AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY
BATCH #18

1. SUBJECT CLASSIFICATION

A. PRIMARY
Agriculture AF00-0120-0000

B. SECONDARY
Plant production--Cereals--Maize

2. TITLE AND SUBTITLE
World research needs for increasing corn production

3. AUTHOR(S)
Spragu ,G.F.

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1970	4p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
USDA/ARS

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*
(In Agr.engineering,v.51,no.2)

9. ABSTRACT

10. CONTROL NUMBER	11. PRICE OF DOCUMENT
PN-RAB-090	
12. DESCRIPTORS	13. PROJECT NUMBER
Maize Production Research	14. CONTRACT NUMBER PASA RA-4-00 Res.
	15. TYPE OF DOCUMENT

AID 590-1 (4-74)

8

WORLD RESEARCH NEEDS FOR INCREASING CORN PRODUCTION

"I shall consider research needs under two broad headings: improvements in biological efficiency and improvements in mechanization and handling . . ."

G. F. Sprague

CORN ranks third among the world's food cereals, exceeded only by rice and wheat. In Latin America and parts of Africa and India, corn is the primary food cereal. Even within the U. S. corn ranks second to wheat in per capita consumption. Corn is the number one feed grain, with the United States producing approximately half of the world supply.

Corn has been a major crop for us since the days of the early settlers. We have accumulated a tremendous body of research information, and progress has been particularly rapid during the past 50 years. This period has encompassed the development and adoption of hybrid corn plus drastic changes in production practices including increases in plant population, rates of fertilization, chemical controls for weeds and insects, and a tremendous expansion in all aspects of mechanization.

Improving Biological Efficiency

The increases in yield and efficiency of production which have been achieved have utilized the major portion of our accumulated research information. Additional progress will be minimal if research activity is restricted to further refinements of areas already extensively explored. Continued substantial progress is most likely to come from research in previously neglected areas — areas which will require close interdisciplinary cooperation.

Possibly the scope of the research needed can be illustrated by a general consideration of the ideal corn plant, a plant having maximum biological efficiency. Current information is inadequate to provide a precise blueprint for this ideal type but some of the basic requirements appear reasonably clear. This ideal would be shorter than corn commonly grown and would have a leaf angle index to permit light interception with maximum efficiency. It would possess the ability to rapidly develop a closed canopy, a leaf anatomy which would maximize CO_2 utilization, light-controlled reactions, and the transport of photosynthetic products to the sites of utilization or storage, plus efficient enzyme systems for all of the rate-limiting processes in growth and metabolism. It would possess resistance to the major disease and insect pests. Finally, it must possess characteristics which impart efficient harvesting and handling properties. Many disciplines will be involved in the evaluation and perfection of the individual components but the final job of assembly will fall largely to the plant breeder and geneticist.

Interest has been aroused by the success achieved with dwarf wheat and rice. The factor commonly overlooked is that dwarfness, in itself, may be of limited value, e.g. the lack of success with dwarf corn hybrids in the Corn Belt. The short-statured wheats and rices in current use possess important characteristics other than reduction in height. They have the capacity to respond to heavier planting rates and to greatly increased rates of fertilization, particularly nitrogen. The dwarf corns tried in the Corn Belt were no better than average in either of these characteristics. Within the United States we recognize that response to N is nearly universal and that response to P and K is influenced by the parent stock, the climatic factors prevailing during soil formation, and past management practices. Considerable effort has been devoted to establishing economic response levels in different geographical areas. Research has also demonstrated that variation exists among inbred lines in their capacity to accumulate various elements. No major effort, however, has been directed toward the development of lines and hybrids with enhanced capabilities for response to high fertility levels. Work along these lines is long overdue.

In the past few years there has been a substantial increase in planting densities. Prolific types appear to be more tolerant of heavy populations than single-eared sorts. Where supplemental irrigation is not feasible the optimal density is determined by amount and distribution of rainfall and the extent of stored moisture reserves. Efficiency of water use has received little attention but is probably influenced by several factors, including growth habit and fertility level. Water requirement, measured by pounds of water required per pound of dry matter produced, may be relatively invariant but the distribution of dry matter between stover and grain is certainly under some degree of genetic control. This fact is illustrated by the generally decreasing grain/stover ratio from north to south within the United States.

G. F. Sprague is a research agronomist in the Crops Research Division, ARS, USDA, Beltsville, Md. Paper was presented during a General Session of the 1969 Winter Meeting of ASAE and is a contribution of the Crops Research Division of ARS, USDA.

This article is reprinted from AGRICULTURAL ENGINEERING (vol. 51, no. 2, pp. 71, 90, 91, 108, February 1970), the Journal of the American Society of Agricultural Engineers, St. Joseph, Michigan

Extensive research in bacteria and fungi have established that the presence or absence of specific enzymes as well as their relative efficiency is genetically controlled. Comparable studies with higher organisms have been limited. Prospects for such detailed study might include: ribulose diphosphate or pyruvic kinase carboxlase, enzymes that fix CO_2 triosephosphate dehydrogenase, the enzyme that reduces CO_2; glutamic dehydrogenase, the enzyme involved in synthesis of amino acids; acetoacetyl CoA thiolase, the enzyme involved in fatty acid synthesis; and nitrate reductase which influences nitrogen utilization and indirectly protein synthesis. The task then becomes one of developing techniques for the rapid screening of differences in activity of specific enzymes and then initiating an extensive search for enzymes or enzyme systems having maximum efficiency. Genetic tests then would be initiated to establish their mode of inheritance.

Current studies demonstrated the existence of two loci controlling nitrate reductase activity in corn. Strains have been synthesized which possess the favored allele at each locus. Earlier work with the waxy and high amylose genes and the more recent work on opaque$_2$ and floury$_2$ provide convincing demonstrations of the benefits to be derived from a joint physiological or biochemical and genetic approach to breeding. Further work in this area will require an interdisciplinary approach. An expanded program will be both time-consuming and costly — but highly productive.

Losses from disease and insect pests have been estimated at approximately 20 percent, for an annual loss that would approximate $1 billion. With the exception of seed treatment the use of chemicals to control plant diseases has been limited to high value production such as the winter sweet corn crop in Florida. Breeding for resistance appears to be the only logical solution. An effective program requires the joint efforts of the pathologist and the breeder. The pathologist's responsibilities include: identification of the causal organism, determination of etiology, and development of inoculation procedures which will permit large-scale screening for resistance. If resistance is found, studies on inheritance and host-parasite interactions are necessary. The transfer of resistance into commercially useful stocks is normally the function of the plant breeder.

The maintenance of a satisfactory level of disease resistance is a continuing problem. Genetic changes in the parasite or changes in production technology may lead to new disease problems or to the enhancement of previous problems. The increased incidence of stalk rots in the Corn Belt illustrates the influence of changes in technology. Corn inbreds and hybrids which exhibited a satisfactory level of resistance to stalk rots under the agricultural practices of the early 1950's possess inadequate resistance for today's technology. The increased planting densities and use of nitrogenous fertilizers has so changed the host-parasite interaction system that heavy losses due to stalk breaking have been sustained.

The control of injurious insects poses similar problems to those detailed for plant diseases. Both chemical and genetic control have been shown to be effective: genetic control for the European corn borer and chemical control for the Western corn rootworm. Experience with the rootworm and with many other insects suggests that the effectiveness of control by a single chemical may be short-lived. New biotypes develop which tolerate high dosages of a chemical previously effective at low rates of application. Current information may be inadequate but it implies that host-plant resistance provides the more durable protection. Without adequate host-resistance or other control of both insects and diseases, neither the genetic yield potential of the crop nor superior production practices can cause acceptable yield levels.

Where chemical control of either disease or insect pest is involved the agricultural engineer has responsibilities for the design and development of equipment required for dust or spray applications.

Besides an ideal leaf anatomy to permit ready access of CO_2 (hopefully without equally easy loss of water vapor), the rapid translocation of photosynthate, and a leaf angle index to maximize the absorption of sunlight, some have speculated that the corn plant would be a more efficient machine if the grain were borne terminally as in sorghum. Genetic types having this characteristic are known. These have not appealed to the geneticist-breeder as offering economic possibilities — they appear to pose more problems than they solve. The grain, being relatively unprotected, is susceptible to kernel rots and bird damage. However no real effort has been directed toward developing a commercially usable type from these genetic oddities.

The ag engineer has responsibilities in the design of this ideal corn regardless of whether we are considering a terminal or lateral grain-bearing inflorescence. Since an increasing percentage of corn is harvested by corn combine, what characteristics make for maximum efficiency in gathering and shelling; what kernel densities or conformation minimize harvest damage? Can simple and efficient assay techniques be provided the breeder to permit recognition of the desired type at any stage in the breeding operation?

Assuming success in some or all of these objectives, the breeder is going to be faced with the task of assembling the desired components. An impossible assignment? With the development of broad-based synthetics or composites and with increasing information on simple recurrent selection schemes the task of assembly remains difficult, perhaps impossible at the maximum level, but still worth the effort. The process of construction is rendered less formidable by the fact that the array of improved components will not become available simultaneously. Of necessity progress will be achieved by stepwise modifications which will become cumulative over time.

The task of assembly is made more complicated by the need to recognize maturity requirements. This problem could be somewhat simplified if day-length neutral types could be found. Day-length neutrality accounts in part for the wide area of adaptation of the new short-statured wheats and rices. If genetic control for this characteristic exists in corn it has not been adequately identified and certainly is not in general use.

Improving Mechanization, Handling

Fortunately developments in this area do not depend on the availability of our ideal type. I would presume that further gains will be minimal in those areas in which the greatest progress has been achieved. Labor inputs per acre of corn grown were approximately 46 hr in 1880. This may be reduced to 1.0 hr by 1980. Certainly the major advances from this type of mechanization have already been achieved. Additional gains may depend upon further increases in farm size to reduce amortization costs or from increased specialization.

In the past, major emphasis has been on machine design and power requirements for a particular task, such as seedbed preparation. Less attention has been given to the suitability of the finished task. This is not surprising and certainly not the fault of the engineers. While extensive empirical data contrasts different methods of seedbed preparation, existing data on seedbed requirements for optimal growth may be inadequate. As more information becomes available it should be given consideration in machinery design.

Major costs in corn production are for machinery and power. Little attention has been given to the mechanical aspects of corn production as an integrated system.

Research Needs Within Less Developed Countries

Only a few years ago it was assumed that the agricultural needs of the less developed countries could be solved by a direct transfer of modern technology. Fortunately this misconception is becoming less widely held and the research needs in the tropical areas are being considered with more realism.

Our present agricultural technology rests upon two sequential developments. First there was the long period of trial and error by individual farmers from which evolved the general guidelines on time and rates of planting, the widely grown crop varieties, and improvements in animal-powered equipment. The second development began shortly after the establishment of the Land Grant Institutions. Each innovation helped condition the farmer to further changes and improvements. The more progressive farmers are now reluctant to wait for adequate evaluation of new varieties or machines and do much experimentation on their own initiative. In contrast the subsistence farmer tends to be ultra-conservative. He fears that any departure from custom may place the survival of his family and himself in jeopardy.

Experiment stations were established during the colonial period. Research was largely confined to export crops and the food crops received little attention. This is gradually changing but the accumulated research information is still inadequate. Much of the research information available is not effectively used. An extension service, where it does exist, is understaffed and underpaid. Extension techniques are patterned after those used so effectively in the United States but which, unfortunately, may have limited effectiveness under a different social, economic, and political situation.

Our technology has developed under temperate conditions suitable for temperate soils and weather patterns. Such practices and techniques may be totally unsuited to tropical soils. Our biggest contribution lies not in a direct transfer of techniques or practices but in guidance on how to obtain the necessary experimental data in the shortest time and in the most efficient manner.

One additional factor has relevance: the economic status of the farmer. Our general attitude toward agricultural research has been to find an answer to some specific problem. Little thought is given as to whether the solution is equally applicable to farmers of all economic levels. Such considerations become important in the developing countries because the solution must be compatible with current economic levels and should benefit both the small subsistence farmer and the large landowner.

It is unsafe to assume that current corn production practices satisfy the requirements for high yields; therefore all aspects of production require careful evaluation. Since research needs have a high degree of ecological specificity I shall limit my comments to an area about which I have some knowledge, the tropical highlands of East Africa. While not universally typical, the Kenya example does illustrate the basic components necessary for rapid agricultural progress. These components include:

- The development of new plant types with improved yielding capacity
- The identification of production practices required for increased yield and their relative economic costs and returns
- The establishment of an effective seed production and distribution agency
- The training and effective utilization of an extension force.

These four steps must be involved in any first step toward the improvement of a primitive agricultural economy.

Kenya was more favored than many areas because studies on corn breeding and production had been underway for many years. This early work was limited in scope and suffered in continuity because of frequent changes in personnel. The present program has been continuous since 1955 and was expanded in 1963 and 1964. Improved varieties became commercially available in 1963. The utilization of hybrids has increased from 300 acres in 1963 to approximately 250,000 in 1967 and 1968. At least half of this acreage is being grown by small-scale subsistence farmers whose total land holdings average 10 acres or less. Where the combination of recommended practices is followed yield increases of 200-400 percent have been realized.

TABLE 1. FACTORS AFFECTING 1966 YIELDS AT 6 LOCATIONS IN WESTERN KENYA*

Factor	Level	Yield q/ha	Difference	Increased return	Cash outlay	Profit per ha
Time of planting	Early	52.8	18.6	$80.91	$ nil	$80.91
	Late	34.2				
Variety	H613B	52.9	18.8	81.78	4.17	77.61
	Local	34.1				
Plant population	36,000	49.1	11.2	48.72	2.78	45.94
	18,000	37.9				
Weed control	Clean	48.4	9.8	42.63	6.96	35.67
	Once-late	38.6				
Phosphate (P_2O_5)	56 kg	44.6	2.2	9.57	11.65	— 2.08
	0	42.4				
Nitrogen (N)	79 kg	45.0	3.0	13.05	24.60	— 11.55
	0	42.0				

*Fourth Annual Report, Major Cereals in Africa Project.

Factorial experiments were designed to contrast variables affecting yield performance. The data from one series of experiments is presented in Table 1. The figures are averages over all other treatments.

One of the most important single factors in this and other comparable tests was time of planting. The conventional system of corn production involves soil preparation, by hand labor in the case of the subsistence farmer, after the rainy season has begun. Thus planting is delayed at least 2 weeks later than optimum. The cash outlay figure does not provide a complete measure of cost. More labor is required for preparation of a seedbed in dry than in moist soil. Animal power available to the subsistence farmer is not adequate. Small, low-cost, trouble-free tractors would be desirable at a price the small farmer can afford. Tractor rental service is being tried on a limited scale and may provide an answer to the power problem.

The second most important factor was type of corn. Local types (corn, sorghum, rice, etc.) appear to have a limited capacity to respond to improved practices. During the long process of selection for survival under minimal cultural conditions, genes responsible for ability to respond to favorable conditions have been lost. Thus one of the first requirements in any new location is the development of improved types. One common aspect of this improvement process is the introduction and utilization of types from other areas having similar ecological conditions. (Hybrid 613B in Table 1 is a cross involving inbred lines from Kitale Flat White with the introduction Ecuador 573.) New breeding techniques are better suited to the limited manpower, funds and facilities characteristic of the developing countries than are the conventional breeding procedures which have been the basis of the U.S. hybrid corn development. These procedures are well-suited to both short and long range development needs.

Conventional plant populations are normally well below optimum. At least two factors may be involved — the generally poor quality and low viability of the seed used and the

common practice of mixed plantings. Adequate storage for either seed or crop does not exist. Seed is usually stored on the ear and hung from the roof. Smoke from the cooking fires may reduce weevil and moth damage but the protection afforded is inadequate. The crop is commonly stored with husks attached. Losses from moth, weevil and rodents are from 20 to 50 percent. Adequate low-cost storage structures could make a significant contribution to effective crop production.

Weed control in the tropics tends to be even more of a problem than in temperate regions. The conventional control is one late hand-weeding. Yield reductions under this practice are substantial and chemical weed control would be profitable. The main deterrents are lack of knowledge on the proper chemicals for the major weed species, scarcity of such chemicals, and lack of small-scale equipment for application. As with tractor plows, custom application may be required.

One normally expects response to application of N. Response to P and K are more erratic depending on parent soil material, the climatic conditions during soil formation, and previous management practices. While results obtained with fertilizer in Kenya may have limited applications, they do emphasize that the concept of N, P and K fertilization as a generalized solution to production problems has limitations. Many tropical soils exhibit minor element deficiencies or toxicities which must be identified and corrected before economic responses can be obtained from the application of the major elements.

The data on response to N and P_2O_5 in Table 1 requires some explanation. These soils have a high native fertility and have been under intensive cultivation less than 50 years. These figures are means over all other factors. Fertilizer response is normally greatest under high management levels.

Results from the factorial experiments provide an approximate guide to the economic returns from the individual components which contribute to good management. The individual plot data can be used to establish management practices which will maximize yields and economic returns with varying cost inputs (Fig. 1).

Even before local food needs are satisfied problems other than production capabilities take on great importance. A relatively stable and profitable market is a requirement for a sustained increase in production. AID experience in Nigeria has indicated that substantial yield increases of corn can be achieved by a concerted extension effort that stresses timeliness of planting, seed of good viability and increased plant populations. Yield increases of 200 to 300 percent were achieved. These practices were not continued beyond the first year, however, due to the lack of local market for the increased production.

As the local market approaches saturation, transportation facilities adequate to reach the larger urban markets becomes crucial. If development is not to stop at the self-sufficiency level other outlets must be sought for the increased production. Three obvious possibilities are livestock feed, industrial processing, and export. Any of these will require greatly improved facilities for farm storage and for bulk-handling.

Increased production of livestock would be desirable to satisfy protein deficiencies. Local demand for such products, however, will depend upon income level. Expansion beyond local requirements will depend upon the development of slaughtering, processing, and cold storage facilities. Such expansion is even more dependent upon the eradication or control of various diseases which restrict export possibilities such as foot and mouth disease.

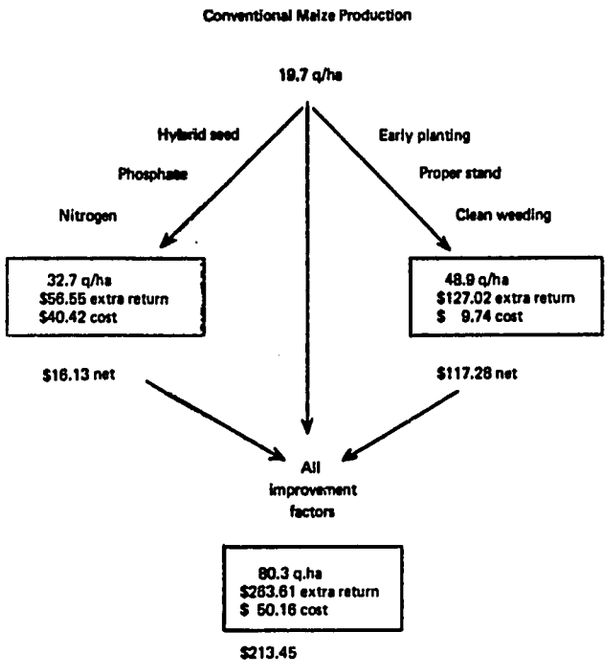

Fig. 1 Economic benefits from three combinations of improved management practices used to achieve increased corn production in Kenya. (Data from Fourth Annual Report, Major Cereals in Africa Project)

Opportunities for expansion in industrial processing are limited. The current world processing capacity exceeds demand. New processing plants would be justified only under such favorable economic circumstances as a very low raw product price or a large local demand, reducing transportation costs.

The development of a continuing export market requires a farm price which will encourage production, assembly and transportation costs which will permit an FOB price competitive on the world market.

This transition period from a subsistence to a surplus economy poses many special problems relating to agricultural engineering. In the U.S. economy we tend to equate agricultural progress with mechanization. This concept may also hold in the less developed countries if proper recognition is given to local needs.

For the subsistence farmer we are concerned with a different level of mechanization. Laborsaving devices have low priority until an industrial labor market can be developed. He needs only such items as will increase his over-all efficiency at costs compatible with his economic level. Possibly his greatest immediate need is for tillage implements. Small tractors and plows may be useful where custom pools are feasible. Where power requirements must be met by small draft animals small moldboard plows may represent the first important step toward mechanization. Simplicity of construction and low initial and maintenance cost are essential — the average income of subsistence farmers will be less than $100 per year.

Thus the research needs of the developing countries are relatively clear. Some of the problems are new to our experience. With the efficient utilization of research methodology can be solved if adequate manpower and finances are provided. Procedures for encouraging the adoption of new technology are less well understood but it appears the subsistence farmer responds to economic incentives as does the U.S. farmer. The transition from a food self-sufficiency economy to a surplus economy will pose the more difficult problems. ● ●