 1985-86, 1988.

Plant type cultivars	1985			1986			1988		
	Cowpea grain	Cowpea fodder	Millet grain	Cowpea grain	Cowpea fodder	Millet grain	Cowpea grain	Cowpea fodder	Millet grain
Extra-early, determinate (60-65 days)									
IT82E60	0.10	0.32	2.04	0.09	0.11	1.30	0.10	0.21	1.01
IT82D716	0.12	0.40	2.17	0.10	0.18	1.14	0.19	0.41	0.99
Eary, indeterminate (70 days)									
TVX3236	0.40	0.83	1.79	0.20	0.23	1.10	0.22	0.54	0.72
SUVITA2	0.62	1.34	1.55	0.55	0.50	1.13	0.26	0.61	0.77
Medium maturity, indeterminate (80 days)									
TN88-63	0.42	1.06	0.60	0.18	0.46	1.23	0.30	0.58	0.54
58-57	0.60	1.30	1.56	0.38	0.77	1.17	0.41	0.91	0.77
Late maturity, indeterminate (120 days)									
Local cowpea	1	1.97	0.63	0.03	1.31	0.68	0.17	1.16	0.68
Sole millet (cv. CIVT)	-	-	2.24	-	-	1.30	-	-	1.20
SE	±0.08	±0.08	±0.12	±0.06	±0.06	±0.21	±0.03	±0.05	±0.04

Table 2. Average yield (t ha^{-1}) of different cowpea maturity and plant types grown in sole and intercropping with pearl millet in trial 1, rainy seasons 1985 and 1986.

Parameter and cropping systems	Maturity and plant types[1]							
	1985				1986			
	I	II	III	IV	I	II	III	IV
Cowpea grain								
Sole	0.47	0.51	0.67	0.67	0.33	0.33	0.47	0.17
Intercrop	0.31	0.34	0.46	0.44	0.15	0.22	0.33	0.13
SE	±0.027	±0.020	±0.022	±0.058	±0.012	±0.011	±0.016	±0.025
Cowpea fodder								
Sole	1.04	1.38	2.00	2.40	0.82	0.91	1.02	1.33
Intercrop	0.60	1.03	1.49	1.81	0.51	0.53	0.51	1.08
SE	±0.064	±0.048	±0.094	±0.079	±0.077	±0.095	±0.128	±0.063
Millet grain								
Sole	1.40	1.40	1.40	1.40	0.93	0.93	0.93	0.93
Intercrop	1.04	0.97	0.81	0.73	0.69	0.53	0.51	0.40
SE	±0.040	±0.035	±0.061	±0.075	±0.048	±0.035	±0.056	±0.060

I	=	15	Extra-early, determinate (60-65 days)
II	=	36	Early, indeterminate (70 days)
III	=	17	Medium maturity, indeterminate (80 days)
IV	=	7	Late maturity, indeterminate (120 days)

v. ***Effect of Sowing Patterns and Relative Date of Sowing***. Pearl millet is traditionally sown with the first rainfall and cowpea is intercropped later, depending on the evolution of the rains. The planting time lapse between the two crops may vary as much as 15-30 days. There is potential for increased production in intercrop combinations through modification of sowing date and spatial arrangements. A better understanding of the interaction between these factors with cowpea cultivars may contribute to improvement of the production system.

A two-year study was conducted over two sites in western Niger to compare six cowpea cultivars for their response to two sowing patterns in combination with two sowing dates relative to pearl millet. The cowpea cultivars were IT82D716 (erect and indeterminate, maturing in 65 days), ITX3236 (semi-erect with profuse flowering habit and matures in about 70 days), B111-2 (spreading type, maturing in 65 days) SUVITA 2 (spreading and maturing in 75 days), TN5-78 (spreading type and matures in 75 days) and Sadore Local, (highly vegetative photoperiod sensitive, prostrate cultivar, maturing in more than 90 days). The sowing patterns were single rows of cowpea alternating with single rows of millet and two rows of cowpea alternating with two rows of millet. The sowing dates of cowpea were one week and three weeks after millet.

Table 3. Yield (t ha^{-1}) for three cowpea and four millet cultivars from a trial conducted at the ISC, rainy season 1985.

Pearl millet cultivar [1]	Cowpea cultivar [2]	Pearl millet grain	Cowpea grain	Cowpea fodder
Local cv	Local cv	1.27(1.3)[3]	0.13(0.42)	0.29(1.79)
CIVT	Local cv	0.82(1.1)	0.27	0.59
3/4 HK-B78	Local cv	0.67(0.77)	0.20	0.43
ICMV4 (ICMS 7703)	Local cv	0.52(0.78)	0.37	0.84
Local cv	TN88-63	1.43	0.28(0.95)	0.17(1.32)
CIVT	TN88-63	0.85	0.43	0.32
3/4 HK-B78	TN88-63	0.87	0.44	0.55
ICMV4 (ICMS 7703)	TN88-63	0.80	0.51	0.33
Local cv	IT82E 60	1.37	0.08(0.19)	0.16(0.37)
CIVT	IT82E 60	0.82	0.19	0.26
3/4 HK-B78	IT82E 60	0.85	0.11	0.16
ICMV4 (ICMS 7703)	IT82E 60	0.69	0.14	0.20
SE		0.113(0.112)	0.126(0.072)	0.066(0.164)

1. Local cv - Long duration tall cultivars, CIVT - matures in 110 days, 3/4 HK-B78 is a dwarf, leafy cultivar and ICMV4 is an early-maturing cultivar.

2. Local cv photoperiod sensitive and late-maturing (120-150 days)
TN88-63 - photoperiod insensitive, medium-maturing (70-80 days)
TN82E 60 - photoperiod insensitive, early-maturing (55-60 days).

3. Numbers in parenthesis are sole crop yields of millet and cowpea cultivars.

Because of the variable competitive effects of the cowpea cultivars on the millet, these were assessed across cultivars and sowing dates using a millet to cowpea trade ration (T). This was compute for grain, fodder and total biomass using the equation:

$T = Ci/Ms-Mi$

Where Ci = yield of cowpea in the ith treatment; Ms = yield of sole crop millet, and Mi = yield of millet in the ith treatment (Ntare and Williams, unpublished). Thus, a large result indicates that the competitive effects were balanced by substantial gains in cowpea while a value of 1 indicates merely a substitution of cowpea for millet.

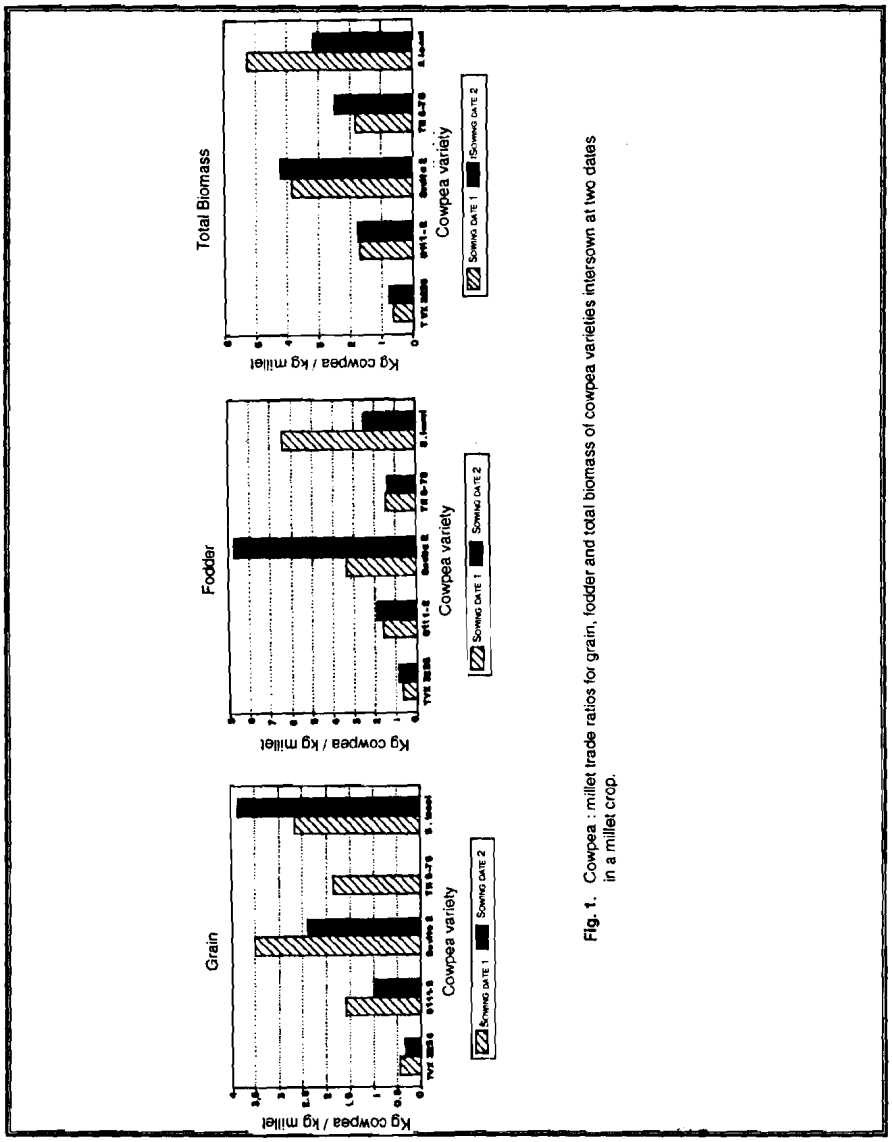

Fig. 1. Cowpea : millet trade ratios for grain, fodder and total biomass of cowpea varieties intersown at two dates in a millet crop.

Cowpea cultivars had a substantial effect on the trade ratios for all parameters (Fig. 1) and interaction of T for date and cultivars appeared in the distribution benefit between fodder and grain. Throughout, TVX3236 decreased millet yields more than its own yield while at the second sowing date, TN5-78 had no effect on millet yield but was close to being a substitute competitor for fodder. SUVITA-2 and Sadore Local both had high trade ratios with considerable sowing date

interaction between grain and fodder. Thus, although there were differences in absolute yields between the genotypes, the large decrease in millet yields offset the benefits in weight terms.

Among the cowpea cultivars, TVX 3236 is unsuitable for intercropping because of its negative impact on millet yield and its own low yield. If the strategy is to ensure maximum productivity of millet grain, then TN5-78 sown at a later date would be the logical choice, since it has no significant negative effect on millet yield. On the other hand, if total productivity is the objective, then the earlier sowing of Sadore Local would be the choice. However, the period of these trials experienced above average rainfall and it is possible (because of the late maturity of this cultivar) that a production system using this technology would be relatively unstable because of the high probability of the end-of-season drought (Sivakumar 1988). SUVITA-2, a medium maturing cultivar, would provide a compromise between the least decrease in millet yield an a very good trade of millet for cowpea. Therefore, cowpea cultivars best suited to intercropping with millet should not strongly compete with the cereal but should themselves maintain acceptable yield of both grain and fodder in the intercrop situation.

One difficulty of selecting cowpea cultivars for intercropping is their impact on competition on the companion crop. In this context, the use of a trade ratio can provide a valuable selection guide to the breeder and a treatment evaluation index for the agronomist. The analysis using trade ratios showed consistent behaviour of all the cultivars for biomass particularly across sowing dates. This suggests that for these environments, relative sowing date may not be significant in cultivar choice. To maximize yields, the earlier sowing date of cowpea relative to millet is necessary. However, this would involve major changes in the livestock management practices and the greater productivity will have to be evaluated relative to the cost of finding alternate feed for livestock as a result of keeping them out of the fields early in the season.

vi. ***Cropping System Choice.*** Present cereal cropping systems are expected to change as improved germplasm of cereals and legumes as well as other new technologies, become available. Though sole crop cowpea is not a traditional system in West Africa, it still holds promise. The role of legumes in the soil N-economy cannot be over-emphasized. Yields of cereals that follow cowpeas are often improved. Research at ISC, has begun to quantify the beneficial rotational effects of cowpea on millet (Bationo *et al.*, 1990). As cowpea is becoming popular as a cash crop in the region, it may also be feasible and desirable to use purchased inputs such as fertilizers and pesticides. Enhancing cowpea yields through fertilization and protection from insect pests results in greater millet yields the following season through the additional soil N sybmiosis and residual P. This is one way of intensifying millet-based systems.

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Effect of Planting Time on Cowpea in Relay Intercropping with Maize.

J.N. ASAFU-AGYEI, and P.B. ALLOU.

Ghana Grains Development Project, Crops Research Institute, Kumasi, Ghana.

Abstract

The risk of crop failure due to low, delayed or abrupt cessation of rainfall is a major constraint in both the unimodal and bi-modal rainfed culture characteristic of West African agriculture. Relay intercropping offers a possible solution to the total crop failures ocassionally encountered, particularly by maize farmers. The study reported herein was to find the effect of planting time on cowpea in relay intercropping with maize.

Four main factors, each at two levels, were evaluated: maize variety component of relay (early and full season); bending-over of maize stalk below ear before interplanting cowpea (non-bending and bending-over); time of interplanting cowpea into maize stand (at black layer and two weeks after black layer of maize grain) and method of weed control before relay cowpea is planted (hand weeding and chemical control). The results suggest that light interception and residual moisture use are critical to yield of the relay cowpea, but the labour-demanding task of bending over can be avoided without any significant reduction in cowpea yield.

Introduction

Water is a limiting resource for crop growth in West Africa, not only because rainfall distribution is variable, but also because soils have low water-holding capacity as a consequence of their low organic matter content. In certain instances, the rains cease aburptly. Lack of moisture for crop growth is, therefore, a major cause of both low yield and yield instability.

To minimize the risk of crop failures due to drought, early planting (Asafu-Agyei, 1983) and the use of early-maturing varieties (Rao *et al.*, 1962; Sindagi and Ansari, 1970) are some of the management interventions suggested. They allow a greater flexibility and a more intensive cropping system. The cultivation of early-maturing cowpea types under residual moisture in both the Southern and Northern Guinea savanna zones of West Africa will, therefore, be a beneficial cropping practice. (Sinner *et al.*, 1983). Cowpea also has been demonstrated to have an added benefit of increasing yields of subsequent non-legume crops (Asafu-Agyei, 1987; Adams *et al.*, 1970). This study was to find the effect of planting time on cowpea in relay intercropping with maize.

Materials and Methods

Field experiments were conducted at two locations of the Crops Research Institute, Kumasi, Ghana, in the central forest belt with a bimodal rainfall regime. In 1988, the study was conducted at Kwadaso and in 1989 at Fumesua, both suburbs of Kumasi. The experimental design was a randomized complete block, with 4 replications in a 24 factorial arrangement. Plots were 6 rows x 5m long. Maize was planted 80cm between rows and 50cm between hills at 2 plants per hill. Cowpea was planted 80cm between rows alternating maize rows. Cowpea hills were spaced 20cm and thinned to 2 plants/hill.

Factors under study were: (1) Maize variety component of relay (early and full season maturity); (2) Bending-over of maize stalk below ear before interplanting cowpea (non-bending and bending-over); (3) Relay cowpea interplanting time into maize stand (at black layer and two weeks after black layer of maize grain), and (4) Method of weed control before relay cowpea is planted (hand weeding and chemical scorching of weeds). Weed regrowth was not controlled after the weed control treatment. The commercial maize varieties used were Aburotia, a medium-maturing (105-day) white dent, and Dobidi, a full season maturing (120-day) white dent released in Ghana. The cowpea variety component of the relay was Asontem, an early (60-65 days) maturing, light red-seeded variety also released in Ghana. Measurements made included pod weight and grain yield.

Results and Discussion

There were more rainy days in the minor season of 1988 than in 1989 and yields were depressed accordingly in 1989. The second plantings (two weeks after black layer formation of maize grain) matured under moisture stress, especially in 1989 when the minor season rains ceased on 15 October.

Table 1. Effect of maize variety and relay planting time on cowpea pod and grain yields (kg/ha) at Kwadaso, 1988.

	Planted at black layer		Planted 2 wks later	
Maize variety	Pod wt.	Grain wt.	Pod wt.	Grain wt.
Aburotia	2091	1519	1635	1126
Dobidi	1328	930	1265	838
CV (%)	16.9	18.3	16.9	18.3
SED (±)	133.3	101	133.3	101

In both years, cowpea yield was significantly determined by maize variety, relay planting time and method of weed control. This indicates the importance of maize plant size and leafiness, residual moisture and density of weed cover in influencing yield of relay cowpea. Bending-over did not influence cowpea yield significantly in both years.

The yield difference between cowpea interplanted into Aburotia and into Dobidi ranged between 23-36% for pod weight in 1988 (Table 1). The corresponding value ranged between 26-39% for grain yield.

In 1989, it was still better to interplant cowpea into Aburotia when planting was done two weeks after black layer (Table 2). Shading by Dobidi and the late planting combined to severely depress cowpea yield. Yield was 43 and 47% less for pod weight and grain yield, respectively. At the black layer stage, no differences in cowpea yield were established when cowpea was planted into either of the maize varieties.

Cowpea yield under chemical weed control was better than under hand weeding in both environments. Yield of cowpea under chemical weed control in Aburotia was, however, higher than in Dobidi. This could be due to more residual moisture under Aburotia than under Dobidi.

The results presented are in agreement with the suggestion of Muleba & Ezumah (1985) for cereal-cowpea relay intercropping in both the savanna and humid areas of Africa. The results also suggest a feasible and appropriate technology for a maize-cowpea relay intercropping system.

Table 2 Effect of maize variety and relay planting time on cowpea pod and grain yields (kg/ha) at Fumesua, 1989.

	Planted at black layer		Planted 2wks later	
Maize variety	Pod wt.	Grain wt.	Pod wt.	Grain wt
Aburotia	849	598	928	621
Dobidi	991	656	531	328
CV (%)	20.8	21.5	20.8	21.5
SED (±)	85.7	59.3	85.7	59.3

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PART VI

Notes

NOTES

Nous avons réuni dans cette section les résultats préliminaires de travaux de recherche toujours en cours au moment de la tenue de la conférence dont les actes font l'objet de la présente publication. Etant donné la qualité et la pertinence des données préliminaires, il est de notre souhait que les résultats confirmés et complets de ces travaux soient publiés par leurs auteurs, aussitôt que possible, afin d'en faire bénéficier le monde de la recherche et de la production agricole.

This section includes preliminary results of research work still on-going at the time of the conference, the proceedings of which are hereby presented. In view of the quality and relevance of these preliminary data, we wish that they be further confirmed and that complete results of such work be published by their authors as soon as possible, so that they can benefit the research and food production communities.

La Production du Maïs et Etat Actuel de la Recherche pour le Développement de la Culture au Niger.

NAINO JIKA.

INRAN, Niamey, Niger.

Bien que les terres agricoles du Niger semblent peu propices à une grande production de maïs grain en pluvial, la consommation croissante (tant en vert que sous forme de " tuwo ") de cette céréale dans les zones urbaines fait que sa culture prend de plus en plus d'importance tant en pluvial qu'en irrigué (Tableau 1). Des travaux de sélection massale ont été entrepris en vue d'améliorer le rendement du cultivar P3 Kolo, d'en réduire la hauteur des plants et d'insertion de l'épi. La sélection épi àla ligne a donné des résultats intéressants dans ce domaine (Tableau2).

Tableau 1. Evolution des superficies cultivées en pluvial et de la production du maïs au Niger 1982-1989.

	1982	1983	1984	1985	1986	1987	1988	1989
Superficies (ha)	12645	10515	10700	7200	9400	14010	9500	3634
Production (T)	7280	6690	7055	3400	6100	7778	4947	2571
Rendement moyen (kg/ha)	576	636	659	472	649	555	518	708

Tableau 2. Résultats des tests réalisés à Bengou en 1989.

	P3 Kolo-Sélec.	P3 Kolo Rég.	Ecart type
Rdt (kg/ha)	5334	5043	392
Cycle (50 % flor.)	51	53	1.1
Hauteur plants (cm)	174	192	99
Hauteur Insert. (cm)	80	115	8.8

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Identification des Sources de Résistance au Charbon Allongé (*Tolyposporium ehrenbergii*) sur le Sorgho (*Sorghum bicolor* L. *Moench*) et Effet de la Date de Semis sur la Séverité.

ISSOUFOU-KOLO ABDOURHAMANE,

INRAN, Niamey, Niger.

Soixante-quinze variétés de sorgho ont été criblées pour l'identification des sources de résistance au charbon allongé *Tolyposporium ehrenbergii*, dans des conditions d'infestation naturelle très forte. La réaction des entrées a été notée suivant une échelle qui varie de zéro à quatre (0 = résistant...4 = très sensible). Onze entrées ont eu une note de 0. Il s'agit de Terra, SC326-6, SC630-11E, BTx2775, BTx378, B8106, Tx7075, QL3, R9188, 87L3450 et 84C9408. La résistance de ces variétés doit être vérifiée par une inoculation artificielle. En plus il a été démontré que dans les conditions d'infestation naturelle, il existe une relation positive entre la réaction des entrées et leur cycle végétatif (r = 0.74). Enfin il a été montré que la date de semis joue un rôle important sur la sévérité du charbon allongé.

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L'Intensification de la Culture du Maïs/Niébé en Zone CMDT du Sud-Mali : Quelques Leçons.

ABDOULAYE DOLO.

CMDT, Bamako - Mali

Le projet maïs, démarré en 1981, a adopté une démarche de recherche-développement qui s'est traduite par une augmentation de la production du maïs tant en superficie (Tableau 1) qu'en rendement du fait d'un certain nombre de facteurs favorables, au nombre desquels : (i) un système efficace d'encadrement du paysan, (ii) une bonne politique de prix pour la vente/l'achat du maïs, (iii) l'existence d'un marché intérieur puisque le maïs est consommé, apprécié par la population malienne, même si sa mouture s'avère plus difficile que celle du mil et du sorgho. Plus de 7000 essais et tests de démonstrations ont été réalisés en milieu paysan de 1981 à 1989 et ont abouti à la vulgarisation de nouvelles variétés de maïs dont le Tuxpeno 1 (3 t/ha), le Molobala-2 (2,5 t/ha) et le Tiémantié (2,5-3 t/ha) et de nouvelles variétés de niébé telles la TN88-63 et la KN-1.

Les conditions climatiques relativement bonnes de 1981/1982, lors du démarrage du projet, ont été capitales pour le développement de la maïsiculture. Les années suivantes ont été plus difficiles et ont ainsi rappelé le risque que représente cette culture face aux aléas climatiques, notamment la mauvaise répartition des pluies. Ce risque peut être considéré comme permanent dans le contexte de sécheresse au Sahel. L'explosion des maladies virales, bien que d'incidence variable et non généralisée, souligne la nécessité de proposer rapidement des variétés résistantes.

Des problèmes sont apparus qui ont permis de prendre conscience des risques liés à l'intensification de la maïsiculture, notamment la pratique de la monoculture dans les conditions actuelles du monde paysan. Ainsi avons-nous été amenés à considérer le développement des exploitations agricoles àtravers une notion de triple équilibre : (i) équilibre entre superficies à intensifier et superficies à exploiter de façon traditionnelle, (ii) équilibre entre cultures intensifiables, (iii) équilibre entre diverses formes d'intensification, par exemple, culture pure ou culture associée. Ce triple-équilibre doit être déterminé par les paysans en fonction de leurs disponibilités financières, en équipement, en main d'oeuvre ou autres facteurs socio-économiques.

L'application de la notion de triple-équilibre pourra imprimer une dimension nouvelle à la vulgarisation, qui ne consistera plus à donner des recettes infaillibles, mais il s'agira maintenant de faire connaître au monde rural les différentes cultures rentables, les techniques à appliquer, leurs avantages et leurs inconvénients. Il s'agira, en somme, de fournir aux paysans des éléments leur permettant de déterminer les niveaux d'équilibre propres à leurs potentialités. Une telle approche présuppose que les rapports vulgarisateur-paysan soient modifiés : le vulgarisateur doit devenir plus polyvalent, capable de saisir des techniques plus variées, des messages plus divers et être apte à analyser et à transmettre les connaissances aux paysans ; ces derniers doivent s'attendre à des conseils plus nuancés, donc plus

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compliqués et être en mesure de les saisir, de les analyser et de décider de ce qui leur convient. Il s'agira là d'une tâche de longue haleine où la formation de l'encadrement, tout comme celle des paysans, sera primordiale.

Tableau 1. Evolution des superficies maïs, mil/sorgho et niébé (ha).

Campagnes	Mil / Sorgho	Maïs	Niébé
1978 / 1979	-	17863	-
1979 / 1980	114238	24271	-
1980 / 1981	147631	24302	-
1981 / 1982	144731	25340	-
1982 / 1983	123101	27230	-
1983 / 1984	135570	31203	-
1984 / 1985	165282	38167	-
1985 / 1986	198002	49272	-
1986 / 1987	196747	53496	21856
1987 / 1988	261791	48443	30991
1988 / 1989	290721	63750	35182
1989 / 1990	298081	74602	51221
1990 / 1991	-	80592	59241

Effets de l'Association Céréale-Niébé sur la Densité de *Striga* attaquant le Niébé.

OUEDRAOGO T.J., J.B. TIGNEGRE, et G.R. ZANGRE.

INERA, Ouagadougou, Burkina Faso.

Résumé

Le mode de culture du niébé en association avec les céréales (mil et/ou sorgho) a-t-il un effet sur le niveau d'infestation du niébé par le *Striga gesnerioides* ? Afin de répondre à cette interrogation, une variété de niébé très sensible au *Striga*, KVx396-18-10 a été testée en association avec une variété de petit mil et une variété de sorgho avec fumure (celle recommandée pour la céréale) et sans fumure. Une culture pure de niébé avec et sans fumure a servi de témoin. Les résultats montrent que les effets de la céréale (sorgho ou mil) étaient nuls pour la date d'émergence du 1er plant de *Striga*. Par contre le nombre de plants de *Striga* est plus élevé en culture pure qu'en culture associée (Tableau 1).

Tableau 1. Dates d'émergence, nombres de *Striga*/m² et rendements grains (kg/ha) à Fada (F) et Kamboinsé (K), Burkina Faso, 1990.

Traitements	Dates d'émergence 1er *Striga* (JAS)*		Nombre *Striga* /m²		Rendements	
	F	K	F	K	C**	C**
Niébé+mil+Fo	46A	46A	11B	15B	13B	679B
Niébé+mil+Fl	52A	50A	4B	12B	8B	642B
Niébé+sorg.+Fo	45A	46A	5B	13B	9B	716B
Niébé+sorg.+Fl	54A	50A	14B	15B	14B	697B
Niébé pur + Fo	45A	43A	47A	38A	43A	887A
Niébé pur + Fl	45A	43A	44A	35A	40A	952A
PPDS (5 %)	13	7,6	14	14	9,9	110

* JAS = Jours après semis
** C = Résultats de l'analyse combinée des 2 localités.

Présentation d'une Méthodologie d'Etude des Plantes Parasites Herbacées des Cultures.

G. HOFFMANN et C. DIARRA.

Projet Conjoint IRAT-ICRISAT WASIP, Bamako, Mali.

Des enquêtes conduites dans trois villages maliens ont permis de recenser six espèces parasites des cultures dont la plus nocive est le *Striga hermonthica*. Les principales cultures vivrières (sorgho, mil, maïs, riz) sont parasitées (Tableau 1). Les champs infestés sont très nombreux quel que soit le village considéré et leur surface représente plus de 50 % des terres cultivées. En tenant compte de la surface réellement infestée, c'est-à-dire la partie du champ occupée par le ou les parasites, on note que les surfaces infestées représentent en moyenne pour les trois villages 10 % des terres cultivées (Tableau 2). La différence entre la surface des champs parasités et la surface réellement infestée nous donne la surface susceptible d'être envahie si l'extension des espèces parasites n'est pas endiguée. Dans les trois villages cette surface est très importante et met en évidence la gravité de la situation puisque les plantes parasites des cultures sont remarquablement bien adaptées à leur milieu et à leurs hôtes et qu'aucune technique de lutte efficace n'est pratiquée actuellement par les paysans.

Tableau 1. Liste des cultures infestées ou non et des espèces parasites.

Cultures	Villages			Espèces parasites
	Nankilabougou	Dibaro	Garasso	(1)
Cultures pures	+	+	+	SH SA SA BH
Sorgho	+	+	+	SH SG SG BH
Mil	+	+	+	SH
Maïs	+	+		SH SA SA BH
Fonio	+	+	+	SH
Arachide	+	+		
Gombo	+	+		
Pois de terre	+			
Coton		+		
Niébé			+	
Aubergine			+	
Hibiscus sabdarifa	+			
Riz	+			SH RF
Cultures associées				
Sorgho/niébé	+	+	+	SH SA SG BH AV
Mil/niébé		+	+	SH
Maïs/niébé			+	SH

+ : Cultures non infestées ; * : Cultures infestées ; (1) : SH : *S. hermonthica, SA : S. aspera, SG : S. gesnerioides, BH : B. hispida, RF : R. fistulosa, AV : A. vogelii.*

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Tableau 2. Etude globale de l'infestation.

Surfaces et nombre de champs	Villages		
	Nankilabougou	Dibaro	Garasso
Surface totale cultivée (ha)	53	138	259
Nombre de champs cultivés	75	112	139
Surface des champs infestés (ha)	34 (64)*	121 (88)	150 (58)
Nombre de champs infestés	40 (53)	83 (74)	87 (63)
Surface des champs non infestés (ha)	19 (36)	17 (12)	109 (42)
Nombre de champs non infestés	35 (47)	29 (26)	52 (37)
Surface réellement infestée (ha)	6 (12)	14 (10)	17 (7)
Surface réellement non infestée (ha)	47 (87)	120 (87)	243 (94)
Surface non infestée des champs avec parasites (ha)	28 (53)	107 (78)	134 (52)

* : Entre parenthèses les valeurs sont exprimées en pourcentage.

PART VII

Recommendations/Recommandations

REPORT AND RECOMMENDATIONS OF THE PLENARY SESSION

Population pressure in sub-Saharan Africa has increasingly brought millions of hectares of marginal land under cultivation. As a result, degradation of the resource base for productive agriculture has been exacerbated due to soil erosion, deforestation, poor soil and water conservation, intensive cultivation in areas that are less proned to drought, etc.

A number of issues were addressed during the plenary session. Two lead papers stressed the importance and the devastating effect of *Striga* on the production of food grains. Various species of *Striga* infest over two thirds of the 73 million hectares devoted to food grains viz maize, sorghum, millets, cowpea and rice, causing an average of 40% crop yield loss. In many cases complete crop losses occurred.

It is ironical that various efforts being made to intensify food grain production, including intensive land-use, monocropping with susceptible crops and use of improved seed varieties, among others, seem to exacerbate the *Striga* problem. Various existing *Striga* control methods and their limitations were discussed. These include the tedious inefficient hand pulling, hoe weeding and uprooting, expensive herbicides, host plant resistance where some success has been recorded in maize, sorghum and cowpea, cultural practices including trap cropping, nitrogen application and intercrop whose benefits are not immediately realisable.

In order to solve the *Striga* problem, some of the researchable issues include :

1) Host plant relationship with studies on biology and mechanism of parasitism leading to the development of varieties with broad genetic base for resistance

2) Cultural control including nitrogen application and various cropping systems and

3) Evaluation of cheap and easy-to-apply preplant incorporated, pre-emergence and post-emergence herbicides.

It was concluded that integration of the component in a package which has been tested on-farm will be necessary to provide a technically feasible and socio-economically acceptable, sustainable solution to the *Striga* problem. This should be complemented by massive campaigns at national level on preventive measures to reduce its spread.

Four papers were presented by two IARCs on their current and proposed activities in the region. ICRISAT emphasizes its Strategic Plan (up to the year 2000) which focusses on the Semi-Arid Tropics and dry land farming. The goal of research is on sorghum, pearl and finger millets, groundnut and pigeon pea and chick pea, crop improvement in yield, quality and resistance/tolerance to biotic and abiotic constraints and new uses for the crop and biomass for fodder and soil amelioration. The programme aims at providing links between high-income and low-income countries.

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IITA's maize and cowpea programmes focus attention on crop improvement with the overall objective of developing varieties that would reduce risks associated with intensive production of the crops, through breeding for resistance to various biotic and abiotic constraints, with *Striga* as high priority. The programmes collaborate with the NARS and SAFGRAD Networks in their activities. IITA intends focussing on the use of biotechnology for the transfer of genes for resistance/tolerance to various constraints of maize and cowpea production and development of varieities adapted to various cropping systems including mixed cropping. Both short-term and long-term training programmes will be conducted, as the need arises, in collaboration with NARS and SAFGRAD Networks. The IITA station in Kano shall interact with SAFGRAD and NARS cowpea programmes in East, West and Central Africa, while a maize station will be opened in Côte d'Ivoire.

The conference notes with satisfaction the activities of IARCs in providing technical support for network development, especially by IITA for maize and cowpea and ICRISAT for sorghum.

Two papers were presented on soil fertility and related subjects. The importance of soil testing and mapping as basis for fertilizer recommendation in sole and mixed cropping and the need to develop appropriate soil testing methods were discussed. Furthermore, the exploitation of suitable indigenous rock phosphates for agricultural production was advocated.

Fifteen papers were presented on cropping systems and various cropping practices and post-harvest technology. The importance of mixed cropping in the farming system of the sub-region was discussed. Cropping systems research should be multidisciplinary in approach and the development of production packages should be eco-edaphic specific. There is need for a close link between cropping systems research and resource management research for the development of sustainable agriculture, post-harvest processing using indigenous materials and storage using natural products. These should be explored to reduce food grain losses.

Two papers were presented on utilization of grains for various home foods and agro-industrial uses. The successful substitution of imported wheat with sorghum in bread flour and the implication on foreign exchange conservation were discussed.

Papers on the experiences and approaches of the SAFGRAD Networks (maize, cowpea, sorghum and farming systems research) in strengthening NARS, the future strategy of sorghum and millet improvement in Eastern Africa as well as new frontiers of food grain research for the 1990's were presented. From the presentations, it was evident that the network approach to strengthen NARS had been very effective. The networks had enhanced interaction among scientists, exchange of information and germplasm, and influenced the research agenda of the IARCs to address the problems of NARS, and enhanced the research capabilities of NARS scientists as well as technical staff.

RECOMMENDATIONS

STRIGA

In view of the importance of the problem of *Striga* to agricultural development in the Semi-Arid Tropics (SAT), the commonality of the problem to major food grain crops and the threat to the attainment of food self-sufficiency and security in SAT, the Conference hereby recommends that FAO, OAU/STRC-SAFGRAD, IITA, ICRISAT, Overseas Advanced Laboratories, OAU/STRC-IAPSC and other relevant inter-regional organizations should work out concrete collaborative projects to strengthen the Pan-African *Striga* Control Network (PASCON) whose main objective is to coordinate efforts to minimize the devastating effect of *Striga* on food grain production.

In order to facilitate the strengthening of activities of PASCON and ensure the realisation of its goals, the Conference further recommends that a meeting of FAO, OAU/STRC-SAFGRAD, OAU/STRC-IAPSC and PASCON be convened to discuss ta collaborative approach to the *Striga* problem.

The Conference notes with delight the progress made in identifying sources of resistance/tolerance to *Striga* in cowpea, sorghum and maize by various research organizations in the sub-region and hereby recommends intensification of collaborative activities among NARS, IARCs Overseas Advanced Laboratories and all the Networks, in the areas of research, including biology of *Striga*, mechanism of parasitism, development of resistance/tolerance in various food grain crops, cultural practices and herbicide use for *Striga* control.

The Conference further notes that none of the components can by itself solve the *Striga* problem and, hereby, recommends the integration of available components in a package for on-farm testing to ensure their technical feasibility, socio-economic acceptability and sustainability.

In order to minimize the spread of *Striga*, the Conference recommends immediate intervention of governments through national campaign and extension activities for the destruction of *Striga* plants before they attain the stage of seed production.

Other recommandations

The Conference recommends the need for developing appropriate soil testing and mapping methods for determining soil productivity both for sole and mixed cropping systems. Furthermore, utilization research should be intensified to maximize the efficient use of suitable indigenous rock phosphates to enhance agricultural production.

The Conference recommends close links between cropping systems research and resource management research for the development of sustainable agriculture.

The Conference further recommends the need to intensify research on diversified utilization of food grains and their by-products for consumption and agro-industrial

use, especially for the development of livestock industries aimed at reducing cerealsimports.

The comparative advantage of networks as regional strategies to strengthen national research programmes was noted. To ensure the adoption of improved technologies by farmers, it was recommended that SAFGRAD scientists in their respective countries should make greater effort to influence agricultural policies.

Furthermore, it was stressed that networks should enhance verification and validation of technologies through on-farm research.

Three other recommendaions, specially addressed to the OAU, were adopted by the Conference.

In view of the key role of research in promoting agriculture in the semi-arid zone and considering that this field is not always given the due attention which it deserves, the Conference recommended that OAU convene a special summit devoted to agriculture in Africa and encourage member state governments to fund agricultural research.

Since SAFGRAD has gained prominence as a research coordinating organ with the principal objective of contributing to the attainment of food self-sufficiency, the Conference recommended its transformation into a specialized institution of OAU in charge of agricultural research.

The conference also recommended that OAU Member States, through OAU, provide SAFGRAD with substantial financial support in order to benefit from its continuous existence.

RECOMMANDATIONS

STRIGA

Considérant l'importance du problème du *Striga* pour le développement agricole dans les zones tropicales semi-arides (SAT), le caractère commun des problèmes des principales cultures et la menace qui pèse sur la réalisation de l'auto-suffisance et de la sécurité alimentaire dans les SAT, la conférence a recommandé que la FAO, l'OUA/CSTR-SAFGRAD, l'IITA, l'ICRISAT, les Laboratoires Avancés d'Outre-Mer, l'OUA/CSTR-IAPSC et autres organisations inter-régionales compétentes élaborent des projets coopératifs concrets pour renforcer le Réseau Panafricain de Lutte contre le *Striga* (PASCON) dont l'objectif principal est de coordonner les efforts visant à minimiser l'effet dévastateur du *Striga* sur la production des cultures vivrières.

Afin de faciliter le renforcement des activités du PASCON et faire en sorte qu'il réalise ses objectifs, la conférence a par ailleurs recommandé qu'une réunion de la FAO, de l'OUA/CSTR-SAFGRAD, de l'OUA/CSTR-IAPSC et du PASCON se tienne en vue d'examiner l'approche coopérative pour la solution du problème du *Striga*.

La conférence a noté avec satisfaction les progrès accomplis par les différentes organisations de recherche de la sous-région pour l'identification des sources de résistance/tolérance au *Striga* et a recommandé l'intensification des activités de recherche coopérative entre les SNRA, les CIRA, les Laboratoires Avancés d'Outre Mer et tous les réseaux, dans les domaines de la biologie du *Striga*, du mécanisme de parasitisme, du development de la résistance/tolérance de diverses cultures vivrières, des pratiques culturales, et de, l'utilisation des herbicides contre le *Striga*.

La conférence a noté qu'aucun volet ne pouvait à lui seul résoudre le problème du *Striga*. Elle a recommandé l'intégration des différentes technologies disponibles en un paquet à tester en milieu paysan afin de s'assurer de leur faisabilité technique, de leur acceptabilité socio-économique et de leur durabilité.

Afin de minimiser l'expansion du *Striga*, la conférence a recommandé une intervention immédiate des gouvernements à travers des campagnes nationales et des activités de vulgarisation pour la destruction des plants de *Striga* avant la production de semences.

Autres recommandations

La conférence a recommandé d'élaborer des méthodes appropriées d'expérimentation du sol et de cartographie pour déterminer la productivité des sols dans les systèmes de culture pure et d'association de cultures. En outre, la recherche devrait être intensifiée pour maximiser l'utilisation efficace de phosphate naturel local approprié en vue de l'accroissement de la production agricole.

La conférence a également recommandé des liens plus étroits entre la recherche sur les systèmes de production et la rècherche sur la gestion des ressources, afin de développer une agriculture durable.

La conférence a par ailleurs recommandé une plus grande intensification de la recherche sur l'utilisation diversifiée des cultures vivrières et de leurs sous-produits pour la consommation et l'agro-industrie et particulièrement pour le développement des industries animales et la réduction de l'importation de céréales.

L'avantage comparatif des réseaux en tant que stratégie régionale pour renforcer les programmes nationaux de recherche a été noté. Cette démarche assure l'adoption des technologies améliorées par les paysans. La conférence a donc recommandé que les chercheurs du SAFGRAD s'éfforcent davantage d'influencer les politiques agricoles dans leurs pays respectifs.

Il a en outre été souligné que les réseaux devraient promouvoir la vérification et la validation des technologies à travers la recherche en milieu paysan.

Trois autres recommandations spécialement formulées à l'intention de l'OUA ont été adoptées par la Conférence.

Eu égard au rôle-clé de la recherche dans la promotion de l'agriculture en zone semi-aride et considérant que ce domaine ne reçoit pas toujours l'attention qu'il mérite, la conférence a recommandé que l'OUA convoque un sommet spécial consacré à l'agriculture en Afrique et encourage les gouvernements des états-membres à financer la recherche agricole.

Dans la mesure où le SAFGRAD a acquis de l'importance en tant qu'organe de coordination de la recherche et a pour objectif de contribuer constamment à la réalisation de l'autosuffisance alimentaire, la conférence a recommandé la transformation du SAFGRAD en institution spécialisée de l'OUA chargée de la recherche agricole.

La conférence a aussi recomandé que les Etats Membres de l'OUA, àtravers l'OUA, fournissent au SAFGRAD un soutien financier substantiel afin de profiter de son existence continue.

APPENDIX I

Opening ceremony

ALLOCUTION PRONONCEE PAR LE DR. PAPA DAOUDA FALL, SECRETAIRE EXECUTIF ADJOINT DE LA COMMISSION SCIENTIFIQUE, TECHNIQUE ET DE LA RECHERCHE,

Excellence, Monsieur le Ministre de l'Enseignement Supérieur et de la Recherche Scientifique,
Excellence, Monsieur le Secrétaire d'Etat auprès du Ministre de l'Agriculture et de l'Elevage,
Excellence, Monsieur le Secrétaire d'Etat au Plan
Excellences, Mesdames et Messieurs les Membres du Corps Diplomatique,
Messieurs les Représentants des Organisations Internationales,
Messieurs les Directeurs Nationaux,
Chers Experts,
Honorables Invités,
Mesdames, Messieurs,

C'est pour moi un énorme privilège doublé d'une fierté légitime que de prendre la parole à cette honorable tribune, au nom de S.E. le Dr. SALIM AHMED SALIM, Secrétaire Général de l'Organisation de l'Unité Africaine et dont je me fais l'agréable devoir de vous transmettre le salut et les encouragements.

Le Projet de Recherche et de Développement sur les Cultures Vivrières en zone semi-arides-SAFGRAD de son nom anglo-saxon-est une Institution de l'OUA. C'est en effet, à la suite des assises du Conseil des Ministres de l'Organisation pan-africaine tenue en 1976 à Port-Louis-Ile Maurice- que les Chefs d'Etat et de Gouvernement prirent la résolution de mettre sur pied le projet SAFGRAD.

Cette volonté politique traduisait ainsi, sans équivoque, la ferme détermination de nos dirigeants de pallier les conséquences désastreuses du cycle de sécheresses des années 1972, 1973 et 1975 d'une part; et d'autre part, de prévenir de telles situations et, partant, d'améliorer qualitativement et quantitativement la production agricole au niveau du Continent, pour le plus grand bien des populations rurales.

Depuis cette mémorable date, le SAFGRAD a fait bien du chemin. Le Coordinateur International de ce Projet, qui vient de me précéder à cette tribune, en a donné un bref aperçu. D'autres voix plus autorisées que la mienne - parce qu'émanant d'hommes de terrain - vous en diront plus long les jours à venir.

Je me bornerai donc simplement à citer :

- la mise au point de variétés de maïs et de niébé résistantes à la sécheresse, aux maladies et aux autres stress;

- la mise au point de variétés de sorgho adaptées aux moyennes et hautes altitudes;

- l'identification des autres contraintes au développement de la production agricole (gestion de l'eau, fertilité du sol, action de l'homme, etc..) et les possibilités d'y remédier;

- les essais de transfert de technologies en milieu rural;
- la formation à tous les niveaux.

A l'évidence, le SAFGRAD a obtenu des résultats encourageants ; mais à l'évidence, également, le chemin qui reste à faire est long et plein d'embûches.

En effet, aux raisons premières qui ont présidé à la naissance du SAFGRAD sont venus s'ajouter d'autres facteurs. Tels, les prescriptions du Plan d'Action de Lagos de 1980 et celle du Programme Prioritaire pour le Redressement Economique de l'Afrique de 1985, toutes axées sur la recherche de l'auto-suffisance alimentaire du Continent. Tels, également, le retour et l'apparition de la sécheresse et sa persistance dans les zones jusqu'ici épargnées, au point que des pays jadis considérés comme zones humides sont actuellement confrontés à des problèmes de déficit pluviométrique

Et c'est pour toutes les raisons que voilà que la Conférence de Niamey revêt une importance toute particulière et constitue tout un symbole.

Symbole des efforts persévérants des chercheurs africains et d'ailleurs, sous-tendus par une volonté inébranlable d'aider les masses rurales à faire face et à vaincre les méfaits des aléas climatiques.

Symbole d'échange d'expériences entre Réseaux de recherche qui ont jusqu'ici travaillé séparement, mais qui s'adressent tous aux mêmes paysans, en vue d'une meilleure efficience par le biais d'une coordination harmonieuse des actions, la conjugaison des efforts et la suppression des duplications inutiles.

Symbole, enfin, d'une coopération internationale Nord-Sud et Sud-Sud en tous points exemplaire.

Celà me donne l'occasion, au nom de S.E. Le Secrétaire Général de l'OUA, de féliciter chaleureusement tous les Experts nationaux et d'ailleurs qui ont largement contribué à la réalisation des résultats non négligeables sus-mentionnés, sous la supervision clairvoyante du Bureau de Coordination du SAFGRAD. Et, ensuite, de réexprimer notre profonde gratitude aux Bailleurs de fonds du SAFGRAD : USAID, FIDA, CRDI, Fondation Ford, Fonds Français d'Aide et de Coopération, Banque Africaine de Développement - la liste n'est pas limitative - de leur assistance financière et matérielle généreuse et désinteressée. Nous ne saurions oublier, dans ces remerciements, les Instituts Internationaux, IITA, ICRISAT, ICRAF et tant d'autres sans l'assistance technique soutenue desquels les progrès réalisés n'auraient pas été aussi significatifs.

Excellence, Monsieur le Ministre de l'Enseignement Supérieur et de la Recherche Scientifique,
Excellence, Monsieur le Secrétaire d'Etat auprès du Ministre de l'Agriculture et de l'Elevage,
Excellence, Monsieur le Secrétaire d'Etat au Plan
Excellences, Mesdames et Messieurs les Membres du Corps Diplomatique,
Messieurs les Représentants des Organisations Internationales,

Messieurs les Directeurs Nationaux,
Chers Experts,
Honorables Invités,
Mesdames, Messieurs,

Je disais tantôt que le chemin qui reste à faire est long et c'est pourquoi, après les satisfecit, je voudrais maintenant, avec votre permission, en appeler au concours de toutes les parties prenantes de cette exaltante bataille pour le développement agricole de notre cher Continent.

D'abord aux Gouvernements des Etats membres du SAFGRAD, en particulier, des Etats membres de l'OUA en général, en leur suggérant respectueusement de faire en sorte que les résultats obtenus en station ne restent pas lettre morte, mais fassent plutôt l'objet de vulgarisation à large échelle, par l'entremise du renforcement significatif des structures nationales, la mise à la disposition des chercheurs nationaux des facilités requises (équipements, matériels et techniques adaptés aux besoins sans cesse accrus de la recherche, moyens humains et financiers suffisants) et de facteurs incitatifs.

Ensuite, aux Donateurs, pour la poursuite de leur assistance financière et surtout, pour le renforcement de leur confiance en l'Afrique.

Mais, me diriez-vous fort justement et l'OUA alors ? Eh bien, l'Organisation de l'Unité Africaine a mis en place dès 1964, c'est-à-dire juste un an après sa propre création, une Commission Scientifique, Technique et de la Recherche (CSTR-OUA) basée à Lagos, Nigeria, et chargée d'élaborer et de proposer à la sanction du Conseil des Ministres et des Chefs d'Etat et de Gouvernement la politique industrielle et technologique à l'échelle du Continent.

C'est cette même Commission qui, une fois la politique industrielle et technologique approuvée, procède à la recherche des fonds complémentaires à ceux propres à l'organisation, pour la mise en oeuvre de projets conjoints ou régionaux d'intérêt commun. Il convient de mettre à l'actif de la CSTR la négociation et la signature de tous les accords de coopération concernant le SAFGRAD.
Enfin, last but not least, l'OUA a décidé lors de son dernier Conseil des Ministres de tenir :

- Une réunion interne à l'effet de discuter du futur et de la restructuration du SAFGRAD ainsi que de l'opportunité d'une plus grande contribution de l'OUA, à la lumière des conclusions des missions d'évaluation internes et externes du projet ;

- et une Réunion de Bailleurs de Fonds, en vue de la poursuite des autres volets du SAFGRAD, notamment le transfert des réseaux de recherche aux structures nationales.

Ces deux importantes réunions auront lieu en Juillet de cette même année à Ouagadougou.Vous le voyez donc, l'OUA est à vos côtés, mais aussi devant et derrière vous.

Quant à vous, Excellence, Monsieur le Secrétaire d'Etat auprès du Ministre de l'Agriculture et de l'Elevage, le choix de votre belle capitale Niamey pour abriter cette conférence SAFGRAD n'est pas le fait du hasard. Il procède de la tradition d'hospitalité toute africaine qui caractérise le Niger, du rôle déterminant joué par votre pays au sein du SAFGRAD et surtout des résultats remarquables réalisés par votre Gouvernement, au coeur du Sahel, en matière de développement agro-pastoral.

Aussi, vous prierais-je respectueusement, Excellence, de bien vouloir transmettre à S.E. le Général de Brigade Ali SAIBOU, Président de la République, Chef de l'Etat, les vifs remerciements du Secrétaire Général de l'OUA pour nous avoir permis de tenir nos assises à Niamey et pour toutes les facilité mises à notre disposition depuis notre arrivée.

Je m'en vais maintenant conclure en renouvelant mes encouragements àtous les Experts ici présents et en exprimant le voeu que des discussions des prochains jours, émergent des conclusions et recommandations pertinentes qui éclaireront d'un jour nouveau notre marche commune à la recherche du mieux-être de nos populations.

Vive le SAFGRAD !
Vive l'OUA !
Vive la Coopération Internationale !

Je vous remercie de votre bienveillante attention.

DISCOURS D'OUVERTURE DE MONSIEUR LE SECRETAIRE D'ETAT AUPRES DU MINISTRE DE L'AGRICULTURE ET DE L'ELEVAGE CHARGE DU DEVELOPPEMENT COOPERATIF.

Messieurs les Ministres,
Excellences Messieurs les Ambassadeurs,
Monsieur le Secrétaire Exécutif Adjoint de la Commission Scientifique, Technique et de la Recherche de l'Organisation de l'Unité Africaine,
Messieurs les Représentants des Bailleurs de Fonds,
Monsieur le Coordinateur International du SAFGRAD,
Mesdames et Messieurs les Participants,

Après Lomé en 1989, c'est Niamey qui accueille aujourd'hui la Conférence conjointe biennale sur les Réseaux Maïs, Sorgho, Niébé, du Projet de Recherche et de Développement des cultures vivrières dans les zones semi-arides d'Afrique, connu sous le nom de SAFGRAD.

Par ma voix, le Niger tout entier se rejouit de cet acte qui l'honore et vous souhaite la cordiale bienvenue et un agréable séjour à Niamey.

Je suis convaincu que le choix de mon pays pour abriter cette importante rencontre du donner et du recevoir n'est pas un fait du hasard.

En effet, fidèle à sa politique de développement économique et social, le Niger accorde de plus en plus une priorité absolue au développement du secteur agricole, basé essentiellement sur la recherche de l'auto-suffisance alimentaire et la protection de son environnement. A ce sujet, il me paraît important de souligner que le Niger, pays enclavé et très continental, tire l'essentiel de ses ressources de l'activité agricole au sens large du terme, pour nourrir ses quelques 7.250.000 habitants répartis sur 1.267.000 km2, avec un croît démocratique annuel de l'ordre de 3 %.

Cette forte dépendance d'une activité agricole parfois très précaire est caractéristique aux zones semi-arides, car s'exerçant dans un environnement agro-climatique extrêmement vulnérable.

Aux périodes fréquentes de sécheresse qui sévissent dans ces zones, s'ajoute le phénomène de désertification accentuant ainsi le processus de dégradation de leurs environnements les rendant de plus en plus rudes et hostiles à la production des denrées nécessaires à l'alimentation des hommes et des animaux.

Il est cependant réconfortant de constater que face à ce défi, l'Afrique a pris conscience au niveau politique le plus élevé, de la gravité de la situation et qu'elle tente d'y rémédier de manière efficace par la mise en oeuvre des activités de recherche coopérative spécifiques aux régions semi-arides.

Je puis vous assurer que mon pays souscrit pleinement à cette démarche qui consiste en la mise sur pied de Réseaux de Recherche Coopérative sur les principales cultures vivrières à l'échelle régionale, en vue du renforcement des

capacités des Services Nationaux de Recherche Agronomique (SNRA), complétant ainsi l'action des Centres Internationaux de Recherche Agronomique (CIRA).

Messieurs les Ministres,
Mesdames et Messieurs les Participants,

Les faiblesses et insuffisances de moyens des SNRA, constituent la contrainte majeure au développement des activités de recherche dans nos pays. Pour y rémédier, le Projet de Recherche et de Développement des Cultures Vivrières dans les zones semi-arides d'Afrique (SAFGRAD) a été créé en 1977 à la suite d'une concertation d'un groupe de donateurs avec pour objectif de promouvoir et d'utiliser la recherche scientifique en vue d'augmenter et de soutenir la production des cultures vivrières principales dans les zones semi-arides d'Afrique.

C'est ainsi que cinq (5) réseaux de recherche coopérative sur le mil, le sorgho, le niébé, le maïs et sur les systèmes de production, sont aujourd'hui opérationnels au titre de SAFGRAD II et fonctionnent de manière très satisfaisante.

Issu du Projet conjoint PC 26, entrepris par l'USAID dès 1969, le SAFGRAD est le fruit d'une volonté politique commune des Chefs d'Etat africains traduite dans une résolution adoptée en Conseil des Ministres de l'OUA en 1976 à l'Ile Maurice ; d'où la naissance du projet conjoint PC 31, ayant pour objectif le développement des cultures vivrières dans les zones semi-arides d'Afrique.

Par ailleurs, il me plaît de rappeler que la naissance de SAFGRAD et le développement de ces activités, ont été rendus possibles grâce au concours de la Communauté Internationale et plus particulièrement, grâce au soutien financier de l'USAID, du FIDA, du FAC, du CRDI et à l'appui scientifique et technique des Centres Internationaux de Recherche Agronomique (CIRA) auxquels je rends un vibrant hommage.

Messieurs les Ministres,
Mesdames et Messieurs les Participants,

Le Niger, à l'instar des autres pays du Sahel, continue d'éprouver la sévérité des contraintes naturelles sur sa production agricole. Au nombre des efforts consentis par l'Etat dans la recherche de l'autosuffisance alimentaire, figure la création de l'Institut National de la Recherche Agronomique du Niger (INRAN) dès 1975. Je suis heureux de constater que notre jeune institution est aujourd'hui un partenaire important et actif, dans la mise en oeuvre des programmes des Réseaux/SAFGRAD.

La restructuration très prochaine de l'INRAN et l'adoption imminente par le Gouvernement de ses textes statutaires, contribueront sans aucun doute àaméliorer ses capacités de recherche le rendant ainsi beaucoup plus apte non seulement à consolider les acquis, mais aussi à entreprendre des programmes nouveaux de recherche coopérative dans le cadre des réseaux générés par le SAFGRAD.

Messieurs les Ministres,
Mesdames et Messieurs les Participants,

Du SAFGRAD I (1977-1986) au SAFGRAD II (1986-1991), beaucoup de progrès ont été accomplis grâce aux efforts conjugués de nos éminents chercheurs, pleins de bonne volonté, mais travaillant parfois dans des conditions peu satisfaisantes. C'est pourquoi, je m'en voudrais beaucoup si je ne m'acquittais d'un agréable devoir ; celui de présenter à toute la communauté scientifique intervenant dans le système des réseaux/SAFGRAD, mes très vives félicitations pour le travail accompli. Et c'est aussi l'occasion de leur adresser tous mes encouragements pour la poursuite de ce qui reste à faire en ayant toujours à l'esprit la noblesse du travail du chercheur. Cette noblesse se caractérise à n'en point douter par une contribution àl'accroissement de la production agricole dans les Etats membres, grâce à la formation scientifique des chercheurs nationaux, la circulation de l'information ainsi que les échanges de technologies entre les Services Nationaux de Recherche Agronomique (SNRA).

Messieurs les Chercheurs,

En souhaitant plein succès à vos travaux, je déclare ouvert l'Atelier Conjoint 1991 des Réseaux/SAFGRAD.

Je vous remercie.

APPENDIX II

Closing ceremony

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ALLOCUTION DE CLOTURE PRONONCEE PAR MONSIEUR LE SECRETAIRE GENERAL DU MINISTERE DE L'AGRICULTURE ET DE L'ELEVAGE.

Messieurs les Ministres,
Excellences Messieurs les Ambassadeurs,
Messieurs les Représentants des Organisations Internationales,
Monsieur le Secrétaire Exécutif de la Commission Scientifique, Technique et de la Recherche de l'OUA,
Monsieur le Coordinateur International de l'OUA/SAFGRAD,
Mesdames et Messieurs les Participants,

Nous voici enfin au terme de sept jours de travaux de cette première conférence Inter-Réseaux SAFGRAD, sur le Maïs, le Niébé, le Sorgho, et les Systèmes de Production, organisée conjointement avec l'Institut National de Recherches Agronomiques du Niger.

Je suis heureux de constater que durant une semaine, les participants ont pu examiner et discuter de manière très méthodique, les résultats des programmes de recherche des différents réseaux que je citais tantôt.

Cette conférence inter-réseaux a permis à ne point douter, de faire non seulement le point sur l'état d'avancement des activités spécifiques à chacun des réseaux, mais aussi, de déceler les points faibles, de manière à pouvoir entreprendre les ajustements nécessaires.

Mesdames et Messieurs les Participants,

La qualité des résultats de vos travaux et le sérieux avec lequel vous les avez menés, me donnent l'occasion de vous féliciter pour le sacrifice consenti en travaillant parfois à des heures très tardives.

Eminents chercheurs que vous êtes, vous avez pu identifier en si peu de temps les principales contraintes et limites majeures du développement de la production vivrière dans les zones semi-arides de l'Afrique. Ainsi, de vos discussions d'un très haut niveau technique et scientifique, j'ai retenu entre autres thèmes, l'invasion du Striga, véritable calamité qui extermine nos cultures, l'amélioration variétale du maïs, du sorgho et du niébé, ainsi que l'amélioration des systèmes de production.

J'ai aussi noté avec satisfaction, les recommandations très pertinentes que vous avez formulées pour le développement de Programmes de Recherche sur le Striga, l'amélioration de la coopération non seulement entre chercheurs, mais aussi entre les Institutions de Recherche, notamment dans le domaine des systèmes de production et de celui de la diversification des produits alimentaires pour la consommation et l'Agro-Industrie.

Il s'agit là, Mesdames et Messieurs, de dispositions d'une grande importance qu'il conviendrait de mettre en oeuvre au niveau des Etats Membres du SAFGRAD.

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Je suis convaincu que le Secrétariat Exécutif de la Commission Scientifique, Technique et de la Recherche de l'OUA, saura véhiculer l'ensemble de ces recommandations aux Etats Membres concernés. A ce sujet, je puis vous assurer que le Niger, Membre actif du SAFGRAD par le truchement de son Institution de Recherche Agronomique, mettra tout en oeuvre pour la concrétisation de ces nobles dispositions.

Mesdames et Messieurs les participants,

Permettez moi de remercier une fois de plus les principaux Bailleurs de Fonds qui ont soutenu jusqu'ici les activités du SAFGRAD et qui ont de ce fait permis la tenue de cette importante rencontre.

Mes remerciements vont également en direction des Organisateurs SAFGRAD et INRAN dont l'apport méthodologique et matériel a été d'un grand appui pour le bon déroulement de votre conférence.

Mesdames et Messieurs, Honorables Délégués,

En espérant que votre séjour au Niger a été agréable, et en vous souhaitant un bon retour dans vos familles respectives, je déclare clos, les travaux de la Conférence Inter-Réseaux SAFGRAD.

Je vous remercie.

Semi-Arid Food Grain Research and Development (SAFGRAD)

OAU/STRC-SAFGRAD	Tel	(226) 30 60 71
Coordination Office		(226) 31 15 98
01 BP 1783	Telex	5381 BF
Ouagadougou 01	Fax	(226) 31 15 86
Burkina Faso		

Scientific, Technical and Research Commission of the Organization of African Unity (OAU/STRC)

OAU/STRC Secretariat	Tel	(234) 63 34 30
26/28 Marina		(234) 63 32 89
N.P.A. Building	Telex	22199 TECOAU NG
P.M.B. 2359	Cable	TECNAFRICA
Lagos	Fax	(234) 126 36093
Nigeria		

Organization of African Unity (OAU)

General Secretariat	Tel	(251) 15 77 00
P.O. Box: 3243	Telex	21046 OAU OUA ET
Addis Ababa	Cable	OAU Addis Ababa
Ethiopia	Fax	(251) 51 78 44