# GERMPLASM PROGRAM
# CEREALS

Annual Report for 1994

PN ABX 927
ISN 98262

# About ICARDA

Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is governed by an independent Board of Trustees. Based at Aleppo, Syria, it is one of 16 centers supported by the Consultative Group on International Agricultural Research (CGIAR), which is an international group of representatives of donor agencies, eminent agricultural scientists, and institutional administrators from developed and developing countries who guide and support its work.

The CGIAR seeks to enhance and sustain food production and, at the same time, improve socioeconomic conditions of people, through strengthening national research systems in developing countries.

ICARDA's mission is to meet the challenge posed by a harsh, stressful, and variable environment in which the productivity of winter rainfed agricultural systems must be increased to higher sustainable levels; in which soil degradation must be arrested and possibly reversed, and in which the quality of the environment needs to be assured. ICARDA meets this challenge through research, training, and dissemination of information in a mature partnership with the national agricultural research and development systems.

The Center has a world responsibility for the improvement of barley, lentil, and faba bean, and a regional responsibility in West Asia and North Africa for the improvement of wheat, chickpea, forage and pasture—with emphasis on rangeland improvement and small ruminant management and nutrition—and of the farming systems associated with these crops.

Much of ICARDA's research is carried out on a 948-hectare farm at its headquarters at Tel Hadya, about 35 km southwest of Aleppo. ICARDA also manages other sites where it tests material under a variety of agroecological conditions in Syria and Lebanon. However, the full scope of ICARDA's activities can be appreciated only when account is taken of the cooperative research carried out with many countries in West Asia and North Africa.

The results of research are transferred through ICARDA's cooperation with national and regional research institutions, with universities and ministries of agriculture, and through the technical assistance and training that the Center provides. A range of training programs is offered extending from residential courses for groups to advanced research opportunities for individuals. These efforts are supported by seminars, publications, and specialized information services.

PN-ABX-927

# GERMPLASM PROGRAM
# CEREALS

Annual Report for 1994

International Center for Agricultural Research in the Dry Areas
P.O. Box 5466, Aleppo, Syria

This report was written and compiled by program scientists and represents a working document of ICARDA. Its primary objective is to communicate the season's research results quickly to fellow scientists, particularly those within West Asia and North Africa, with whom ICARDA has close collaboration. Owing to the tight production deadlines, editing of the report was kept to a minimum.

## Table of Contents


| | | |
|---|---|---|
| **1.** | **Introduction** | 1 |
| **2.** | **Barley Improvement** | 6 |
| **2.1.** | **Spring Barley Breeding** | 6 |
| 2.1.1. | Introduction | 6 |
| 2.1.2. | New Developments in Barley Breeding | 8 |
| 2.1.3. | Head Quarters Activities | 10 |
| 2.1.4. | Activities in Collaboration with NARS | 15 |
| 2.1.5. | Landraces: Decentralization of a Methodology | 25 |
| 2.1.6. | Progress with Hordeum spontaneum | 37 |
| 2.1.7. | Response to Selection in Unfavorable Environments | 40 |
| **2.2.** | **Winter and Facultative Barley Breeding** | 42 |
| 2.2.1. | Characterization of Agroclimatic Environments | 43 |
| 2.2.2. | Germplasm Development | 44 |
| 2.2.3. | Breeding for Cold, Drought, and Adaptability | 45 |
| 2.2.4. | Crown Node Depth | 48 |
| 2.2.5. | Evaluation for Cold and Drought Tolerance | 51 |
| 2.2.6. | Yield Structure in Barley | 52 |
| 2.2.7. | Breeding for Earliness and Lodging Resistance | 54 |
| 2.2.8. | Breeding for Specific Adaptability | 56 |
| 2.2.9. | Breeding for Disease Resistance | 57 |
| 2.2.10. | Powdery Mildew Resistance | 57 |
| 2.2.11. | International Testing of Improved Germplasm | 59 |
| 2.2.12. | Grain Quality | 62 |
| **2.3.** | **ICARDA/CIMMYT Barley Project** | 64 |
| 2.3.1. | Introduction | 64 |
| 2.3.2. | New barley Varieties | 64 |
| 2.3.3. | Germplasm Development | 65 |
| 2.3.4. | Hull-less Barley | 66 |
| 2.3.5. | High Quality Hull-less Barley | 68 |
| 2.3.6. | Resistance to Biotic Stresses | 68 |
| 2.3.7. | Barley-Medic Rotation | 72 |
| 2.3.8. | Barley for Animal Feed | 73 |
| **2.4.** | **Physiology/Agronomy** | 73 |
| 2.4.1. | Boron Toxicity in Barley & Temperature | 73 |
| 2.4.2. | Screening for Boron Toxicity Tolerance | 74 |
| 2.4.3. | Zinc Deficiency Screening | 78 |

| | | |
|---|---|---|
| 2.4.4. | Carbon Isotope Discrimination & Water Use | 78 |
| **2.5.** | **International Nurseries** | 81 |
| 2.5.1. | Spring Barley | 81 |
| 2.5.2. | Winter/Facultative Barley | 85 |
| **2.6.** | **Pathology** | 88 |
| 2.6.1. | Leaf Diseases | 88 |
| 2.6.2. | Seed-borne Diseases | 92 |
| **3.** | **Durum Wheat** | 99 |
| 3.1. | Durum Breeding | 99 |
| 3.1.1. | Widening Genetic Base of Durum | 101 |
| 3.1.2. | Selection for Multiple Stress Resistance | 105 |
| 3.1.3. | Use of Molecular Markers | 106 |
| 3.1.4. | Progress in Mediterranean Contl. Envt. | 109 |
| 3.1.5. | Progress in Mediterranean Temp. Envt. | 117 |
| 3.1.6. | Progress in Mediterranean Highlands | 125 |
| **3.2.** | **Physiology/Agronomy** | 128 |
| 3.2.1. | Tiller Development in Relation to Moisture | 128 |
| 3.2.7. | Vernalization and Photoperiod Response | 132 |
| 3.2.3. | Micronutrient Studies | 136 |
| **3.3.** | **International Nurseries** | 139 |
| **4.** | **Spring Bread Wheat Improvement** | 141 |
| 4.1. | Spring Bread Wheat Breeding | 141 |
| 4.1.1. | Introduction | 141 |
| 4.1.2. | Research Priorities | 144 |
| 4.1.3. | Breeding for Abiotic Stress Resistance | 143 |
| 4.1.4. | Enhancing Disease Resistance | 144 |
| 4.1.5. | Double Haploids for Hessian Fly Resistance | 146 |
| 4.1.6. | Evaluation of Landraces for Stress | 149 |
| 4.1.7. | Photoper., Vernl. and Phyllochron Response | 151 |
| 4.1.8. | Breeding for High Yield and Yield Stability | 155 |
| 4.1.9. | Adoption of Improved Bread Wheat Germplasm | 155 |
| **4.2.** | **Physiology/Agronomy** | 158 |
| 4.2.1. | Vernalization and Photoperiod Response | 158 |
| 4.2.2. | Water Use Efficiency | 161 |
| 4.2.3. | Micronutrient Studies | 164 |
| **4.3.** | **International Nurseries** | 166 |
| **5.** | **Facultative & Winter Wheat Improvement** | 168 |
| 5.1. | Objectives | 168 |
| 5.2. | Screening for Common Bunt | 168 |

| | | |
|---|---|---|
| 5.3. | Screening for Yellow Rust | 169 |
| 5.4. | Combined Results | 169 |
| **6.** | **Wheat Pathology** | 170 |
| **6.1.** | **General** | 170 |
| 6.1.1. | Disease Development in WANA | 170 |
| 6.1.2. | Collaboration with NARSs | 171 |
| 6.1.3. | Aegilops spp. for Disease Resistance | 172 |
| 6.1.4. | Crop Loss Assessment | 173 |
| **6.2.** | **Durum Wheat Pathology** | 173 |
| 6.2.1. | Key Location Disease Nursery | 173 |
| 6.2.2. | Disease Reaction of Nurseies | 174 |
| 6.2.3. | Crop Loss from Yellow Rust | 176 |
| **6.3.** | **Bread Wheat Pathology** | 176 |
| 6.3.1. | Key Location Disease Nursery | 176 |
| 6.3.2. | Disease Reaction of Nurseries | 178 |
| 6.3.3 | Crop Loss from Yellow Rust | 180 |
| 6.3.4. | Germplasm Pools with Disease Resistance | 180 |
| **6.4.** | **Winter and Facultative Wheat** | 180 |
| **7.** | **Cereal Viruses** | 180 |
| 7.1. | Screening of Cereals for BYDV | 182 |
| 7.2. | BYDV Infection Sensitivity by TBIA | 184 |
| 7.3. | Reaction of Wheat Wild Relatives to BYDV | 184 |
| **8.** | **Cereals Entomology** | 187 |
| 8.1. | Survey of Wheat and Barley Insects in Syria | 187 |
| 8.2. | Rotation Effects on Ground Pearl in Barley | 188 |
| 8.3. | Russian Wheat Aphid Screening | 189 |
| 8.4. | Wheat Stem Sawfly Screening | 190 |
| 8.5. | Wheat Stem Sawfly Trials | 191 |
| **9.** | **Biotechnology** | 195 |
| **9.1.** | **Double Haploid Production in Barley** | 195 |
| 9.1.1. | Anther Culture | 195 |
| 9.1.2. | Crosses with H. bulbosum | 199 |
| **9.2.** | **Double Haploid Production Wheat** | 201 |
| **9.3.** | **Wide Crossing in Durum Wheat** | 202 |
| 9.3.1. | Protocol for Detached Tiller Culture | 202 |
| 9.3.2. | Colchicine Treatment Machine | 205 |
| 9.3.2. | Immature Embryo and Spike Culture | 205 |
| **9.4.** | **Barley Marker Project** | 206 |

| | | |
|---|---|---|
| 9.4.1. | Single and Low-copy RFLP Analysis | 208 |
| 9.4.2. | Markers for MLG Locus | 217 |
| 9.4.3 | DNA-fingerprinting with Oligonucloctides | 219 |
| **9.5.** | **Genetic Distance in Barley Genotypes** | 219 |
| **9.6.** | **Use of PCR markers for Durum Quality** | 221 |
| 9.6.1. | LMW-glutenin Amplification | 222 |
| 9.6.2. | Gamma Gliadin Amplification | 222 |
| 9.6.3. | HMW-glutenin Amplification | 223 |
| 9.6.4. | Comparison of Quality and Screening | 223 |
| **10.** | **North African Regional Program** | 225 |
| 10.1. | Introduction | 225 |
| 10.2. | Seasonal Conditions and Production | 225 |
| **10.3.** | **Salient Country Research Highlights** | 226 |
| 10.3.1. | Algeria | 226 |
| 10.3.2. | Morocco | 228 |
| 10.3.3. | Libya | 229 |
| 10.3.4. | Tunisia | 231 |
| **10.4.** | **Regional Collaborative Activities** | 232 |
| 10.4.1. | Cereal Travelling Workshop | 232 |
| 10.4.2. | Barley Development for North Africa | 233 |
| 10.4.4. | Characterization of Durum Collection | 234 |
| 10.4.5. | IFAD Project on Transfer of Technology | 235 |
| **11.** | **Training and Visits** | 237 |
| 11.1. | Long-term Course in Cereal Improvement | 237 |
| 11.2. | Insect Control Course | 237 |
| 11.3. | Diagnosis of Plant Viruses | 238 |
| 11.4. | DNA Molecular Marker Techniques | 238 |
| 11.5. | Cereal Breeding and Disease Methodology | 239 |
| 11.6. | IAEA-AEC Course on Mutation Techniques | 240 |
| 11.7. | Individual Training | 240 |
| 11.8. | Visits | 241 |
| **12.** | **Publications** | 243 |
| 12.1. | Journal Articles | 243 |
| 12.2. | Conference Papers | 246 |
| 13.3. | Miscellaneous Publications | 250 |
| **13.** | **Varieties Released by NARSs** | 251 |
| **14.** | **Staff List** | 257 |

## 1. INTRODUCTION

The cereals crop-improvement research at the International Center for Agricultural Research in the Dry Areas (ICARDA) is done by the Germplasm Improvement Program and covers barley, durum and bread wheat. The Center has world-wide responsibility for the improvement of barley and a regional responsibility for durum and bread wheat. Both spring and winter/facultative types of these cereals are grown in ICARDA's mandate region; hence research on the improvement of both types is conducted. Improvement of durum and bread wheat is done jointly with the International Maize and Wheat Improvement Center (CIMMYT), Mexico, which has worldwide responsibility for the improvement of wheat. In fulfilling ICARDA's responsibility for the improvement of barley, the barley crop-improvement research for Latin America and areas of favorable and high input environments is jointly done with CIMMYT from it Mexico base. CIMMYT has placed a durum breeder and a spring bread wheat breeder at ICARDA while ICARDA likewise has placed a barley breeder at CIMMYT. Thus this 1993-94 report reflects the contribution of the scientists from both the centers to the fulfillment of cereal crop-improvent mandates of ICARDA.

The general objective of the cereal-improvement research of the Germplasm Program of ICARDA is to develop a range of improved germplasm and/or cultivars of barley, durum and bread wheat, with specific adaptation to different agroecological conditions and cropping systems, through cooperative research with national crop-improvement programs. Working with some mentor institutions, ICARDA also ensures that new crop-improvement tools and biotechnologies are applied in its crop-improvement efforts and appropriate technologies transferred to the national programs through collaborative research and training.

A major part of our research work is done at the Tel Hadya site of ICARDA, but use is also made of other subsites in Syria (Breda, Bouedar and Jindiress) and Lebanon (Terbol and Kfardan). High elevation sites of the national programs of Syria, Turkey, Iran and Magareb countries are used, in a collaborative mode, for developing improved winter and

facultative barley and bread wheat germplasm and the germplasm of durum adapted to cold environments. Jointly with other national programs, their research sites and facilities are used for developing breeding material with specific resistance to some key biotic and abiotic stress factors because of the presence of ideal screening conditions and/or expertise there. The process of decentralization of breeding work is being continued with the help of appropriate national programs. Thus, targeted breeding material at an early stage of development is increasingly provided to the collaborators with commensurate changes in the distribution of our International Nurseries.

The weather conditions during the season at Breda, Tel Hadya, Jindiress, Terbol and Kfardan are depicted in Fig. 1. The long-term average rainfall at these sites is 280, 328, 470, 600 and 380 mm, respectively. During the 1993-94 cropping season the total seasonal precipitation at the first four locations was 290.4, 373.3, 533.7 and 475 mm, respectively. Recordings for Kfardan station could only start in February; therefore, weather data for this station are incomplete. The winter in general was mild at ICARDA sites which prevented good screening for cold tolerance, although vernalization-requirement differences could be discerned. The temperatures at all the sites were abnormally high in mid April which caused crop damage particularly at the locations in Lebanon. Yellow rust developed well this season permitting good screening of wheat germplasm and breeding lines.

During the season several staff movements occurred. The Cereal Entomologist (Dr. Ross Miller), CIMMYT/ICARDA Winter & Facultative Wheat Breeder (Dr. T. Payne), Winter Barley Breeder (Dr. V. Shevtsov); visiting scientists in Biotechnology (Dr. A. Comeau), Crop Physiology (Dr. V. Mahalakshmi), and Bread Wheat Breeding (Dr. M. Guirgis Mosaad); and the Post-doctoral Fellow in Barley Breeding (Dr. M. Mayer) left the Program. The Barley Pathologist (Ing. Joop van Leur) moved to IAR, Addis Ababa, Ethiopia in the Ethiopia/ICARDA Barley Project supported by the Netherlands Government.

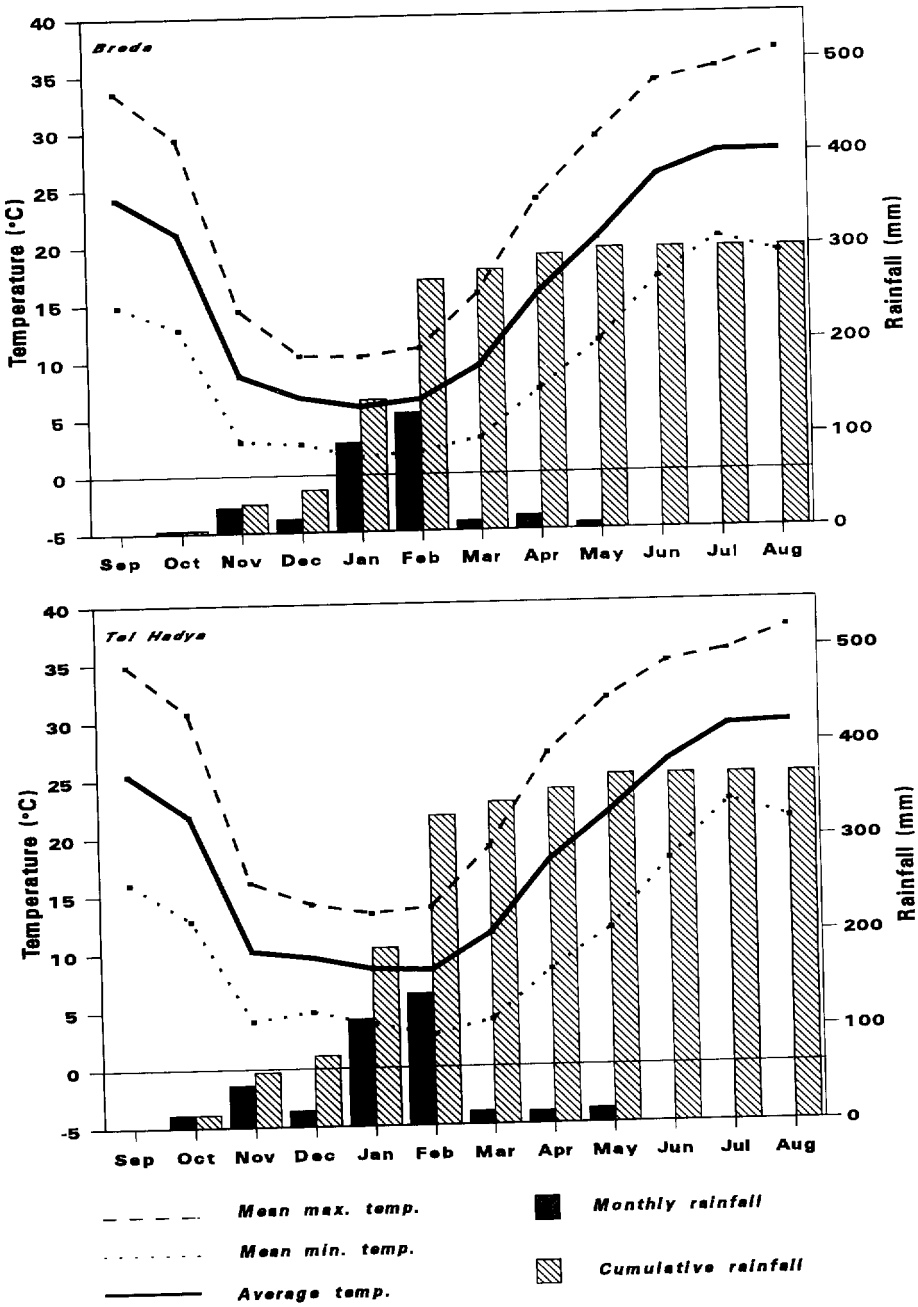



Fig. 1.1. Weather conditions at Breda and Tel Hadya during 1993-94.

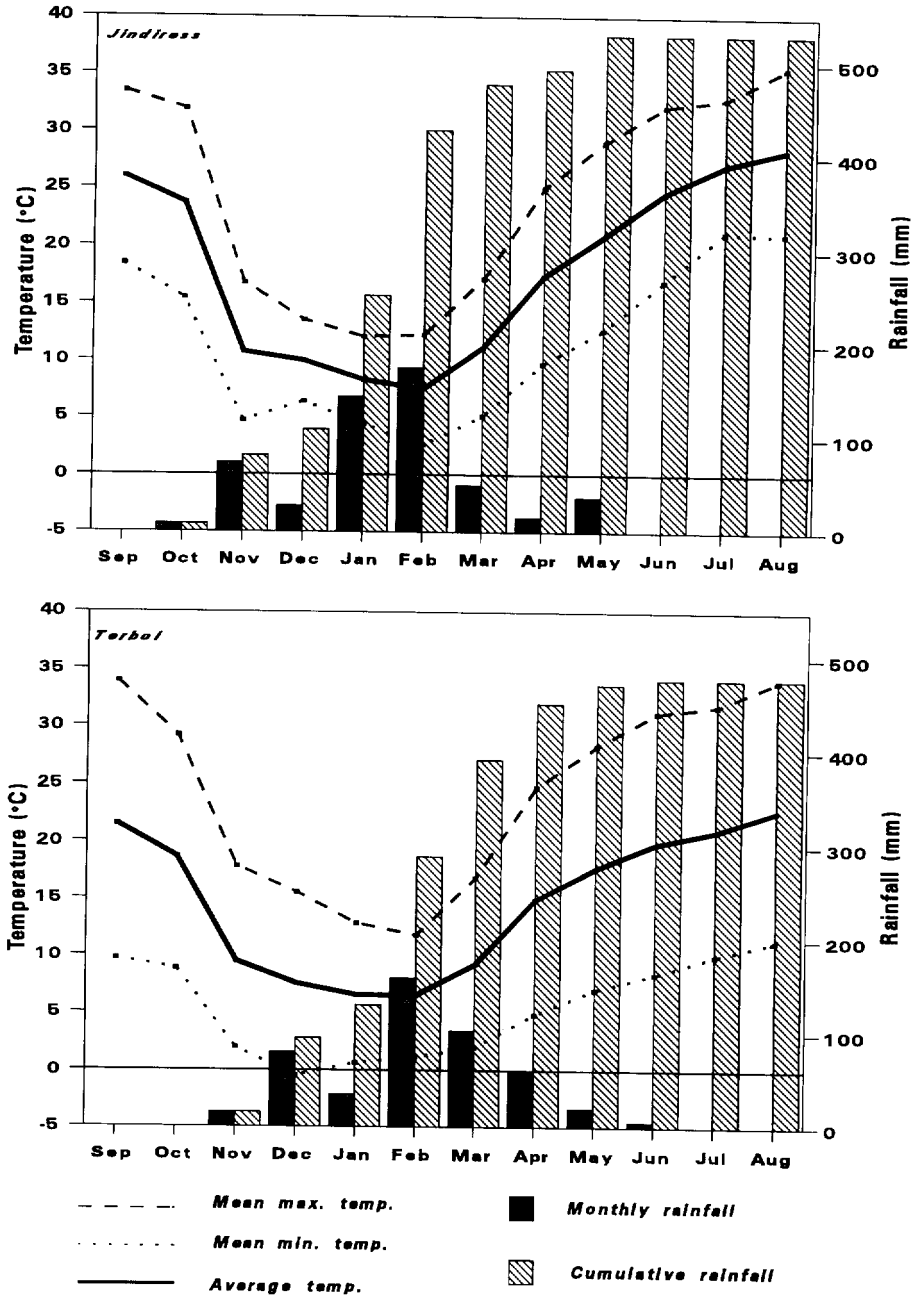



Fig. 1.2. Weather conditions at Jindiress and Terbol during 1993-94.

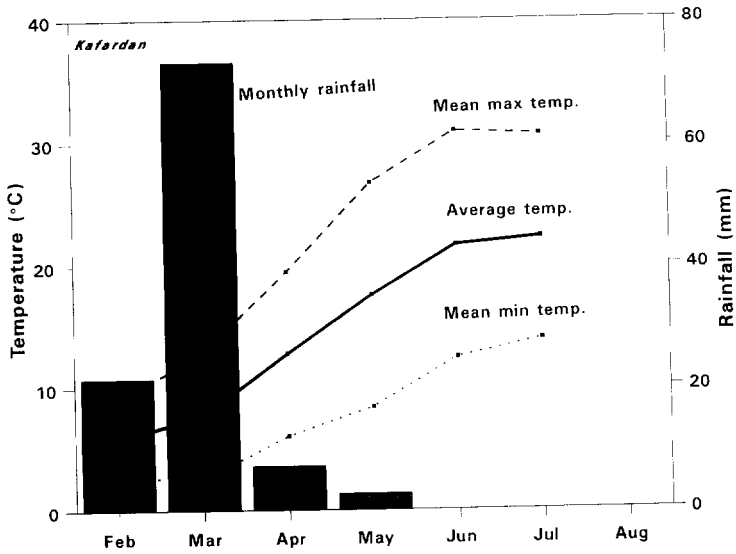



Fig. 1.3. Weather conditions at Kfardan during 1994.

Dr. Habib Ketata, Cereal Training Scientist returned from his sabbatical leave. Dr. L. Mustapha joined the biotechnology team as a Post-doctoral Fellow. Dr. Khaled Makkouk, Virologist moved from GRU to the Germplasm program. Whereas no replacement of Dr. T. Payne from CIMMYT arrived, CIMMYT placed Dr. A. Morgunov as Wheat Breeder at Ankara, Turkey to look after also the work of winter and facultative wheat. Therefore, the responsibility of winter and facultative bread wheat research at ICARDA was assigned to Dr. Ketata in addition to his responsibility in the training.

This volume contains the result of cereal crop-improvement research mainly done during the 1993-94 season although in some sections work done in earlier years is also reported as it was not included in the past reports. The training and network activities and publications of the Program are also listed. As mentioned earlier, much of the work reported here has been done in collaboration with our colleagues in the national programs in WANA and other developing countries and in some of the mentor institutions in the industrialized countries. To all these colleagues we are greatly indebted. **- M.C. Saxena**

# 2. BARLEY IMPROVEMENT

## Introduction

The overall objective of the project is to contribute to increase barley production in least developed countries where barley is grown on approximately 17 million hectares. Barley is used as human food, as animal feed and for malt, the prevailing use varying in different countries. In most developing countries barley is often a poor man's crop, and the only crop able to give some yield in environments unsuitable to other crops. Different types of biotic and abiotic stresses are the cause of low yields in most developing countries. To cope with the diversity of conditions under which barley is grown, with the diversity of uses, and with the diversity of stresses affecting its yield, ICARDA's activities on barley improvement are divided in three projects: a) spring barley, b) winter and facultative barley, and c) Latin America regional program. The first two projects are based in Aleppo, the third is a collaborative ICARDA/CIMMYT project and it is based in Mexico.

## 2.1. Spring Barley Breeding

### 2.1.1. Introduction

The two main objectives of the spring barley project are 1) to test the efficiency of breeding methodologies for different environments to identify those that can be easily adopted by national programs, and 2) to assist in germplasm development, while encouraging national programs to strengthen their own programs.

During 1994 the project continued the process of replacing the traditional system of germplasm distribution mostly based on fixed or semi-fixed lines, with the distribution of less advanced material. The decentralization of early selection allows better exploitation of specific adaptation and full participation of national program

scientists in the development of the most suitable barley germplasm for their countries. The decentralization is implemented by distributing $F_2$ populations and by conducting all selection work in different environments within and across countries. National program are directly involved in designing the crosses, and in the selection process. ICARDA staff assists in making the crosses, distributing the germplasm, advancing generations to ensure continuity, and training. This process was initiated in Maghreb (Morocco, Algeria, Tunisia and Libya) in 1992. In 1994 the following steps were taken to extend the decentralization to other countries:

a) Egypt was added to the four Maghreb countries (Morocco, Algeria, Tunisia and Libya) and began receiving the special sets of nurseries developed for north Africa. Entomologists in Morocco and pathologists in Morocco, Tunisia and Egypt were fully integrated in the evaluation and selection of the germplasm developed for north Africa.

b) Barley lines selected from the barley international nurseries in India, Korea, Vietnam and Thailand were assembled in a special nursery for the far east which will be distributed in 1995. The aim is to select parental material and to start a specific crossing program for these countries.

c) Two special nurseries were assembled and distributed in Iraq, one for the irrigated areas (mostly six-rows with compact head) and one for the rainfed areas in the north (largely two-rows types with black seed, selected in the 'Gezira' area of north east Syria).

d) A special nursery for irrigated and high inputs environments was assembled based on barley lines selected in the past by NARS in these environments.

e) Our experiment stations in Lebanon will be used more to screen early generations and less as additional testing sites for advanced material.

Our work with mixtures continues in collaboration with the University of Hohenheim. A Ph.D student, Mr. Claus Einfeldt, works on the role of heterozygosity and heterogeneity as buffering mechanisms against unpredictable

climatic conditions.

Two projects were initiated in 1994 to use molecular markers to assist in the transfer of powdery mildew resistance from WI2291 to Tadmor, and to characterize barley lines with different degrees of adaptation to stress environments.

During 1994 the following national programs were visited either to carry out joint selection work, or to attend travelling workshops and coordination meetings: Libya, Morocco, Tunisia, Egypt, Iraq, Ethiopia and Eritrea. - **S. Ceccarelli**

### 2.1.2. New Developments in Barley Breeding

#### 2.1.2.1. Computerization of Pedigree Management and Transfer to NARS

The new computerization of data and pedigree in spreadsheet files was completed during 1994. On request, national program scientists can receive lists of entries in the 1995 nurseries on diskettes. A brief demonstration on the use of spreadsheet files for handling of breeding material was given during the Maghreb/ICARDA coordination meeting, and it has raised considerable interest.

#### 2.1.2.2. Generalized Use of α-lattices

With the collaboration of CBSU, all the yield trials, including those which are carried out in north Africa, are now designed as α-lattices. This allows a reduction of the total number of plots because of less replications, while maintaining the same degree of precision as in the past.

#### 2.1.2.3. Bulk-pedigree as Main Breeding Method

During 1994 we reduced considerably the amount of individual plant selection in $F_2$ opulations and we gave more emphasis to

the bulk-pedigree (Ceccarelli and Mekni 1985)* as main breeding method.

### 2.1.2.4. More Emphasis on Decentralization

Following the positive response of NARS in north Africa, more breeding activities were decentralized during 1994. The philosophy is to make full use of the training activities conducted in the past, which have created a wealth of expertise in many countries, and to exploit specific adaptation.

### 2.1.2.5. Nematode Survey in Syria

A survey was conducted in March 1994 to obtain preliminary information on the presence of nematodes in major barley growing areas in Syria. The survey was conducted in collaboration with Dr. N. Greco and Dr. T. Dabbabbo (Istituto di Nematologia Agraria del Consiglio Nazionale delle Ricerche, Bari, Italy) and with Mr. Y. Sweidan (Syrian Ministry of Agriculture and Agrarian Reform, Douma, Syria). Ninety soil and root samples were collected, mainly in barley fields, in the provinces of Raqqah, Hama, Idlib, Aleppo, and Hassake. Only 7 root samples were free of nematodes. The most frequent (80% of the samples) were root-lesion nematodes (*Pratylenchus* spp.). Both *P. thornei* and *P. mediterraneus*, previously found in chickpea roots, were present although other species may also occur. *Heterodera latipons*, a cyst nematode, was found in 23% of the samples, and another root-lesion nematode (genera *Pratylenchoides*) was found in 19% of the samples. The stem and bulb nematode *Ditylenchus* spp. was present in 11% of the samples. The root-knot nematode (*Meloidogyne artiellia*), known to cause severe damage on chickpea in Syria, was observed in only 2% of the samples.

Among the nematodes found in the samples, *Pratylenchus* spp., *Heterodera latipons* and *Meloidogyne artiellia* should be

---

* Ceccarelli, S., Mekni, M. 1985. Barley breeding for areas receiving less than 250 mm annual rainfall. Rachis, 4:3-9.

considered as noxious to barley. Of these, *Pratylenchus* spp. have a wide host range and are known to affect cereals in the Mediterranean basin, but no specific information is available for barley, while *Heterodera latipons* attacks mainly barley and it is considered as a severe pest in Cyprus.

In general the number of nematodes was low and most of the specimens of *Pratylenchus* were juvenile stages. The survey needs to be repeated at a later stage and extended to cover other barley areas in Syria before developing a strategy to tackle this potentially serious problem.

#### 2.1.2.6. Release of New Barley Varieties in Syria, Algeria and Iraq

The release of a new variety, if not followed by its adoption, is only a sterile achievement. However, it has a value because in many countries it is a prerequisite to let farmers test the new varieties in farmers' fields.

During 1994 Syria released ARTA, with the name of "Improved Arabi Abiad", Iraq released Rihane-03, IPA9 and IPA 7, and Algeria released Rihane-03. **- S. Ceccarelli and S. Grando**

### 2.1.3. Head Quarters Activities

The emphasis on developing barley germplasm tolerant to the three predominant abiotic stresses in northern Syria (cold in winter, intermittent and terminal drought, and terminal heat) continues to receive high priority. This activity is important both to develop barley lines for the target area and to develop and fine-tune breeding methodologies for stress environments in general.

After a number of changes and adjustments, the following methodology is now in place to maximize efficiency of selection and use of resources:

a) Breeding material is tested in the target environments using farmers' agronomic practices. This involves the use of two sites (Breda with long term rainfall of 290 mm, and Bouider with long term average rainfall of 233

mm) where the three stresses have a high probability to occur. In these two sites the breeding material is evaluated without use of fertilizers, pesticides and weed control. Concurrently, the material is evaluated at the main experiment station (Tel Hadya with long term average rainfall of 373 mm) with a level of inputs commonly used in moderately favorable areas. In all the experiment sites the material is evaluated strictly under rainfed conditions.

b) The major selection criterion is grain yield. At each site and in each cropping season, only the material outyielding the best check is promoted to further testing. In addition to grain yield, traits used as selection criteria are: plant height, tillering, straw softness and disease resistance in the two driest sites, earliness, lodging and disease resistance in the wettest sites. Breeding lines with a highly desirable expression of these traits but not high yielding are retained as parental material.

c) Breeding material is tested for three years taking advantage of the large year-to-year variation in total rainfall, rainfall distribution and temperature patterns. Each year breeding material yielding less than the check is discarded unless it possesses useful traits.

d) The most widely used breeding method is the bulk-pedigree. Segregating populations (typically starting with the $F_3$'s) are yield tested and selection is practiced only between populations as described in c). After the second year of yield-testing, individual plants are extracted from the selected populations and advanced as pure lines. After the third year of testing only the pure lines from the selected populations are kept.

e) Germplasm development for stress environments in Syria is largely based on the use of pure lines extracted from the two locally adapted landraces (Arabi Abiad and Arabi Aswad). Because of their specific adaptation, landraces are not expected to generate germplasm useful in other countries (see pg. 21). Therefore the value of this approach is of methodological nature, indicating an avenue to NARS in their breeding programs

for stress environments.

An example of the performance of the best breeding material recently developed by the project is given in Tables 2.1.1 and 2.1.2. Among the breeding material tested for three cropping seasons (1991/92, 1992/93 and 1993/94) 13 lines outyielded the best check in each of the five sites with the highest level of abiotic stresses (Bouider in 1992 and 1994, Breda in 1992, 1993 and 1994). Table 2.1.1 gives the average grain yield of these lines in the five stress sites (YS) together with their average grain yield in the four highest sites (YP) during the same three cropping seasons.

The average yield advantage of the lines over the widely grown landrace Arabi Abiad ranged from 28 to 15%. Only one of the best lines under stress was six rowed, confirming that in dry environments two-row types are generally superior over six-row types.

Most of the lines (9 out of 13) had one or more landraces (such as SLB 39-60, Tadmor, SLB 39-05, SLB 34-07, Arta) in their pedigree. Only three lines had yields similar or higher than the best check in favorable environments.

The best lines specifically developed for favorable environments (Table 2.1.3) yielded between 3.5 and 4.0 t/ha (as average of four high yielding sites) with a yield advantage over the best check between 4 and 20%. Although the average grain yield in stress sites of six of these lines was higher than the best check, none of these lines consistently outyielded the best check in each of the five stress sites. A large number of breeding material performing well under stress conditions was identified in both the preliminary (47 lines) and initial yield trials (174 lines). Details on these lines will be given in the section on landraces.

Tables 2.1.1 and 2.1.2 confirmed the problem of a large genotype by environment interaction even in a relatively small geographical area. Selection for high yield potential in relatively favorable conditions is not an efficient way to identify the breeding material with specific adaptation to stress conditions. Not surprisingly, we also found that landraces collected in the target areas continue to represent the bulk of the breeding material which performs better in

stress conditions.

**Table 2.1.1. Average grain yield (kg/ha) in five sites with high levels of abiotic stresses (YS) of 13 lines which outyielded the best check at each site. YP is the average grain yield of the same line in four high yielding sites.**

| Name (Row type) | YS | YP |
|---|---|---|
| WI2197/CI 13520//SLB 39-60 (2) | 1740 | 3163 |
| Tadmor//WI2291/WI2269 (2) | 1731 | 3232 |
| Tadmor//Roho/Mazurka (2) | 1708 | 3133 |
| Avt/Attiki//Aths (6) | 1663 | 3363 |
| Roho//Clipper/CI 03614 (2) | 1661 | 3471 |
| 7028/2759/3/69-82//Ds/Apro/4/H272//WI2198/ID60 | 1652 | 3092 |
| ArabiAbiad//ER/Apm/3/Tadmor/4/ArabiAswad/WI229 | 1649 | 3379 |
| ArabiAbiad//ER/Apm/3/Tadmor/4/ArabiAswad/WI229 | 1646 | 3307 |
| Tadmor//Roho/Mazurka (2) | 1637 | 3316 |
| SLB 39-05/4/7028/2759/3/69-82//Ds/Apro (2) | 1610 | 3032 |
| Tadmor/3/ChiCm/An57//Albert (2) | 1590 | 3015 |
| SLB 34-07/Arta (2) | 1578 | 3781 |
| Mo.B1337/WI2291//Moroc 9-75/PmB (2) | 1564 | 3614 |
| | | |
| Best check (Arabi Abiad) | 1383 | 3403 |
| Arabi Aswad[a] | 1304 | 2825 |
| Rihane-03[a] | 1201 | 3155 |

[a] Arabi Aswad is the most commonly grown barley landrace in dry areas of Syria and Rihane-03 is a high-yielding variety released in four countries

**Table 2.1.2. Average grain yield (kg/ha) in four high yielding sites (YP) of 9 lines which outyielded the best check at each site. YS is the average grain yield of the same line in five stress sites.**

| Name (Row type) | YP | YS |
|---|---|---|
| Mr25-84/Att//Mari/Aths*3-02 (6) | 4074 | 1287 |
| JLB 08-06/WI2198 (2) | 3909 | 1581 |
| WI2291/WI2269//WI2291/Roho (2) | 3900 | 1529 |
| WI2269/Arta (2) | 3892 | 1604 |
| 80-5013/Rihane-03 (6) | 3772 | 1144 |
| Mr25-84/Att/3/Mari/Aths//Bc (6) | 3722 | 1426 |
| Aths/Lignee 686//Harmal-02/Arabi Abiad*2 (6) | 3714 | 1528 |
| WI2291/WI2269//JLB 06-33 (2) | 3647 | 1488 |
| M64-76/Bon//Jo/York/3/M5/Galt//As46/4/Hj34-80/ | 3550 | 1267 |
| Best check (Arabi Abiad) | 3403 | 1356 |
| Arabi Aswad[a] | 2825 | 1343 |
| Rihane-03[a] | 3155 | 1145 |

[a] Arabi Aswad is the most commonly grown barley landrace in dry areas of Syria and Rihane-03 is a high-yielding variety released in four countries

The question of how to reconcile a breeding strategy based on selection in the target environment, specific adaptation and locally adapted germplasm, with the mandate of an international breeding program has been resolved by decentralizing barley breeding activities into a number of countries. - **S. Ceccarelli and S. Grando**

**Table 2.1.3. Performance (kg/ha) of barley lines in initial and preliminary yield trials in two locations in north Syria.**

| | Breda | | Tel Hadya | |
|---|---|---|---|---|
| Material | Init. | Prel. | Init. | Prel. |
| Rihane-03 | 1284 | 1609 | 3624 | 3384 |
| Mari/Aths*2 | 1059 | 1730 | 3243 | 4244 |
| Harmal | 1164 | 1246 | 3309 | 3740 |
| A.Aswad | 1199 | 1791 | 2704 | 2901 |
| A.Abiad | 1187 | 1752 | 3435 | 3812 |
| Arta | 1558 | 2109 | 3966 | 4190 |
| Zanbaka | 1139 | 1427 | 2457 | 3270 |
| Grand mean | 1202 | 1576 | 3108 | 3325 |
| % >best check | 12.4 | 8.3 | 3.3 | 2.0 |
| Mean yield[a] | 1539 | 2029 | 4070 | 4377 |

[a] Average yield (kg/ha) of lines outyielding the best check

### 2.1.4. Activities in Collaboration with National Programs

Germplasm development for different developing countries (objective nr. 2) is pursued with three different modes of action ranging from full decentralization at one extreme, to fully centralized activities at the other. All our breeding work will be eventually decentralized, and therefore these three modes of action do not reflect three different strategies, but three different levels of implementation of the same strategy.

#### 2.1.4.1. Fully Decentralized Breeding: North Africa

Decentralization of barley breeding in Maghreb continued in 1993/94 according to the time-table presented in the Annual Report for 1991/92 (Table 2). Two types of special nurseries, namely, an observation nursery (263 lines) and $F_2$'s (224 populations, some of which derived from crosses

designed by NARS), were distributed for evaluation and testing in 1994. The total frequency of selection in the $F_2$ populations and in the nursery was higher than in 1993 in Libya (but only for the $F_2$) and in Morocco, but lower in Tunisia possibly due to the severe drought which affected that country (Table 2.1.4).

The total frequency of selection was high, ranging from 43 to 62%. The selections from the nursery will be yield tested in 1994/95. The selected $F_2$'s will be evaluated (as bulks) in the nursery in 1994/95 and plant selection will be made only within those $F_2$'s selected for two consecutive cropping seasons. This will considerably reduce the amount of work needed to handle thousands of individual plant selections.

In addition to the nurseries, four yield trials, one for each country, were distributed. The yield trials included the entries selected in 1992/93 from the special nursery. The total number of lines selected in the four countries was too large to be accommodated in only one trial. It was also considered unnecessary that entries selected in a given country should be tested in other countries where they were not selected.

The number of lines tested in each country was 45 in Morocco, 39 in Tunisia, 80 in Algeria and 41 in Libya (a total of 205). Of those 23 were common to all trials. The performance of the barley lines in the four trials for north Africa is summarized in Tables 2.1.5 to 2.1.8.

In Libya only one testing site (Misurata) was harvested and 9 lines outyielded the widely grown cultivar California Mariout (Table 2.1.5). The yield advantage ranged from 6 to more than 80%.

In Algeria the yield trial was evaluated at three locations (Setif, Tiaret and Sidi Bel Abbes). Many entries were not harvested at Tiaret and Sidi Bel Abbes because of severe drought which caused average yields of 1 t/ha or less. Table 2.1.6 gives, for each location, the grain yield of the best 5 lines at that location together with their grain yield at the other two locations. The local landrace Saida outyielded Rihane-03 in all the three sites and the second improved check (Lignee 527) at Setif.

**Table 2.1.4. Frequency of selection (%) in two nurseries for Maghreb ($F_2$ and Observation Nursery) in 1993 and in 1994.**

| Country | Location | $F_2$ | | Nursery | |
|---|---|---|---|---|---|
| | | 1993 | 1994 | 1993 | 1994 |
| Libya | Azizie | 16.9 | 12.1 | 35.2 | 11.8 |
| | Misurata | 33.5 | - | 17.8 | - |
| | Khoms | - | 30.8 | - | 25.5 |
| | Fataeh | - | 14.7 | - | 20.5 |
| | **Total** | **34.6** | **44.6** | **44.3** | **43.7** |
| Tunisia | Beja | 51.6 | 18.8 | 23.2 | 16.0 |
| | Kef | 42.9 | 6.7 | 24.7 | 10.6 |
| | Tajerouine | 30.7 | - | 13.3 | - |
| | Foussana | 29.9 | 41.5 | - | 25.9 |
| | **Total** | **69.7** | **51.8** | **57.2** | **43.0** |
| Morocco | Annaceur | 20.0 | 31.7 | 12.1 | 33.1 |
| | Merchouch | 28.8 | 33.0 | 25.3 | 19.8 |
| | Jemaa Shaim | 18.9 | 25.9 | 12.1 | 19.0 |
| | **Total** | **53.5** | **62.1** | **43.7** | **52.9** |

The top 5 yielding lines were different at each location with the exception of line 74 which was among the top yielders both in Tiaret and Sidi Bel Abbes. In general, the best lines at each locations did not perform well at other locations. Even when they outyielded the checks at other locations, they yielded less than the top yielding lines.

This pattern of specific adaptation, not only between countries but also within countries, also emerged from the yield trials in Tunisia (Table 2.1.7) which were evaluated at Beja and Kef. Like in Libya and Algeria, the season was very dry and, particularly in Kef, yields were very low. With the exception of line nr. 14, which performed well in both locations, all the others were specifically adapted to either one of the two locations.

**Table 2.1.5. Grain yield (kg/ha) of the best lines in the yield trial for Libya at Misurata (41 lines tested).**

| Entry nr.[a] | Grain yield (kg/ha) | %check |
|---|---|---|
| 36 | 821 | 182.6 |
| 21 | 667 | 148.4 |
| 26 | 636 | 141.4 |
| 42 | 596 | 132.5 |
| 41 | 593 | 132.0 |
| 8 | 567 | 126.1 |
| 43 | 566 | 125.8 |
| 5 | 552 | 122.8 |
| 12 | 488 | 108.5 |
| 23 | 477 | 106.0 |
| California Mariout | 449 | 100.0 |
| Beecher | 311 | 69.3 |
| Athenais | 229 | 51.0 |

[a] Entry names:
36 = Badia/5/Cr.115/Pro//Bc/3/Api/CM67/4/Giza 120
21 = As46/Aths*2//Sarras
26 = Api/CM67//Ager/3/Kantara
42 = As46/Rihane-05
41 = As46/Rihane-05
8 = Arizona5908/Aths//Lignee640/5/CI01021/4/CM67/U.Sask.1 800//Pro/CM67/3/DL70
43 = Api/CM67//Mona/3/DI//Asse/CM65-1W-B/4/Assala-02
5 = Harma-01//AwBlack/Aths
12= Arizona5908/Aths//Lignee640/5/Aths/4/Pro/TolI//Cer*2/ TolI/3/5106
23 = As46/Aths

**Table 2.1.6. Grain yield (kg/ha) of the best lines in the yield trial for Algeria (80 lines tested).**

| Entry nr.[a] | Setif | Tiaret | S.B.Abbes |
|---|---|---|---|
| Setif | | | |
| 20 | 1893 | - | 842 |
| 49 | 1883 | - | 787 |
| 50 | 1624 | - | - |
| 5 | 1597 | - | - |
| 32 | 1534 | 588 | - |
| Tiaret | | | |
| 71 | 898 | 917 | - |
| 40 | 1132 | 857 | - |
| 74 | 1347 | 857 | 1073 |
| 31 | 1180 | 828 | - |
| 73 | 992 | 814 | - |
| Sidi B. Abbes | | | |
| 12 | 1489 | - | 1136 |
| 10 | 1423 | - | 1127 |
| 74 | 1347 | 857 | 1073 |
| 45 | 1258 | - | 1017 |
| 60 | 1165 | 671 | 938 |
| Checks | | | |
| Lignee 527 | 1121 | 642 | 780 |
| Saida | 1304 | 725 | 601 |
| Tichedrette | 1486 | 682 | - |
| Rihane-03 | 1239 | 634 | 446 |

[a] Entry names:
20 = Arizona5908/Aths//Lignee640/3/Lignee527/Arar
49 = Apm/11012-2//Np = CI00593/3/IFB974
50 = Apm/11012-2//Np = CI00593/3/IFB974
5 = Quinn/3/Harma-02//11012-2/CM67/4/Aths/5/AwBlack/Aths/ /Matnan-05/3/Arar
32 = As46/Aths*2/5/Cr.115/Por//Bc/3/Api/CM67/4/Giza 120
71 = Gloria'S'/Celo'S'//Teran 78
40 = M6/Robur-35-6-3//Attiki
74 = Lignee527/Aths
31 = M69-77/Shi-r-KciNo.87/4/Pro/TolI//Cer*2/TolI/3/5106/5 /Por/Nopal'S'
73 = Rihane-08/Arar
12 = Chaaran-01/3/Arizona5908/Aths//Bgs/4/Lignee640/Bgs//Cel
10 = Arizona5908/Aths//Lignee640/3/Gerbel/Harma
45 = As46/Rihane-05
60 = SINIS-12

**Table 2.1.7. Grain yield (kg/ha) of the best lines in the yield trial for Tunisia (39 lines tested).**

| Entry nr.[a] | El Kef | Rank | Beja | Rank |
|---|---|---|---|---|
| El Kef | | | | |
| 25 | 883 | 1 | 2483 | 21 |
| 37 | 877 | 2 | 2627 | 24 |
| 32 | 847 | 3 | 2463 | 23 |
| 14 | 817 | 4 | 3203 | 2 |
| 17 | 807 | 5 | 2723 | 15 |
| 36 | 777 | 6 | 2343 | 33 |
| 31 | 757 | 7 | 2460 | 25 |
| 29 | 703 | 8 | 1403 | 40 |
| Beja | | | | |
| 11 | 273 | 35 | 3257 | 1 |
| 14 | 817 | 4 | 3203 | 2 |
| 12 | 466 | 21 | 3163 | 3 |
| Checks | | | | |
| Rihane-03 | 487 | 17 | 2983 | 8 |
| Manal 92 | 483 | 18 | 3023 | 4 |
| Martin | 500 | 15 | 2663 | 17 |

[a] Entry names:
25 = Giza121/CI06248/4/Apm/IB65//11012-2/3/Api/CM67//Ds/Apro/5/M5/Galt//As46
37 = Ase/CM*3//Sut/3/Sb401/4/M.Rnb6-80
32 = Aths/Lignee686
14 = Arizona5908/Aths//Lignee640/3/Lignee640/Lignee527
17 = Arizona5908/Aths//Lignee640/3/Lignee640/Lignee527
36 = Lignee527/Aths
31 = Lignee527/NK1272
29 = Lignee527/Aths
11 = Arizona5908/Aths//Lignee640/3/Lignee527/Arar
12 = Arizona5908/Aths//Lignee640/3/Gerbel/Harma

The yield trials for Morocco were tested at one high yield yielding location (Merchouch), in the Atlas Mountains (Annaceur), and in the semiarid south (Jemaa Shaim). Average

grain yields were the highest in Merchouch and the lowest in Annaceur (Table 2.1.8). The two improved checks (both released cultivars) outyielded the widely grown cultivar Arig 8 in all three locations. The number of lines performing well in more than one location was higher than in other countries. Line nr. 18 was among the top yielding lines in Merchouch and Jema Shaim, line nr. 47 was among the top yielders in Merchouch and Annaceur, and two lines were among the highest yielding both in Annaceur and Jema Shaim. - **A. Amri, A. Yahyaoui, M. Fellah, M. Laddada, M. Maatougui, K. Bembelkacem, A. Shreidi, A. Zeitani, M.S. Mekni**

**Table 2.1.8. Grain yield (kg/ha) of the best lines in the yield trial for Morocco (45 lines tested).**

| Entry nr.[a] | Annaceur | Rank | Merchouch | Rank | Jemaa Shaim | Rank |
|---|---|---|---|---|---|---|
| Merchouch | | | | | | |
| 18 | 829 | 18 | 4299 | 1 | 2655 | 3 |
| 47 | 1065 | 1 | 4285 | 2 | 2309 | 19 |
| 42 | 732 | 32 | 4117 | 3 | 2072 | 36 |
| 33 | 887 | 12 | 3968 | 4 | 2534 | 8 |
| Annaceur | | | | | | |
| 47 | 1065 | 1 | 4285 | 2 | 2309 | 19 |
| 10 | 1023 | 2 | 3841 | 10 | 2921 | 1 |
| 9 | 1006 | 3 | 3901 | 9 | 2348 | 16 |
| 11 | 978 | 4 | 3627 | 16 | 2836 | 2 |
| Jemaa Shaim | | | | | | |
| 10 | 1023 | 2 | 3841 | 10 | 2921 | 1 |
| 11 | 979 | 4 | 3627 | 16 | 2836 | 2 |
| 18 | 829 | 18 | 4299 | 1 | 2655 | 3 |
| 39 | 803 | 21 | 3251 | 28 | 2633 | 4 |
| Checks | | | | | | |
| Er/Apm | 879 | 13 | 3959 | 5 | 2253 | 22 |
| Rihane-03 | 861 | 14 | 3652 | 15 | 2319 | 17 |
| Arig 8 | 531 | 48 | 3348 | 25 | 1526 | 46 |

[a] Entry names:
18 = Arizona5908/Aths//Lignee640/3/Lignee640/Lignee527
47 = Cr.115/Por//Bc/3/Api/CM67/4/Giza120/5/H272/Bgs/3/Mzq/Gva//PI002917
42 = Lignee527//Bahtim/DL71/3/Api/CM67//Mzq
33 = Lignee527/NK1272
10 = Arizona5908/Aths//Lignee640/3/Lignee527/Arar
9 = Arizona5908/Aths//Lignee640/5/CI01021/4/CM67/U.Sask.1800//Pro/CM67/3/DL70
11 = Chaaran-01/3/Arizona5908/Aths//Bgs/4/Lignee640/Harma-01
39 = Aths/Lignee686

### 2.1.4.2. Countries where Decentralization is Starting

Special nurseries were prepared for a number of countries (Iraq, Spain, Syria, and Egypt) to begin a process of decentralization. In collaboration with the Genetic Resources Unit, landraces from Iraq and Ethiopia were added to those from Yemen, Afghanistan, Libya, Algeria, Iran, Jordan, Pakistan, Tunisia and Turkey and were introduced in the breeding program to form the basis for specific crossing blocks. **- S. Ceccarelli**

### 2.1.4.3. No Decentralization

In a number of countries, including some of those mentioned in 2.1.4.2, the development and distribution of germplasm is still largely based on the traditional system of international nurseries. As shown in the following Tables, centralized breeding is not necessarily ineffective, as indicated by the number of lines outyielding significantly the national check: the two main disadvantages are that it does not exploit specific adaptation, it only involves national programs in testing germplasm and not in its development, and it erodes biodiversity.

Tables 2.1.9, 2.1.10, 2.1.11, and 2.1.12 show barley lines outyielding significantly the national check in countries of West Asia, Arabian peninsula, Europe and south America and Asia, respectively. The Tables do not include north African countries and Syria because of the specific program of germplasm development implemented for these countries.

In all the countries of West Asia (Table 2.1.9) where the regional yield trials (the more advanced germplasm distributed through the international nurseries system) were tested, one or more lines outyielded the national check. Some lines such as Lignee 527/NK1272, Aths/Lignee 686, Rihane//Bc/Coho, and ER/Apm//Cerise/3/Lignee 131//ER/Apm outyielded significantly the national check in more than one country. By contrast, few lines outyielded the national check in the Arabian peninsula (Table 2.1.10) where barley is only grown under irrigation.

**Table 2.1.9. Barley lines distributed with the Regional Yield Trials 1992/93 outyielding significantly (P < 0.05) the national check in different countries in West Asia.**

| Country | Location | Name/Cross | Yield (kg/ha) Test line | Nat. check |
|---|---|---|---|---|
| Cyprus | Dromolaxia | Rihane//Bc/Coho | 9306 | 7607 |
| | " | Aths/Lignee 686 | 9511 | 7607 |
| | " | Lignee 527/NK1272 | 10487 | 7607 |
| Iran | Zabol | Aths/Lignee686 | 6832 | 5035 |
| | Kuhriz | WI2291//Mzq/DL71 | 5083 | 3683 |
| | Gachsaran | Rihane/Lignee 527 | 5350 | 3408 |
| | Kuhriz | WI2198/Harmal-02 | 4417 | 3683 |
| | Gachsaran | ER/Apm//Cerise/3/Lignee131 //ER/Apm | 4882 | 3408 |
| | Kuhriz | WI2291/WI2269 | 4817 | 3683 |
| | Kuhriz | 24572 = (Walfajr/Lignee686) | 4633 | 3683 |
| Iraq | Mosul | Pld10342//Cr.115/Por/3/Bah tim 9/4/Ds/Apro/5/WI2291 | 3081 | 2119 |
| Jordan | Al-Karak | Harmal-02/Emir | 3533 | 1633 |
| | " | 80-5013/5/Cr.115/Pro//Bc/3 /Api/CM67/4/Giza 120 | 2367 | 1633 |
| | " | 2762/Bc//11012-2/Tery/3/10 L-2621-2Y/Bante025 | 1613 | 1167 |
| Pakistan | Pirsabak | ER/Apm//WI2291 | 1822 | 1072 |
| | Islamabad | Lignee527/NK1272 | 5700 | 3933 |
| | " | 80-5013/5/Cr.115/Pro//Bc/3 /Api/CM67/4/Giza120 | 5700 | 3933 |
| | Pirsabak | Lignee527/NK1272 | 1789 | 1072 |
| | Surab Gidde | INRA55-86-2/B1701 | 752 | 118 |
| | Surab Gidde29 | Lignee131 | 926 | 118 |
| | Surab Gidde29 | SLB47-81 | 774 | 118 |
| Turkey | Diyarbakir | Rihane-03/3/Bc/Rihane//Ky6 3-1294 | 5958 | 4889 |
| | " | Rihane//Bc/Coho | 6694 | 4889 |
| | Adana | Vg/Julia//Zy/3/CM67/Apro// Sv.02109/Mari | 5363 | 3837 |
| | " | ER/Apm//Cerise/3/Lignee131 //ER/Apm | 4733 | 3837 |

This is not surprising because of the differences in management between our selection and testing sites (pg. )

and the testing sites in these countries. High temperatures in most of the locations of the Arabian peninsula also play a role particularly in reducing disease incidence. Gustoe, the dominant barley variety in the Arabian peninsula, is susceptible to practically every disease when grown in northern Syria.

**Table 2.1.10. Barley lines distributed with the Regional Yield Trials 1992/93 outyielding significantly (P < 0.05) the national check in the Arabian Peninsula.**

| Country | Location | Name/Cross | Yield (kg/ha) Test line | Nat. Check |
|---|---|---|---|---|
| S. Arabia | Riyadh | N-Acc4000-301-80/IFB974 | 4115 | 3213 |
| Oman | Jimah | Rihane/Lignee 527 | 6869 | 3851 |
| | Jimah | ER/Apm//WI2291 | 5723 | 3851 |

A number of lines outyielded the national check in some European countries such as Greece and Portugal (Table 2.1.11) but not in other countries such as Italy and Spain. The regional yield trials were tested in only one south American country (Argentina) where three lines (including the long term check Matnan-01 outyielded the national check.

**Table 2.1.11. Barley lines distributed with the Regional Yield Trials 1992/93 outyielding significantly (P < 0.05) the national check in Europe and South America**

| Country | Location | Name/Cross | Yield (kg/ha) Test line | Nat. Check |
|---|---|---|---|---|
| Greece | Halkidiki | Vino'S'/NS2375//Mari/Aths* 2 | 6333 | 5295 |
| | Halkidiki | 24571 = (Walfajr/Lignee 686) | 5974 | 5038 |
| Portugal | Elvas | Arar//Deir Alla 106/Cel | 5547 | 3505 |
| | Elvas | Vg/Julia//Zy/3/CM67/Apro// Sv.02109/Mari | 6196 | 5223 |
| | Elvas | Quinn/IFB974 | 5412 | 3505 |
| | Elvas | ER/Apm/3/5819/1420//Aramir | 5480 | 3505 |
| Argentina | Cordoba | 2762/Bc//11012-2/Tery/3/10 L-2621-2Y/Bante 025 | 6299 | 5411 |
| | Cordoba | Matnan-01 | 5263 | 4208 |
| | Cordoba | ER/Apm//AC253 | 5211 | 4208 |

Among the Asian countries, only in India and in China some lines outyielded the national check. However, only one promising line was found in one location in China and none were found to outyield the national check in Korea. In the past, we had similar difficulties in producing germplasm adapted to other Asian countries such as Thailand and Vietnam. This suggests that it is urgent to implement a program of decentralized breeding for these countries.

**Table 2.1.12. Barley lines distributed with the Regional Yield Trials 1992/93 outyielding significantly (P < 0.05) the national check in China and India**

| Country | Location | Name/Cross | Yield (kg/ha) Test line | Nat. Check |
|---|---|---|---|---|
| China | Xining | Vg/Julia//Zy/3/CM67/Apro//Sv.02109/Mari | 8478 | 7190 |
| India | Karnal | Beecher | 3385 | 2296 |
| | Karnal | Mari/Aths*2//Attiki | 3770 | 2296 |
| | Karnal | ER/Apm/3/5819/1420//Aramir | 3644 | 2296 |
| | Faizabad | Aths/Lignee 686 | 1389 | 1022 |
| | Karnal | Rihane/Lignee 527 | 6956 | 4993 |
| | Faizabad | 2762/Bc//11012-2/Tery/3/10L-2621-2Y/Bante 025 | 1456 | 1022 |
| | Karnal | Arar//Deir Alla 106/Cel | 3267 | 2296 |
| | Faizabad | ER/Apm//AC253 | 1650 | 1022 |
| | Karnal | ER/Apm//Cerise/3/Lignee 131//ER/Apm | 6407 | 4993 |

**- S. Ceccarelli and S. Grando**

### 2.1.5. Landraces: Decentralization of a Methodology

About 50% of the collection of Syrian and Jordanian landraces (nearly 7000 progenies from individual spikes) made in 1981 (Weltzien 1982)* has been evaluated. During 1994 this work was fully integrated with the rest of the breeding program and this allows comparisons between different types of germplasm, including crosses between landraces and improved germplasm, crosses between landraces, and crosses

* Weltzien, E. 1982. Observations on the growth habit of Syrian and Jordanian landraces of barley. Rachis, 1:6-7.

between landraces and *H. spontaneum*.

As mentioned in previous Annual Reports, the work on Syrian and Jordanian landraces of barley was primarily of methodological nature. The main objective was to assess the value of this type of germplasm in breeding program for stress conditions. The assumption was that since landraces still grown in harsh environments evolved under stress conditions, they are likely to possess specific adaptation to those conditions. However, if the assumption is correct, it implies that superior lines developed from Syrian and Jordanian landraces are not expected to perform well elsewhere. Therefore, national programs can benefit from the methodology and not necessarily from the germplasm developed through that methodology.

From 1984, when the work on landraces started, the main achievements have been:

1. One line has been released (Arta, indicated in previous Annual Reports with the collection code SLB 39-58) and shows a rapid adoption.
2. Two lines (Tadmor and Zanbaka) have been tested for a number of years in on-farm trials, and from these trials have been adopted by some farmers in the north and north-east of Syria.
2. A new line (still identified with the collection code SLB 05-96) has performed well in the on-farm verification trials and it is currently evaluated in large scale demonstration trials.

Two of these lines (Arta and Zanbaka) have been added as checks in our yield trials in 1993, and because of the superiority of Arta over both landraces (Arabi Abiad and Arabi Aswad), it has become more difficult to identify superior lines. However, among the material tested for the first time in 1994, lines showing a yield advantage up to 19% over Arta have been found. Table 2.1.13 shows the grain yield in Breda and Tel Hadya, heading date at Tel Hadya and plant height at Breda of the best 1% of the lines in the initial yield trials.

**Table 2.1.13. New promising barley lines for stress environments in the initial yield trials: the 1% highest yielding lines at Breda in 1994 with their grain yield (kg/ha) in Breda and Tel Hadya, days to heading at Tel Hadya and plant height in Breda.**

| Entry nr.[a] | Grain yield (kg/ha) Breda | Tel Hadya | Heading | Plant height (cm) |
|---|---|---|---|---|
| 2263 | 1859 | 4081 | 111.8 | 37.0 |
| 2232 | 1845 | 4264 | 114.5 | 44.3 |
| 4044 | 1837 | 3147 | 112.1 | 50.1 |
| 4304 | 1823 | 3985 | 111.9 | 33.5 |
| 4070 | 1813 | 3435 | 109.8 | 45.1 |
| 2164 | 1789 | 3298 | 111.0 | 49.1 |
| 2075 | 1784 | 3502 | 111.8 | 49.0 |
| 2342 | 1778 | 3767 | 114.5 | 32.1 |
| 4314 | 1777 | 3445 | 107.8 | 40.8 |
| 4136 | 1754 | 2989 | 109.3 | 52.8 |
| 4297 | 1667 | 3353 | 109.4 | 32.7 |
| 4087 | 1651 | 3509 | 110.5 | 41.5 |
| 4018 | 1650 | 2989 | 105.6 | 49.8 |
| 4278 | 1647 | 4094 | 110.3 | 38.4 |
| means | 1762 | 3561 | 110.7 | 42.6 |
| Checks | | | | |
| Arabi Abiad | 1187 | 3435 | 110.3 | 38.3 |
| Arabi Aswad | 1199 | 2704 | 112.7 | 49.5 |
| Arta | 1558 | 3966 | 110.7 | 33.0 |
| Zanbaka | 1139 | 2457 | 112.0 | 50.0 |
| Harmal | 1164 | 3309 | 106.4 | 44.8 |
| Mari/Aths*2 | 1059 | 3243 | 100.5 | 39.0 |
| Rihane-03 | 1284 | 3624 | 114.2 | 48.7 |
| Sawsan/Lignee527// Arar | 1129 | 2760 | 109.5 | 48.0 |

[a] Entry Name(Row type):
2263 = Harmal-02/Arabi Abiad//ER/Apm/3/Arta (2)
2232 = Roho//Alger/Ceres 362-1-/3/Mo.B1337/WI2291 (2)
4044 = SLB 21-24 (2)
4304 = SLB 24-50 (2)
4070 = SLB 21-51 (2)
2164 = Quinn/Arar (6)
2075 = Lignee527/Sawsan//Bc/3/Arizona5908/Aths//Lignee 640(6)
2342 = Roho/Kv/6/Pld10342//Cr.115/Por/3/Bahtim9/4/ Ds/Apro/5/WI2291(2)
4314 = SLB 24-66 (2)
4136 = SLB 22-25 (2)
4297 = SLB 24-40 (2)
4087 = SLB 21-70 (2)
4018 = WI2291/4/Ahor4066-70/3/Pro/TolI//Cer*2/TolI/5/SLB45 -34(2)
4278 = SLB 24-14 (2)

We are particularly interested in plant height under stress because Arta tends to become very short in dry years and we try to find the same yield level of Arta in taller lines. Indeed all the lines in Table 2.1.13 except two, have significantly taller plants and higher grain yield at Breda than Arta. Three of those (2263, 2232 and 4278) have a yield potential similar to Arta in the better environment of Tel Hadya and are taller than Arta in Breda. Four of the lines in Table 2.1.13 (2232, 2164, 2075, and 2342) are unrelated to Syrian landraces.

**Table 2.1.14. New promising barley lines for stress environments in the preliminary yield trials: the 1% highest yielding lines at Breda in 1994 with their grain yield (kg/ha) in Breda and Tel Hadya, days to heading at Tel Hadya and plant height in Breda.**

| Entry nr.[a] | Grain yield (kg/ha) | | Heading | Plant height (cm) |
|---|---|---|---|---|
| | Breda | Tel Hadya | | |
| 2246 | 2306 | 3493 | 113.4 | 48.2 |
| 2251 | 2297 | 3434 | 115.1 | 52.8 |
| 1176 | 2282 | 3580 | 111.7 | 47.4 |
| 1220 | 2261 | 3551 | 111.6 | 40.7 |
| 1192 | 2214 | 3445 | 109.9 | 55.4 |
| 2281 | 2206 | 3002 | 115.5 | 49.2 |
| means | 2261 | 3418 | 112.9 | 48.9 |
| Checks | | | | |
| Arabi Abiad | 1752 | 3812 | 114.7 | 54.4 |
| Arabi Aswad | 1791 | 2901 | 111.2 | 43.3 |
| Arta | 2109 | 4190 | 110.3 | 36.8 |
| Zanbaka | 1427 | 3269 | 113.4 | 48.5 |
| Harmal | 1246 | 3740 | 108.7 | 45.9 |
| Mari/Aths*2 | 1730 | 4244 | 101.7 | 40.7 |
| Rihane-03 | 1609 | 3384 | 114.9 | 47.8 |
| Sawsan/Lignee527// Arar | 1535 | 2938 | 109.7 | 48.2 |

[a] Entry Name(Row type):
2246 = SLB 18-47 (2)
2251 = SLB 18-87 (2)
1176 = SLB 45-90/Arta (2)
1220 = Moroc9-75//Roho/Mazurka (2)
1192 = SLB 45-93//H.Spont.41-1/Tadmor (2)
1176 = SLB 20-25 (2)

The remaining ten are either pure line selections from landraces (the SLB lines), or crosses with pure line selections from landraces now used as parents (2263 and 4018). There were 786 lines unrelated to landraces, 260 crosses with pure line selections and 301 pure line selections from landraces in this trial. Therefore, the relative contribution of this three types of germplasm to the best 1% of the lines in the trial was 0.5%, 0.8% and 2.7%. The advantage of using landraces, particularly in small breeding programs at national level is evident.

A similar pattern emerges from the analysis of the 1994 data of the preliminary yield trials. The 1% highest yielding lines in Breda outyielded Arta by between 5% and 9% and were all considerably taller (Table 2.1.14). However, their yield in the more favorable conditions of Tel Hadya was considerably lower than Arta. In these trials a total of 564 lines were tested for the second cropping season. Of these 300 were non landraces, 197 were derived from crosses with landraces, 40 were pure lines selections from landraces and 27 were crosses with *H. spontaneum*.
Among the best 1% for grain yield in Breda three lines were pure lines selections from landraces, while the other three types of germplasm contributed one line each. The relative contribution of the four types of germplasm to the best 1% of the lines in the trial was 7.5% (pure lines selections from landraces), 3.7% (crosses with *H. spontaneum*), 0.5% (crosses with landraces) and 0.3% (non landraces).

A summary of the main differences between types of germplasm is give in Tables 2.1.15 and 2.1.16 for the same characters used in Tables 2.1.13 and 2.1.14. In both trials the pure lines from landraces had the highest grain yield in Breda, although in the initial yield trials there was no difference with the newest lines derived from crosses between landraces and improved. Of particular interest is that, even the lowest yielding lines from landraces, from crosses between landraces and improved and from *H. spontaneum* crosses, yielded more than the lowest yielding lines unrelated to landraces. The main difference between the two trials is the maximum grain yield in Breda of the *H. spontaneum* crosses which is considerably lower in the initial than in the preliminary yield trials.

**Table 2.1.15. Differences between four types of germplasm[a] in grain yield (kg/ha) in Breda (GY Breda) and in Tel Hadya (GY Tel Hadya), days to heading, and plant height (cm) in Breda (PH Breda). (Initial yield trials 1994).**

| Traits | Improved | Landraces | L x I | *H.* sp. crosses |
|---|---|---|---|---|
| GY Breda | | | | |
| mean ± s.e. | 1131±8 | 1317±12 | 1313±12 | 1053±21 |
| min. | 446 | 707 | 647 | 737 |
| max. | 1856 | 1837 | 2011 | 1433 |
| GY Tel Hadya | | | | |
| mean ± s.e. | 3176±14 | 3024±26 | 3110±30 | 2628±21 |
| min. | 1487 | 1553 | 1882 | 1567 |
| max. | 4647 | 4491 | 4338 | 3841 |
| Heading | | | | |
| mean ± s.e. | 112±0.2 | 110±0.1 | 107±0.3 | 105±0.8 |
| min. | 81 | 105 | 89 | 94 |
| max. | 124 | 115 | 117 | 120 |
| PH Breda | | | | |
| mean ± s.e. | 41±0.2 | 43±0.4 | 44±0.4 | 50±0.9 |
| min. | 26 | 25 | 29 | 32 |
| max. | 65 | 56 | 64 | 66 |

[a] Improved = Unrelated to Syrian landraces (n = 786)
Landraces = pure lines selected from Syrian landraces (n = 301)
L x I = lines from crosses between improved and landraces (n = 260)
*H.* sp. crosses = lines from crosses between *H. spontaneum* and improved or landraces (n = 60)

This is likely to be associated with the progressive reduction of brittle or semi-brittle rachis genotypes during selection. The yield potential of the improved germplasm (estimated by the grain yield at Tel Hadya) is the highest. However, in the preliminary yield trial some crosses between landraces and improved showed a yield potential similar to the improved. Crosses with *H. spontaneum* were always the earliest and the tallest under drought. We will discuss more in detail the characteristics of this type of germplasm in the *H. spontaneum* section (pg. ). The data on the pure lines selected from landraces and tested in the initial yield

trials in 1994 can provide some information on the variability between and within collection sites. In fact, each year we evaluate, within the system of yield testing, all the available lines of three to four collection sites. Among the four collection site tested in 1994 in the initial yield trials there were significant differences for grain yield both in Breda and in Tel Hadya and for plant height in Breda (Table 2.1.17).

**Table 2.1.16. Differences between four types of germplasm[a] for grain yield (kg/ha) in Breda (GY Breda) and in Tel Hadya (GY Tel Hadya), days to heading, and plant height (cm) in Breda (PH Breda). (Preliminary yield trials 1994).**

| Traits | Improved | Landraces | L x I | *H.* sp. crosses |
|---|---|---|---|---|
| GY Breda | | | | |
| mean ± s.e. | 1506±18 | 1792±41 | 1636±23 | 1601±52 |
| min. | 373 | 1268 | 658 | 875 |
| max. | 2261 | 2306 | 2282 | 2214 |
| GY Tel Hadya | | | | |
| mean ± s.e. | 3296±23 | 2961±52 | 3465±34 | 3179±56 |
| min. | 2072 | 2437 | 1637 | 2590 |
| max. | 4771 | 3814 | 4626 | 3657 |
| Heading | | | | |
| mean ± s.e. | 111±0.2 | 114±0.3 | 110±0.2 | 108±0.8 |
| min. | 98 | 109 | 98 | 99 |
| max. | 130 | 118 | 120 | 117 |
| PH Breda | | | | |
| mean ± s.e. | 42±0.3 | 49±0.7 | 45±0.7 | 50±1.3 |
| min. | 16 | 42 | 29 | 30 |
| max. | 60 | 59 | 66 | 61 |

[a] Improved = Unrelated to Syrian landraces (n = 300)
Landraces = pure lines selected from Syrian landraces (n = 40)
L x I = lines from crosses between improved genotypes and landraces (n = 197)
*H.* sp. crosses = lines from crosses between *H. spontaneum* and improved genotypes or landraces (n = 27)

On the average, lines from site 24 yielded

significantly more, both in Breda and in Tel Hadya, but were shorter under drought. A large amount of variation exists within each collection site, confirming that this collection is an immense reservoir of useful genetic variability, which can be readily utilized because it is between homozygous lines.

**Table 2.1.17. Variability between and within the four sites where the landrace-lines tested in the initial yield trials were collected.**

| Coll. sites | Grain yield (kg/ha) Breda | Grain yield (kg/ha) Tel Hadya | Days to heading | Plant height (cm) |
|---|---|---|---|---|
| Site 21 (n = 86) | | | | |
| means±s.e. | 1289±24 | 2903±34 | 111±0.2 | 45±0.4 |
| min | 891 | 2207 | 105 | 30 |
| max | 1837 | 3695 | 114 | 54 |
| Site 22 (n = 79) | | | | |
| means±s.e. | 1311±21 | 2870±26 | 110±0.2 | 47±0.5 |
| min | 706 | 2207 | 106 | 39 |
| max | 1754 | 3497 | 114 | 56 |
| Site 23 (n = 70) | | | | |
| means±s.e. | 1296±23 | 2846±51 | 110±0.2 | 43±0.6 |
| min | 832 | 1553 | 107 | 28 |
| max | 1837 | 3725 | 115 | 55 |
| Site 24 (n = 64) | | | | |
| means±s.e. | 1385±25 | 3566±54 | 110±0.2 | 34±0.6 |
| min | 884 | 1774 | 105 | 25 |
| max | 1823 | 4491 | 113 | 50 |

As mentioned earlier, the value of the work with Syrian landraces is mostly of methodological nature and our objective has been to generate national programs' interest for their locally adapted germplasm. So far the most significant examples of national programs adopting this methodology are Ethiopia and Egypt. There is also an excellent work on landraces in Tunisia which started independently from ICARDA activities.

In Ethiopia, the work on landraces started as an informal collaboration between IAR and ICARDA in 1988 when 180 landrace populations representing five administrative

regions were retrieved from the Plant Genetic Resource Center in Addis Ababa, where they were held in the form of bulks. The 180 landrace populations were tested in 1988 at three locations, and 60 populations were selected based on reaction to diseases and pests, and on agronomic evaluation. Twenty pure lines were extracted from each of the 60 selected populations, and a total of 1200 lines were obtained. The 1200 landrace-lines were multiplied at Holetta during the *Belg* season of 1989, and 600 of these (representing 30 populations) were used to start the selection work. The most significant results of this work are summarized in Table 2.1.18.

**Table 2.1.18. Grain yield (kg/ha) of 3 landrace-lines and of the local landrace in five locations in Ethiopia during 3-5 years testing.**

| | Locations | | | | | |
|---|---|---|---|---|---|---|
| Materials | Sheno | Holetta | Bekoji | Asasa | Adet | Mean |
| Line 3336-20 | 3316* | 1519 | 2069 | 4236** | 2810 | 2607** |
| Line 3291-15 | 3116 | 1335 | 1859 | 4034* | 2159 | 2361* |
| Line 3390-05 | 3250* | 1435 | 1852 | 3804 | 2300 | 2392* |
| Local landrace | 2618 | 1336 | 1726 | 3102 | 2410 | 2100 |
| L.s.d. (0.05) | 520 | 513 | 359 | 745 | 912 | 223 |
| L.s.d. (0.01) | 747 | 720 | 504 | 1130 | 1673 | 297 |

*P < 0.05; **P < 0.01

Three lines were identified which, across the entire set of testing sites and years, had an yield advantage of between 14% and 24% over the local landrace. Line 3336-20 showed a consistent superiority over the local landraces in all locations. The individual yield data (not reported here) indicate that only in three of the 19 comparisons the local landrace yielded more, and in two cases the difference was not significant. The superiority of the other two lines is more location specific. This is hardly surprising given the large climatic variability in the country.

This work is now continuing on a much larger scale as a special project funded by the Government of the Netherlands.

In Egypt the work on landraces is more recent. A trial constructed at ICARDA with Egyptian landraces held by the Genetic Resources Unit, was tested at two locations in the Sinai and in the north west coast in 1993.

The selected entries were tested in 1994 at El-Mathani, in the north west coast, with 99.5 mm rainfall, and at Raffah, in Sinai, with 123.2 mm rainfall. A third site in the north west coast was not harvested because of the severe drought.

**Table 2.1.19. Total biological yield (kg/ha), grain yield (kg/ha) and reaction to powdery mildew (PM, 0 = no disease, 9 = very susceptible) of Egyptian barley landraces and improved cultivars at Raffah (Sinai), Egypt.**

| Line | Biol. yield | Grain yield | PM |
|---|---|---|---|
| ICB 115641 | 3162 | 1097 | 5 |
| ICB 115642 | 2667 | 915 | 0 |
| ICB 115647 | 2255 | 779 | 1 |
| ICB 115653 | 2420 | 1088 | 5 |
| ICB 115654 | 2860 | 873 | 5 |
| ICB 115677 | 2612 | 946 | 4 |
| ICB 116132 | 2365 | 1011 | 5 |
| ICB 116134 (22) | 2750 | 998 | 3 |
| ICB 116134 (26) | 1897 | 668 | 1 |
| Local check | 2502 | 980 | 5 |
| **Improved Checks** | | | |
| Giza 123 | 2447 | 827 | 4 |
| Giza 124 | 2392 | 704 | 1 |
| Giza 125 | 2200 | 633 | 3 |
| Giza 126 | 1787 | 562 | 3 |
| Giza 127 | 1842 | 693 | 2 |
| L.s.d.$_{(0.05)}$ | 808 | 1088 | - |

Table 2.1.19 summarizes total biological yield, grain yield and powdery mildew reaction of some of the most promising landraces compared with a local check and with six improved checks in Raffah. Although none of the best lines outyielded significantly the best improved check, they proved to be as promising, either for total biological yield, or grain yield or resistance to powdery mildew, as the best cultivars developed through long years of breeding work.

This initial work on barley landraces in Egypt seems extremely promising particularly because it is based on a small (about 100) number of lines tested. The promising lines were collected in a restricted number of locations. Therefore, these results may guide in establishing priorities in future collection missions.

Egyptian landraces were also screened, together with breeding lines unrelated to landraces, both in the laboratory and in the field, at Giza Research Station for resistance to *R. maydis*, the major aphid species infesting barley. Two lines from landraces (LBEG 51 and LBEG 78) were found consistently resistant both in the laboratory and the field (Table 2.1.20). A third line from landraces (LBEG 39), together with an improved line (Arar/Lignee 527), was found moderately resistant. The lines found promising for one or more traits have been incorporated in the ICARDA crossing program to generate specific crosses for Egypt within the framework of incorporating this country in the decentralized breeding for north Africa.

**Table 2.1.20. Reaction to *R. maydis* in laboratory (expressed as total number of aphid per pot containing 5 seedlings) and in the field (scale from 1 = 0 to 25 aphids/plant to 5 = >500 aphids/plant) in Egypt**

| Line | Laboratory | Field |
|---|---|---|
| ICB 116132 (17) | 22.75 | 1 |
| ICB 116134 (18) | 24.5 | 1 |
| ICB 116131 (44) | 35.25 | 1 |
| Arar/Lignee 527 | 40.0 | 1 |
| Giza 126 (check) | 38.5 | 1 |

To assist those national programs which are interested

in using local landraces in their breeding programs, a sample of landraces from 11 different countries was assembled during 1993 with the assistance of the staff of the Genetic Resources Unit and was evaluated in 1994 at Tel Hadya in an unreplicated trial with systematic checks. There were two objectives to this work. The first was to characterize the phenology of landraces as one of the most important characters associated with adaptation. This information will be used to provide national programs with germplasm having the right phenology. The second objective was to use this material for training purposes to demonstrate the amount of variability available in this type of germplasm, and thus generate their interests. An example of this variability is shown in Table 2.1.21 for days to heading.

**Table 2.1.21. Days to heading (mean, ± s.e. and range) of barley landraces from 13 different countries.**

| Country | Nr. of lines | Days to heading Mean | S.E. | Range Min | Max |
|---|---|---|---|---|---|
| Afghanistan | 31 | 118 | ± 6 | 111 | 132 |
| China | 4 | 112 | ± 12 | 116 | 123 |
| Algeria | 6 | 120 | ± 3 | 116 | 123 |
| Egypt | 17 | 112 | ± 9 | 88 | 128 |
| Iran | 43 | 122 | ± 10 | 99 | 135 |
| Jordan | 146 | 109 | ± 3 | 106 | 133 |
| Libya | 64 | 111 | ± 5 | 88 | 120 |
| Pakistan | 32 | 110 | ± 5 | 105 | 124 |
| Tunisia | 31 | 119 | ± 4 | 109 | 126 |
| S. Union | 12 | 124 | ± 10 | 105 | 135 |
| Turkey | 45 | 127 | ± 7 | 106 | 139 |
| Syria | 718 | 113 | ± 3 | 101 | 123 |
| Yemen | 37 | 101 | ± 7 | 86 | 115 |
| **Checks** | | | | | |
| Arta | | 109 | ± 0.5 | | |
| Zanbaka | | 112 | ± 0.6 | | |
| Rihane-03 | | 112 | ± 1.1 | | |
| Martin | | 117 | ± 0.2 | | |
| Saida | | 120 | ± 0.5 | | |

The differences between countries of origin are often obvious considering the different environmental conditions prevailing in each country. For example, it is not surprising that landraces from Yemen, Jordan and Libya are earlier than landraces from Turkey, Soviet Union, Iran and Algeria. What is even more interesting is the variability between landraces within the same country. This variability is largely genetic as indicated by the magnitude of the standard error of the checks which is derived from data of 28 plots/check. The range in days to heading was small in the Algerian landraces (only 7 days), probably because of the small number of lines, but it was as high as 40 days in Egyptian landraces. This between and within country variability for an important adaptive trait such as days to heading, tells us the extent of specific adaptation which is needed to fit the crop to its environments. The phenology also is likely to represent an adaptation to a given farming system and/or to a given use of the crop, and a breeder will be unwise to drastically change this characteristic which may determine the adoption of future varieties. **- S. Grando, B. Lakew, Y. Semeane, A.A. El-Sayed, M.M. Noaman, F.A. Asaad and S.I. Bishara**

### 2.1.6. Progress with *Hordeum spontaneum*

Some of the first lines developed through crosses with *Hordeum spontaneum*, the wild progenitor of cultivated barley, have been tested for 4 years in 8 environments (years-locations combinations). Three of the best lines identified in the first year of testing have maintained their superiority over the landrace A. Abiad and even over the improved cultivar Arta (Table 2.1.22). They combine the level of tillering of the best selections from landraces with a lower reduction of plant height under drought than Arta. This is shown by the minimum values of plant height (recorded in Bouider in 1993). A tall crop even in very dry years, is important to farmers because it reduces their dependence on costly hand harvesting, and was one of the objectives of the work with *H. spontaneum*. The average grain yields are similar to those of the landraces, but in addition of being associated with taller plants, the lowest yields tend to be higher than those of Arta, and of the two landraces (A. Abiad

and A. Aswad). This would confirm the value of *H. spontaneum* to stabilize yield in dry years.

**Table 2.1.22. Grain yield (GY, average of 8 environments), total biological yield (TBY, average of 7 environments), plant height (average of 8 environments), and number of tillers per $m^2$ (TIL) of three lines derived from crosses with *H. spontaneum* compared to five checks.**

| Entry | GY (kg/ha) | TBY (kg/ha) | Plant height (cm) | TIL |
|---|---|---|---|---|
| SLB39-60/H.sp. 41-1 | | | | |
| mean ± s.d. | 1011±497 | 3648±1155 | 34±9 | 352±105 |
| min | 370 | 1610 | 22 | 173 |
| max | 2117 | 5433 | 48 | 495 |
| H.sp. 41-1/Tadmor | | | | |
| mean ± s.d. | 990±358 | 3798±795 | 41±12 | 406±102 |
| min | 469 | 2810 | 24 | 281 |
| max | 1560 | 4889 | 63 | 543 |
| SLB56-83/H.sp. 41-5 | | | | |
| mean ± s.d. | 953±450 | 3715±1073 | 45±14 | 342±80 |
| min | 445 | 2078 | 27 | 183 |
| max | 1901 | 5136 | 64 | 434 |
| Arta | | | | |
| mean ± s.d. | 1004±492 | 3508±894 | 28±6 | 339±53 |
| min | 314 | 1961 | 18 | 231 |
| max | 2028 | 4533 | 34 | 388 |
| Zanbaka | | | | |
| mean ± s.d. | 965±424 | 3430±873 | 39±12 | 318±78 |
| min | 467 | 1933 | 23 | 168 |
| max | 1862 | 4484 | 57 | 368 |
| Tadmor | | | | |
| mean ± s.d. | 925±456 | 3201±906 | 32±9 | 349±67 |
| min | 418 | 1985 | 20 | 225 |
| max | 1865 | 4391 | 46 | 433 |
| Arabi Aswad | | | | |
| mean ± s.d. | 921±340 | 3559±720 | 36±9 | 333±70 |
| min | 392 | 2822 | 25 | 267 |
| max | 1381 | 4513 | 49 | 450 |
| Arabi Abiad | | | | |
| mean ± s.d. | 971±607 | 3243±1455 | 31±9 | 304±77 |
| min | 399 | 1654 | 19 | 205 |
| max | 2385 | 5812 | 43 | 419 |

**Table 2.1.23. Differences between seven types of crosses with *Hordeum spontaneum* for grain yield in Breda, grain yield in Tel Hadya, days to heading, and plant height in Breda. (Initial yield trials 1994).**

| Type of cross[a] | Grain yield (kg/ha) Breda | Grain yield (kg/ha) Tel Hadya | Days to heading | Plant height (cm) |
|---|---|---|---|---|
| SPxI (n = 10) | | | | |
| mean±s.e. | 954±45 | 2630±105 | 101±1 | 55±2 |
| min | 738 | 2066 | 95 | 41 |
| max | 1216 | 3144 | 106 | 64 |
| SPxL (n = 14) | | | | |
| mean±s.e. | 1045±47 | 2245±114 | 103±1 | 52±2 |
| min | 820 | 1566 | 99 | 38 |
| max | 1414 | 2935 | 107 | 65 |
| SPx(IxL) (n = 6) | | | | |
| mean±s.e. | 1118±65 | 2384±147 | 102±1 | 52±3 |
| min | 973 | 1847 | 100 | 44 |
| max | 1359 | 3144 | 106 | 64 |
| (SPxI)xI (n = 15) | | | | |
| mean±s.e. | 1010±36 | 2754±123 | 111±2 | 47±2 |
| min | 737 | 2195 | 94 | 32 |
| max | 1232 | 3406 | 120 | 66 |
| (SPxI)xL (n = 4) | | | | |
| mean±s.e. | 1088±74 | 3320±197 | 109±1 | 39±1 |
| min | 947 | 2882 | 107 | 37 |
| max | 1227 | 3841 | 111 | 42 |
| (SPxL)xI (n = 5) | | | | |
| mean±s.e. | 1240±57 | 2870±174 | 105±1 | 50±2 |
| min | 1117 | 2525 | 103 | 45 |
| max | 1433 | 3532 | 106 | 55 |
| (SPxL)xL (n = 5) | | | | |
| mean±s.e. | 1132±33 | 2739±169 | 106±1 | 50±2 |
| min | 1044 | 2126 | 102 | 41 |
| max | 1211 | 3142 | 108 | 56 |
| Arta | 1558 | 3966 | 111 | 33 |

[a] SP = *H. spontaneum*; L = landraces; I = Improved

While the work with *H. spontaneum* continues to further improve plant height and yield stability in very dry years, we also tried to define the most efficient strategy of using *Hordeum spontaneum* in the crossing program. Although this requires a planned crossing program, we attempted a comparison between different types of crosses using the material evaluated in 1994 in the initial yield trial (Table 2.1.23). In Breda progenies from simple crosses between *H. spontaneum* and landraces (SP xL) are yielding better than progenies from crosses between *H. spontaneum* and improved germplasm (SP x I). In general the highest grain yield in Breda is obtained when selected lines from crosses between *H. spontaneum* and landraces are crossed either with improved germplasm (SP x L) x I) or landraces (SP x L) x L). The best results for grain yield in Tel Hadya are obtained with progenies derived from crosses between *H. spontaneum* x improved germplasm and landraces (SP x I) x L). In both cases the superiority of three-way crosses over simple crosses is likely to be associated with a reduction in rachis brittleness. - **S. Grando**

### 2.1.7. Response to Selection in Unfavorable Environments

The decentralization of barley breeding to national programs (described earlier) is a way to reconcile the need to breed for specific adaptation within the structure and the mandate of an international breeding program. Breeding for specific adaptation to stress environments implies the need to select in stress environments. This concept has been opposed by many breeders because of the low heritability in those environments. While this is not confirmed by the literature (Ceccarelli 1994)*, experimental data on actual response to selection in unfavorable conditions are not available. Because of its strategic importance, we have conducted between 1991 and 1994 an experiment to measure the response in unfavorable environments to selection conducted in both favorable and unfavorable environments. The selection took

---

* Ceccarelli, S. 1994. Specific adaptation and breeding for marginal conditions. Euphytica, 77:205-219.

place within the breeding material tested between 1986-1988, 1987-1989 and 1988-1990. In each group of breeding lines we selected the lines with the highest average yield under stress (YD) and the lines with the highest average yield potential (YP) using the same selection intensity. The three groups of selected lines (YD1 and YP1 selected in 1986-1988, YD2 and YP2 selected in 1987-1989, YD3 and YP3 selected in 1988-90) were tested in a range of 21 sites/years combinations between 1991 and 1994.

**Table 2.1.24. Mean and range of yield in unfavorable conditions (means of 5 sites with mean yields of 354, 566, 732, 859 and 1155 kg/ha, respectively) of three groups of barley lines selected in unfavorable (YD1, YD2, YD3) and in favorable (YP1, YP2, YP3) conditions**

| Material[a] | Mean | Range | YD/YP | TopYD/TopYP | Top line/check |
|---|---|---|---|---|---|
| YD1 | 737 | 596-798 | 1.46 | 1.19 | 0.88 |
| YP1 | 506 | 257-668 | | | 0.74 |
| YD2 | 804 | 585-909 | 1.25 | 1.06 | 1.01 |
| YP2 | 643 | 481-755 | | | 0.84 |
| YD3 | 948 | 870-1052 | 1.28 | 1.13 | 1.17 |
| YP3 | 738 | 606-846 | | | 0.94 |
| Best check | 903 | | | | |

[a] YD1, YD2 and YD3 indicate barley lines selected in unfavorable conditions in the three periods 1986-88, 1987-1989 and 1988-1990, respectively, whilst YP1, YP2 and YP3 indicate barley lines selected in favorable conditions in the same periods as the corresponding YD lines.

Table 2.1.24 shows the average yield in the five sites/years combinations with the lowest yields (ranging from 354 to 1155 kg/ha) as an estimate of yield in unfavorable conditions. In the five sites the average yield of the YD lines was between 25% and 46% higher than the YP lines, the top YD line was between 6% and 19% higher yielding than the top YP line, and none of the YP lines outyielded the best check which, not

surprisingly, was the locally grown landrace. It was also not surprising that the larger genetic gains over the best check were made with the group YD3 which was entirely made of pure lines selected from the local landrace.

These data provide a strong indication that a) it is indeed possible to make progress with selection under unfavorable conditions, and b) that a large amount of potential improvement in unfavorable environments is missed by breeding programs using only selection in favorable conditions. **- S. Ceccarelli and S. Grando**

## 2.2. Winter and Facultative Barley Breeding

Cultivation of barley is an essential and integral component of the stable and sustainable farming system in the highlands of WANA. It is the biggest source of animal feed especially during winter for stock feeding when no other feed source is available and the land surface is covered with snow for several months. In some regions it is an essential component of human diet also.

However, the barley production in the highland areas of WANA fluctuates enormously mainly due to variations in the severity of abiotic (temperature extremes, moisture deficiency and problematic soils) and biotic (diseases and insects) stresses. The stability in production of barley is necessary to assure the resource poor farmers a stable income.

The highland areas of WANA are highly diverse; agro-climatically variable and challenging. Therefore, to enhance sustainable barley production a strategy has been developed and is being executed, in close cooperation with the NARS scientists, to minimize the influence of afore-mentioned stresses.

Under this ICARDA/NARS joint strategy: 1. the climatic conditions of major barley growing areas are characterized; 2. the locally adapted germplasm is characterized for a large number of agronomic, physiological, genetical and crop phenological development traits; and 3. based on the information secured from 1 & 2 above a hybridization program is executed for the introgression of desirable genes from diverse sources into the genetically desirable agronomic background.

The process of introgression of desirable genes, subsequent selection of appropriate recombinants and evaluation and verification of their performance is carried out by a multi-disciplinary team of pathologist, entomologist, physiologist, soil scientist, biotechnologists, quality control scientist; and breeder. Ultimately field evaluation is done of all those lines where gene(s), or a part of chromosome segment or a small sequence of DNA has been incorporated for a given trait, functioning normally and not getting masked under much bigger genetic make up. Once the material has gone through this intensive and careful genetical manipulation process, the best performing lines are transferred to the collaborating NARS for their evaluation, testing and selection under their specific environments.

In pursuance of the above strategy the research activities carried during 1993/94 are reported briefly:

### 2.2.1. Characterization of Agro-climatic Environments

The long-term climatic data of five sites of Iran (Karmanshah, Orumiya, Zanjan, Hamadan, Ardabil) and a few sites in Turkey were critically examined. Each site revealed different agricultural features and therefore the need for a specific type of germplasm which can give better and stable production. The Zanjan, Hamadan and Ardabil are more cold and dry as compared to Karmanshah, Orumiya and Ankara. The rainfall pattern and other climatic data of the former three sites reveal that it is impossible to conserve enough moisture from the previous season rains for the germination and establishment of fall-sown crop there. Furthermore, the probability of early autumn rains is very low and the late on-set of winter precipitation (rain and snow) is not helpful in the germination of the dry-sown crop as the temperatures by that time would have already fallen below $0^0$C. Therefore, the seeds over-winter in the soil without germination. The effective germination and crop establishment takes place in late winter which leaves very short period for the crop to complete its life cycle. On the other hand, the weather at Karmanshah, Orumiya and Ankara is less severe and the rainfall distribution is well spread; the crop can get established before the on-set of severe winter. Therefore,

at these two sites very different type of germplasm is needed to obtain higher production.

### 2.2.2. Germplasm Development

Winter and facultative barley germplasm development involved recombination of desirable genes, and multilocation evaluation of the new germplasm.

**Introgression of desirable genes**

To cater to the diverse needs of different ecological regions to combat abiotic stresses, the crossing program was carried out by employing locally adapted germplasm on one hand and, the lines/cultivars carrying one or more desirable agronomic traits on the other. In total 840 single, double, top and backcrosses were made out under the following categories:

a. Cold and drought tolerance: 355
b. Cold and boron toxicity tolerance: 50
c. Cold and powdery mildew resistance: 65
d. Cold and multiple disease resistance: 185
e. High vernalization requirement with short reproductive phase: 56
f. Mild vernalization requirement, frost resistance at seedling stage with extra earliness: 35
g. Deep crown node with high tillering capacity: 94

Beside these new cross combinations, 10463 segregating populations were evaluated for different agronomic characteristics at Tel Hadya and Breda, out of which 2317 lines were selected for further evaluation (Table 2.2.1). In addition to the segregating populations 6390 genetically homozygous lines were also evaluated in the form of various nurseries, out of which a total of 2851 lines were selected for further testing at key locations in Turkey and Iran.

### 2.2.3. Breeding for Cold, Drought and Adaptability

Cultivation of barley is an essential component of the farming system in the highlands of WANA but its production fluctuates enormously due to sever abiotic and biotic stresses. Of these factors, drought, cold and winter-kill are the most important ones. Stability in production and adaptability to different high-elevation environments of winter barley primarily depends on cold tolerance, winter hardiness, growth habit and drought tolerance.

**Table 2.2.1. Winter barley germplasm development.**

| Nursery* | Number | | Testing site |
|---|---|---|---|
| | Total | Selected | |
| F0 | 840 | - | Tel Hadya |
| F1 | 751 | 675 | Tel Hadya |
| F2 | 1080 | 710 | Tel Hadya, Turkey, Iran and Internationally |
| F3 | 460 | 397 | Tel Hadya, Breda, Terbol, Turkey, Iran |
| F4 | 900 | 210 | Tel Hadya, Breda |
| F5 | 7272 | 325 | Tel Hadya |
| Elite Bulk | 4125 | 1433 | Tel Hadya, Turkey |
| PBSN | 1386 | 835 | Tel Hadya, Breda, Turkey |
| WFBYT | 24 | 14 | Internationally |
| FBYT | 24 | 11 | Internationally |
| WFBON | 152 | 77 | Internationally |
| FBON | 152 | 68 | Internationally |
| Elite BON | 30 | 22 | Tel Hadya, Turkey, Iran |
| Hulless BON | 60 | 30 | Tel Hadya |
| WFB-CB | 201 | 150 | Internationally |
| Exotic WB Germ | 236 | 211 | Tel Hadya, Turkey (5 locations) |

* PBSN: Preliminary Barley Screening Nursery; WFBYT: Winter & Facultative Barley Yield Trial; FBYT: Facultative Barley Yield Trial; WFBON: Winter & Fac. Barley Observation Nursery; FBON: Facultative Barley Observation Nursery; CB: Crossing Block.

These characters are inter-woven and associated with each other. Beside the genetic control the growth habit is also affected by degree of vernalization and photoperiodism. High degree of vernalization and long photoperiod requirements contribute to cold tolerance and adaptation of

winter barley to highly variable highland environments in WANA.

In addition to the strong association of vernal genes with cold tolerance the winter hardiness is also greatly affected by the crown node depth; i.e., the cultivars with deep crown node can better tolerate sever cold, make use of moisture stored beyond the normal sowing depth for early crop establishment, and escape massive winter damage in sever cold areas with out snow cover. Therefore, the problems of drought, cold and winter damage in winter barley is being tackled from four angles to bring stability in production:

a. Study the growth habit of locally adapted and new barley germplasm.
b. Incorporation of vernal and photoperiod gene(s) to tailor the crop phenology that matches with agroclimatic conditions of different regions.
c. Identify lines with deep crown node and incorporate this character in to the new germplasm.
d. Test the developed germplasm at various temperatures below $0^0$C under controlled environments to determine precisely its cold tolerance level (LT-50) and under field conditions at a number of cold and drought-prone sites in the high elevation areas of the region.

The earlier studies carried out on growth habit of locally adapted germplasm from continental highlands of WANA had revealed a gradual gradation in growth habit ranging from spring types (with-out vernal gene) to pure winter types (carrying vernal genes). The available materials were classified in to three categories, i.e., spring (15%), facultative (with moderate vernalization requirements) (55%), and winter types (30%) with strong or long vernalization requirements. In the light of these results all the newly developed germplasm of winter and facultative barley was evaluated first under field conditions by planting in summer, as the temperature is high (above 10°C) and can not fulfil the vernalization requirements of winter types which will, therefore, not head; the spring types devoid of vernal genes will head and the facultative types with weak vernal genes will have only partial heading. After field screening the selected material was evaluated under controlled environments

for determining the vernalization and photoperiod response. With this strategy a major genetic shift, from spring to facultative and winter types, has been brought about (Fig.2.2.1). In 1990, 71% of the material was spring type and only 20 and 9%, was of facultative and winter types, respectively. However, the studies on growth habit carried out on 1763 newly developed advanced barley germplasm, in 1993/94 showed that 65, 25, and 10% of the lines were of winter, facultative and spring types, respectively. This evaluation and screening has helped in better targeting the material.

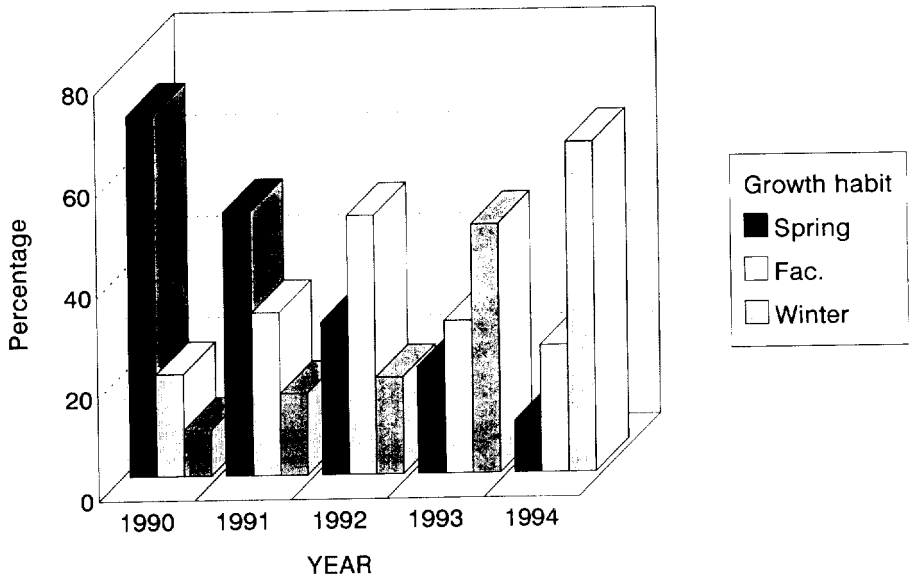



Fig.2.2.1. Genetic shift in growth habit of W & F barely germplasm based on vernalization requirements

The growth habit is controlled by the number and type of Sh gene(s) which subsequently determine the vernalization requirements in barley. Therefore, efforts have been made to develop a simple parameter for the identification of winter and spring types under field conditions. In wheat the prostrate growth habit is associated with winter types where as the plants of spring types are eract. However, in barley the information on this association is lacking. Therefore, studies on a wide range of germplasm (1155 lines/cultivars)

were carried out according to the procedure described above during the summer of 1994. In addition, data on heading date and prostrateness on a scale 1 (eract) to 5 (very prostrate) were scored. These studies revealed that all the winter types (697 lines/cultivars) have prostrate growth habit, however, all the prostrate types were not found to be winter types because four spring cultivars i.e., Rrsk, Perelom, K625 and K615 also had very prostrate early growth and almost fully headed during summer planting without vernalization.

All the 454 spring-type lines were eract and fully headed during summer planting at Tel Hadya except four lines from Russia (Odessa 100, K623, K253/Perelom, and K66 M8) (Table 2.2.2). However, when these four spring-type lines were planted at Krasnodar, Russia during spring, they fully headed without vernalization, therefore this non-heading behaviour at Tel Hadya is not explainable. The possible reasons could be their weak vernalization requirement coupled with sensitivity to high temperature and decreasing day length.

These studies nevertheless suggest that by planting the new germplasm during early summer and securing the data on growth habit and heading time, the material can be classified to a great extent into winter and spring types without evaluation under expensive controlled environments.

### 2.2.4. Crown Node Depth

Major winter damage in barley is due to the direct effect of low temperature on plant tissue, soil heaving, smothering and desiccation (Dafing and Schmidt 1985)*. In highland environments in parts of Turkey and Iran sever cold, often without snow cover, and moisture stress occur during early plant development stages. In the young barley seedling, crown is the most sensitive part to cold and its exposure to freezing temperature can cause 100% non-recoverable damage. Moisture deficiency in the top layer of soil aggravate the

---

* Dafing, S.M. and Schmidt, J.W. 1985. Relationship between subcrown internode length and winter survival in winter barley. Crop Sci. 25:690-692.

adverse effect of cold from germination to tillering stage.

**Table 2.2.2. Growth habit (GH) and heading behaviour in barley sown in summer of 1994.**

| Variety/Cross | GH* | GV** | Heading date | Percent heading |
|---|---|---|---|---|
| Mean of 450 spring types | 2 | 4 | 4/9 | 90-100 |
| Mean of 695 winter types | 4-5 | 4 | - | 0-20 |
| *Exceptions*: | | | | |
| Rrsk - spring type | 4 | 4 | 10/9 | 70 |
| Perelom - spring type | 5 | 4 | 10/9 | 60 |
| K625 - spring type | 5 | 4 | 12/9 | 60 |
| K615 - spring type | 5 | 5 | 10/9 | 60 |
| Odessa 100 - spring type | 2 | 5 | - | - |
| K623 spring type | 3 | 4 | - | - |
| K253-Perelom - spring type | 2 | 5 | - | - |
| K66 M8 - spring type | 3 | 4 | - | - |

* GH = 1 Eract (Spring type) - 5 Prostrate (winter type).
** GV = Growth Vigor: 1 (Poor - 5 Excellent).

Every 1 cm layer of soil is able to prevent the lowering of soil temperature by 0.5°C between depth of 2.5 and 7.6 cm during periods of lowest low temperatures. Hence a difference of 1°C in the depth of crown node can result in a difference of bewteen 0 and 100% survival (Gusta and Fowler 1979; Tahir et al 1991)*. Therefore, deep crown formation would appear to enhance winter survival. There are, however, some negative aspects associated with deep crown formation. In areas where planting is done on conserved mositure or dry soil, deep sowing is highly advantageous for the crop establishment before the on-set of severe cold winter,

---

* Gusta, L.V. and Fowler, D.B. 1979. Cold resistance and injury in winter cereals. P. 159-178. In H. Mussell and R.C. Staples (eds.) Stress Physiology in Crop Plants. John Wiley & Sons. New York.
Tahir, M., Pashayani, H. and Hoshino, T. 1991. Breeding of cold tolerant, early maturing wheat and barley varieties. P. 283-2992. In E. Ecevedo, et al (eds.) Improvement and Management of Winter Cereals under Temperature, Drought and Salinity Stresses. Ministry of Agriculture-Spain.

provided the soils are of non-crusting type. However, the deep planting can cause poor germination and low tillering/plant. Considering the agro-climatic conditions and the existing farming practices the advantages of deep planting overweigh the negative aspects. Therefore, studies were carried out to: a) investigate the genetic variation in crown-node depth and its correlation with tillering capacity and cold tolerance; and b) combine deep crown node character with high number of tillers/plant. Brief summary of results are reported here.

A total of 150 genotypes of winter barley were evaluated for their crown node depth (CND) and cold tolerance by planting at a depth of 8 cm and 10 cm with three replications and 20 plants/plot. Table 2.2.3 shows that 36 genotypes had an average of 5.5 cm deep crown node, with a range of 5.1 to 7.8 cm, 3.4 tillers/plant and a very high level of cold tolerance (95% survival). Twenty four genotypes were found to have very high number of tillers/plant but their mean crown node depth was 4.4 cm and the cold survival only 65% as compared to 95% in the lines with deeper crown node. A great majority of the lines (90) were found to have long sub-crown internode and a relatively shallow crown node (4.0 cm). These lines had poor tillering capacity (2.8/plant) and cold only 55% survival. A significant correlation coefficient (r=0.62) between CND and winter survival was found. However, the number of tillers/plant was found to be negatively correlated (r = -0.41) with crown node depth. However, five genotypes (Plaisant, Narcis, Sigra, Cyclone and Roho/Mazurka//ICB103030) had CND of 5 cm or more and tillers/plant ranged from 5-7.6 as compared to widely grown cultivar Tokak which had 3.9 cm CND of and an average of 6 tillers/plant. Those five genotypes, at the same time, had much higher cold survival (90-100%) as compared to 60% in Cv Tokak.

**Table 2.2.3. Crown node depth (CND), tillering per plant and cold tolerance of some barley genotypes.**

| Classification of tested entries | No. of genotypes | Average CND (cm) | Till./P | Cold surv. (%) |
|---|---|---|---|---|
| 1. Lines with deep CND | 36 | 5.5 | 3.4 | 95 |
| 2. Lines with high till/P | 24 | 4.4 | 5.1 | 65 |
| 3. Lines mod. cold toler. | 90 | 4.0 | 2.8 | 55 |
| 4. Lines with deep CND & high till./plant: | | | | |
| Plaisant | | 5.5 | 5.0 | 90 |
| Narcis | | 6.0 | 6.0 | 100 |
| Sigra | | 5.1 | 7.6 | 95 |
| Cyclone | | 5.5 | 5.8 | 100 |
| Roho/Mazurka//ICB 103020 | | 5.0 | 5.8 | 90 |
| 5. Check lines (Tokak) | | 3.9 | 6.0 | 60 |

From these studies it appears that it is possible to develop improved winter barley cultivars with deep CND, better tillering capacity and high level of winter survival. Such cultivars will also be more suitable for deep sowing in conserved moisture situations and widely adapted to variable moisture and cold conditions. - **M. Tahir and V. Shevstov**

### 2.2.5. Evaluation for Cold and Drought Tolerance

The improved W & F barley germplasm developed at ICARDA is evaluated at various testing sites for cold tolerance and winter hardiness in Turkey and Iran in collaboration with the national programs there. In 1993/94, a total of 6581 accessions, comprising segregating populations and advanced material were tested at Haymana, Kazan, Ulas and Altinova in Turkey for cold tolerance and specific adaptability for boron-toxicity tolerance. Due to agroclimatic variations, increasing emphasis has been laid on testing of early segregating populations ($F_2$ onwards) to generate material specifically adapted to highland conditions of Turkey. Of a total of 3382 segregating populations 692 populations on the basis of their cold and boron toxicity tolerance were selected at Kazan and Haymana (Table 2.2.4). However, in

case of genetically homozygous material only 18% of a total of 3200 lines were selected on the basis of their good cold tolerance, boron toxicity resistance and agronomic score for further evaluation at a large number of sites in Turkey. In case of Iran the amount of material tested has been relatively small due to limited technical manpower but the work will be expanded in the coming years.

A set of these genotypes tested in Turkey and Iran were also evaluated for drought tolerance at Breda (Table 2.2.4.) to identify lines that combine the trait of moisture stress tolerance with cold tolerance. With this multi-location testing and selection strategy rapid progress has been made in the identification of high yielding, stress tolerant barley material which is provided to the NARS in the form of observation nurseries and yield trials.

**Table 2.2.4. Evaluation and selection of W & F barley genotypes for cold and drought tolerance during 1993-94.**

| Nursery | | Numbers selected at | | | | | |
|---|---|---|---|---|---|---|---|
| | No. of lines | Haymana | Kazan | Ulas | Altinova | Iran | Breda** |
| WFBCB3 | 150 | 48 | 45* | | | 25 | 91 |
| IWFB-F2 | 150 | 38 | - | | | 47 | 65 |
| WFB-F2 | 940 | - | 340 | | | | 556 |
| WFB-F3 | 303 | 109 | 170 | | | | - |
| WFB-F5 | 1989 | | 144 | | | | |
| EWB-L | 1068 | | 198 | | | | |
| WFBPSN | 1202/1380 | | 151 | | | | 865 |
| PWBYT | 251 | | 168 | 48 | 148 | | 162 |
| IWFBON | 150 | 22 | | | | 76 | 87 |
| IFBON | 150 | 12 | | | | | 117 |
| RWBYT | 34 | 17 | 22 | 16 | 24 | 13 | 14 |
| IWBYT 3 | 24 | 6 | | 4 | 6 | 12 | - |

* Selected at Eskesher; ** Selection at Breda was for drought tolerance

### 2.2.6. Yield Structure in Barley

A study was carried out at Tel Hadya and Breda two sites with different rainfall, involving varieties widely cultivated in the rainfed areas and a high yielding new line (Rihane-03) to understand the role of different agronomic traits in the

build up of yield. The data in Table 2.2.5 did not show major differences in the yield at Tel Hadya (season rainfall 373 mm) whereas at Breda (season rainfall 291 mm) significant differences were observed and Rihan-03 gave the highest yield followed by Roho/Mazurka. The data on yield components show that in variety Rihan-03 has higher grain number per spike, and better root dry weight which might have contributed towards its better performance in spite of its lower total as well as productive tillers per plant. This lower tiller number and better developed roots might have helped the productive tillers to better utilize the available moisture. In case of Roho/Mazurka, beside well developed root system and grain number, it had higher TKW (1000-kernel weight) and relatively greater number of productive tillers which contributed towards its better performance under stress conditions. The mechanisms of yield formation in Arabic Abiad, a land race, and Tokak, a very old Turkish winter barley variety, appear to be very different. Both these cultivars have higher number of total tillers which are reduced drastically under stress situation. However, both these lines have a tendency to respond positively to improved agronomic conditions as their total biomass at Tel Hadya was the highest. Under moisture-stress situation they do not produce large root system, rather a few well developed roots only. Both these varieties, therefore, have a buffering capacity to perform well under variable agroclimatic conditions, hence they are widely adapted.

The correlation coefficients among different agronomic traits of these cultivars given in Table 2.2.6 show that yield was positively correlated with productive tillers/plant, total dry matter, grains/plant and harvest index under both the test environments. Significant negative correlation was observed between yield and time to heading, indicating the importance of earliness in areas with terminal moisture stress and high temperature. That is why early maturing variety Rihan-03 gave significantly higher yield than late maturing varieties. Plant height in the better environment (Tel Hadya) is negatively correlated with most of the yield components whereas no relationship was observed under more stressed environment (Breda). High tillering capacity seems to be a highly desirable trait not only for obtaining good yield but also for providing elasticity to

perform better under variable stressed environments. Productive tillers and harvest index had significant positive effect on yield at both the sites. Thus, high harvest index, productive tillers, total biomass, and grains/plant have significantly positive effect on the yield performance of a genotype. - **M. Tahir and V. Shevstov**

### 2.2.7. Breeding for Earliness and Lodging Resistance

Cold tolerant winter barley varieties normally carry vernal and photoperiod sensitivity genes which induce lateness. In the continental Mediterranean environments, however, the late maturing lines suffer due to terminal moisture stress coupled with rapidly rising temperatures in late spring. Efforts, therefore, have been made to incorporate the vernal genes into day-neutral genetic background to overcome the problem of lateness in the newly developed cold tolerant material. Some 150 improved, cold-tolerant lines were supplied to the NARS in WANA in the form of International Winter and Facultative Barley Observation Nursery (IWFBON). The results from 16 locations in highlands show that 65 lines were selected on the basis of cold tolerance and early maturity. The data of five top-yielding, early-maturing lines are presented in Table 2.2.7 in comparison to spring-type, early maturing improved check cultivar Rihan 03. Though all these lines contained vernal genes but their maturity time was similar to that of spring-type check. It is interesting to note that four of the top yielding lines (Nos. 8, 14, 18 and 33) had locally adapted landraces in their parentage.

All the lines were also evaluated for lodging resistance. Seventeen lines did not lodge at all where as another 24 lines showed less than 10% lodging. The yield of these lodging resistant lines ranged from 3223-4692 kg/ha.

**Table 2.2.5. Yield components and yield of some winter barley varieties at Tel Hadya (373 mm rainfall) and Breda (291 mm rainfall) in 1993/94.**

| Variety | No. tiller /plant | Productive tillers/ plant | Dry matter per plant (g) | | | | Harvest index | Average spike | | TKW (g) | Spikes /m2 | Seed yield kg/ha |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total | Roots | Straw | Grain | | grain number | weight (g) | | | |
| **Tel Hadya** | | | | | | | | | | | | |
| A. Abiad | 7.1 | 4.4 | 12.73 | 3.96 | 3.40 | 3.44 | 0.50 | 18.6 | 0.78 | 42.2 | 550 | 4333 |
| Rihane-03 | 4.9 | 2.6 | 11.22 | 5.03 | 3.20 | 3.22 | 0.50 | 34.7 | 1.24 | 36.3 | 332 | 4110 |
| Salmas | 5.8 | 3.5 | 8.82 | 2.80 | 3.21 | 2.82 | 0.46 | 19.7 | 0.81 | 40.9 | 510 | 4110 |
| Tokak | 8.8 | 4.1 | 11.52 | 4.06 | 4.66 | 2.79 | 0.37 | 15.5 | 0.68 | 43.8 | 560 | 3888 |
| Roho/Mazurka | 7.6 | 5.1 | 10.68 | 3.26 | 3.66 | 3.66 | 0.50 | 18.4 | 0.72 | 39.3 | 590 | 4250 |
| LSD 0.05 | | | | | | | | | | | | 663 |
| **Breda** | | | | | | | | | | | | |
| A. Abiad | 6.3 | 4.4 | 6.25 | 0.83 | 2.76 | 2.66 | 0.49 | 17.9 | 0.67 | 37.6 | 416 | 2788 |
| Rihane-03 | 3.4 | 2.6 | 6.54 | 1.27 | 2.78 | 2.49 | 0.47 | 30.5 | 0.96 | 31.4 | 306 | 2944 |
| Salmas | 4.1 | 3.0 | 5.26 | 0.56 | 2.67 | 2.07 | 0.44 | 18.1 | 0.69 | 38.1 | 325 | 2244 |
| Tokak | 5.6 | 2.9 | 5.34 | 0.75 | 2.74 | 1.83 | 0.40 | 18.0 | 0.63 | 35.0 | 382 | 2410 |
| Roho/Mazurka | 4.9 | 3.3 | 6.41 | 1.04 | 2.78 | 2.58 | 0.48 | 21.0 | 0.78 | 37.1 | 363 | 2833 |
| LSD 0.05 | | | | | | | | | | | | 536 |

**Table 2.2.6. Correlation coefficients between yield and yield attributes structure indices in winter barley at Tel Hadya (site 1) and Breda (site 2).**

| Character | Site | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1.Total tillers | 1 | 0.67 | 0.33 | -0.65 | 0.34 | 0.11 | 0.10 | 0.10 |
| | 2 | 0.82 | -0.30 | -0.62 | 0.04 | 0.35 | 0.31 | 0.31 |
| 2.Productive tillers | 1 | | -0.41 | -0.94 | 0.60 | 0.73 | 0.65 | 0.68 |
| | 2 | | -0.78 | -0.53 | 0.36 | 0.71 | 0.72 | 0.61 |
| 3.Days to heading | 1 | | | 0.38 | -0.47 | -0.76 | -0.66 | -0.70 |
| | 2 | | | 0.30 | -0.56 | -0.84 | -0.89 | -0.63 |
| 4.Plant height | 1 | | | | -0.60 | -0.61 | -0.64 | -0.74 |
| | 2 | | | | 0.24 | -0.11 | -0.15 | 0.08 |
| 5.Total dry weight/plant | 1 | | | | | 0.75 | 0.86 | 0.78 |
| | 2 | | | | | 0.83 | 0.78 | 0.83 |
| 6.No.of grain/ plant | 1 | | | | | | 0.91 | 0.85 |
| | 2 | | | | | | 0.99 | 0.69 |
| 7.Harvest index | 1 | | | | | | | 0.96 |
| | 2 | | | | | | | 0.63 |
| 8.Yield (kg/ha) | | | | | | | | |

**Table 2.2.7. Performance of early maturing lines out of IWFBON at 16 locations in WANA, 1993/94.**

| Entry no./Pedigree | DH | DM | PH(cm) | Yield (kg/ha) |
|---|---|---|---|---|
| Rihane 03 | 140 | 204 | 74 | 4299 |
| 8-Roho/Mazurka//ICB 102874 | 152 | 201 | 79 | 4226 |
| 14-Rihan/Lignee 640//ICB 102854 | 153 | 203 | 78 | 4389 |
| 18-CWB 117-77-9-7/ICB 102893 | 155 | 202 | 72 | 4531 |
| 33-Kitchen Muller Heydla//Salmas | 155 | 203 | 74 | 4588 |
| 51-Lignee 131/5/Cq/Cm//Apm... | 155 | 204 | 75 | 4584 |

DH=days to head; DM=days to mature; PH=plant height

### 2.2.8. Breeding for Specific Adaptability

Three nurseries, i.e. International Winter Barley Segregating Populations (IWBSeg.P.), International Winter Barley Observation Nursery (IWFBON) and Winter Barley Crossing Block

(IWFBCB), each comprising of 150 lines, were supplied to the NARS in the highlands of Algeria, Iran, Jordan, Nepal, Pakistan and Turkey. The data on the number of selections made by the researchers at different stations are presented in Table 2.2.8. The analysis of the lines selected by each station showed very low frequency (<3%) of commonly selected lines at more than two sites, which emphasises the importance of specific adaptation in the improvement of W & F barley for the highland areas. - **M. Tahir and V. Shevstov**

### 2.2.9. Breeding for Diseases Resistance

Several diseases adversely effect the winter barley production. A total of 150 selected lines were evaluated against powdery mildew, net blotch, scald, Helminthosporium sp. and leaf rust at the hot-spot locations of Iran, Turkey, Russia, France, Greece and Uruguay. This testing aimed at identifying broad based resistance against a variety of pathogens and their pathotypes. The number of lines selected as resistant to different diseases in each country are given in Table 2.2.9. A number of lines were found to be resistant to more than one disease.

Four lines, Mahli Shehr Kurd, No. 1246/1-3//4056/1-3/3/Cum 50, Bulbul and ZDM 8307 were resistant to all the diseases. Mahli Shehr Kurd is a landrace from Iran and has also been reported to be tolerant of cold and heat resistant, whereas two of the remaining multiple disease lines have Turkish landraces in their pedigree. Variety ZDM 8307 originated from China. Identification of these multiple disease resistant lines out of the local germplasm shows the richness and usefulness of the local germplasm in winter barley.

### 2.2.10. Powdery Mildew (Erysiphe graminis f.sp. hordei) Resistance

Powdery mildew (PM) is one of the most wide-spread disease throughout the highlands of WANA. Lines totalling 150, supplied to NARS as IWFBON, were screened for powdery mildew resistance on a scale of 1 (resistant) to 9 (susceptible).

Forty nine lines with disease infestation rating of 1-2 were selected having a yield range of 2982 kg to 4656 kg/ha. The agronomic data of the five top yielding, PM resistant lines are given in Table 2.2.10. With the exception of Ent. No. 99 which is from Oklahama, USA all entries were either selections out of landraces (C115695) or crosses involving landraces (ICB 102893 and ICB 102874 from Afyon, Turkey) or local cultivars (Cv. Zarjau from Iran) from the highlands of Turkey and Iran. Two other derivatives of a cross involving local cultivar from Iran (Zarjau/80-5151) were also among the resistant lines.

**Table 2.2.8. Breeding for specific adaptibility. Selction frequency of W&F Barley lines by NARS.**

| Location | No. of entries selected from 150 entries in each nursery | | |
|---|---|---|---|
| | IWFBON | IWB Seg.P. | IWFBCB |
| Sariab, Pakistan | 45 | - | 33 |
| Kebre, Nepal | 34 | 28 | - |
| Karaj, Iran | 66 | 27 | 79 |
| Orumyeh, Iran | 47 | 17 | 34 |
| Haydaride, Iran | 51 | 30 | - |
| Ramtha, Jordan | - | 31 | - |
| Konya, Turkey | 67 | 16 | 65 |
| Kharoub, Algeria | 47 | 44 | - |

**Table 2.2.9. Breeding for disease resistance in winter barley.**

| Disease | No. of lines selected in | | | | | |
|---|---|---|---|---|---|---|
| | Iran | Turkey | Russia | France | Greece | Uruguay |
| Powdery mildew | 19 | 45 | 40 | - | 38 | N.A. |
| Net blotch | - | 35 | 78 | 13 | N.A. | N.A. |
| Scald | 44 | - | - | 21 | N.A | N.A. |
| Helminthosporium | 39 | 76 | - | 29 | N.A. | 35 |
| Leaf rust | N.A | N.A | 65 | N.A | N.A | N.A. |

N.A.= Not Available; -= Not tested.

**Table 2.2.10. Powdery mildew resistant high yielding lines.**

| Entry No. | Cross/line | Yield (kg/ha) | DH | DM | PH (cm) | Lodging % |
|---|---|---|---|---|---|---|
| 99 | OK 84813 | 4478 | 161 | 205 | 86 | 6 |
| 146 | CI 15695 | 4513 | 168 | 204 | 77 | 10 |
| 35 | CWB 22-6-13/ICB 102893 | 4472 | 159 | 204 | 80 | 22 |
| 8 | Roho/Mazurka//ICB 102874 | 4656 | 159 | 205 | 77 | 0 |
| 122 | Zarjau/80-5151 | 4469 | 159 | 205 | 82 | 6 |

DH=days to heading; DM=days to maturity; PH=plant height

### 2.2.11. International Testing of Improved Germplasm

One of the major objectives of W & F barley improvement program is to supply NARS the improved germplasm which can better withstand the abiotic and biotic stresses and give stable, high yield. The improved and targeted germplasm was supplied in the form of various nurseries for local testing, evaluation and selection by the NARS scientists.

#### 2.2.11.1. IWFBON (International Winter and Facultative Barely Observation Nursery)

This nursery comprised 150 entries of the most advanced material developed at ICARDA which had gone through several cycles of selection at selected key locations in the highlands of WANA. It was evaluated at 16 locations. The characteristics of entries selected five times or more out of 16 locations are presented in Table 2.2.11. All the selected lines, except entry Nos. 71, 61, and 47, had locally adapted germplasm in the recombination of desirable genes. The detailed results of each location are published in our International Nursery Report.

**Table 2.2.11. Characteristics of IWFBON entries selected 5 times or more out of 16 locations in the IWFBON 1993/94.**

| Entry no. | Name/Cross | Sum Sel | Mean Yield (kg/ha) | DH | DM | PH (cm) | PM | Lodging (%) |
|---|---|---|---|---|---|---|---|---|
| 4 | Rihan/Lignee 640//ICB 102854 | 7 | 4389 | 153 | 203 | 78 | 4 | 40 |
| 108 | Bkf/Magnelone 1604//Aloutte | 6 | 3899 | 160 | 204 | 61 | 3 | 0 |
| 54 | Lignee 131/Soufara-02 | 6 | 3771 | 157 | 203 | 76 | 2 | 22 |
| 33 | Kitchen/Mullers Heydla/Salmas | 6 | 4588 | 155 | 203 | 74 | 3 | 26 |
| 58 | YEA455-25//4679/105 | 6 | 3782 | 158 | 204 | 83 | 3 | 6 |
| 76 | GB3433/TOK II | 5 | 4076 | 164 | 206 | 88 | 3 | 58 |
| 71 | Alpha/Quinn | 5 | 3948 | 164 | 205 | 85 | 4 | 44 |
| 51 | Ligneel31/5/Cq/Cm//Apm/3/12410/ Giza 134 | 5 | 4584 | 155 | 204 | 75 | 4 | 20 |
| 98 | 26106 | 5 | 4088 | 159 | 205 | 81 | 3 | 16 |
| 61 | Kitchen/Mullers Heydla | 5 | 3496 | 158 | 204 | 82 | 3 | 6 |
| 47 | Victoria | 5 | 4356 | 160 | 204 | 79 | 3 | 19 |
| 14 | CWB22-6-13/ICB-102893 | 5 | 4441 | 162 | 206 | 79 | 3 | 53 |
| 12 | Roho/Mazurka//ICB-103020 | 5 | 4518 | 157 | 202 | 79 | 2 | 60 |
| 48 | Roho/Mazurka | 5 | 4656 | 159 | 205 | 77 | 2 | 0 |
| 126 | ICB103515/80-5144 | 5 | 3954 | 156 | 202 | 71 | 3 | 38 |
| 84 | Roho//Alger/Ceres 362-1 | 5 | 4458 | 159 | 201 | 79 | 3 | 38 |

DH=days to heading; DM=days to maturity; PH=plant height; PM=powdery mildew resistance rating

**2.2.11.2. IWFBYT (International Winter and Facultative Barley Yield Trial)**

This replicated trial comprising of 24 best, widely tested entries, provides access to NARS of the most advanced material for their direct or indirect use, depending on their needs and capability for use. Like IWFBON this trial is also distributed globally on request, however, here the results of three highland sites from Iran are summarized in Table 2.2.12. Each of the three sites represents a different ecological region. Ardabil is very cold and moderately dry, whereas Zanjan is very cold and moisture stressed site with short span of rainfall distribution. Karmanshah is a high yielding with site only moderate cold and adequate and good rainfall distribution. At each location check was a local improved variety.

The yield at Ardabil ranged from 1.76 - 3.83 t/ha. Two lines, YEA 422.1/YEA 455.25//..., and Boyer/Ij-126/6/cm 14, F1/3/--- gave significantly higher yield (Table 2.2.12) than the two check varieties (Zarjau and Star). The high yielding lines have a higher thousand kernel weight and were more cold tolerant as compared to the local checks. At Zanjan all the entries out yielded the local check, Gorgan-4. The yield of the top five lines ranged for 185-308% of the check cultivar (Table 2.2.12). The better performance of the tested entries was due to high level of cold and drought tolerance. At Karmanshah, there was an increase of 115 - 135% in the yield of best test entries over the national check but only two entries, CWB 117-77-9-7/ICB 104073 and Roho/Mazurk//ICB 103020 ICB 103020 gave significantly higher yields than the check cultivar.

From these data it is obvious that the three sites are very different from each other as none of the best performing line was among the top yielders across all sites. All the selected lines have been included in the national trials for further testing.

From the studies and results reported in the preceding pages it is evident that the strategy of multi location testing and use of locally adapted germplasm in the introgression of desirable genes in good genetic background is a dependable strategy for rapid progress in the W & F barley germplasm improvement for highland areas.

**Table 2.2.12. Characteristics of top yielding winter barley lines in Iran, 1993-94.**

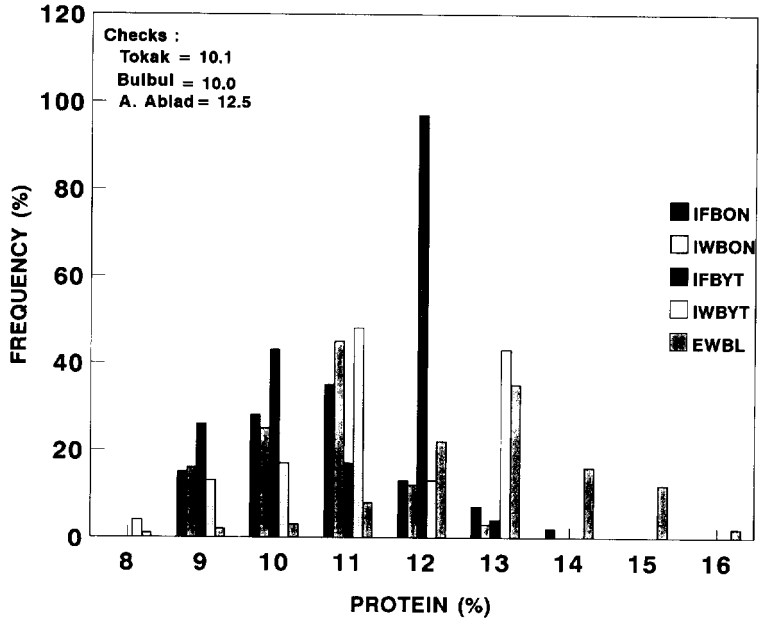
| Variety/cross | DH | DM | PH (g) | TKW | Yield (t/ha) |
|---|---|---|---|---|---|
| **a. Ardabil:** | | | | | |
| YEA 1276/132TH//5053 YEA... | 209 | 248 | 69 | 41 | 2.73 |
| Hj 33-81/Malta//YEA 196-3... | 201 | 247 | 75 | 42 | 2.85 |
| YEA 422.1/YEA 455.25//... | 205 | 246 | 70 | 41 | 3.83 |
| Boyer/Ij-126/6/Cm14,F1/3/... | 202 | 247 | 83 | 45 | 3.41 |
| Zarjow (check) | 205 | 249 | 59 | 34 | 2.21 |
| Star (improved check) | 205 | 250 | 71 | 36 | 2.58 |
| CV (%) | | | | | 25.05 |
| LSD at 5% | | | | | 0.87 |
| **b. Zanjan:** | | | | | |
| 1246/78//1246/105 | 223 | 254 | 56 | | 1.23 |
| Tokak | 221 | 248 | 58 | | 1.68 |
| Bulbul | 221 | 252 | 61 | | 2.05 |
| 132 TH/Tokak | 220 | 250 | 63 | | 1.55 |
| YEA 560.2//Luther/BK259 | 222 | 251 | 61 | | 1.75 |
| Gorgan-4 (check) | 217 | 248 | 50 | | 0.66 |
| CV (%) | | | | | 13.53 |
| LSD at 5% | | | | | 0.31 |
| **c. Karmanshah:** | | | | | |
| Lignee 131/5/Cq/Cm//Apm... | 173 | 215 | 75 | 34 | 6.04 |
| CWB117-77-9-7/ICB 104073 | 173 | 213 | 85 | 37 | 6.27 |
| Robur/J-126//OWB 753431D/S13 | 173 | 221 | 85 | 41 | 5.94 |
| Roho/Mazurka//ICB 103020 | 173 | 215 | 85 | 44 | 6.6 |
| YEA 560.2//Luther/BK 259 | 187 | 221 | 105 | 35 | 5.68 |
| National check | 182 | 221 | 110 | 40 | 4.92 |
| CV (%) | | | | | 15.61 |
| LSD at 5% | | | | | 1.32 |

DH=days to heading; DM=days to maturity; PH=plant height; TKW=1000 kernel weight;

### 2.2.12. Grain Quality

In view of the fact that barley in the highlands is used for both feed and food, emphasis is laid on developing germplasm not only with high yield but also with good quality.

Germplasm material is tested for their thousand-kernel weight (TKW) and protein content. A total of 1851 lines/cultivars from various nurseries along with three checks (Tokak, Bulbul and Arabic Abiad) were evaluated. The data are presented in Fig. 2.2.2.



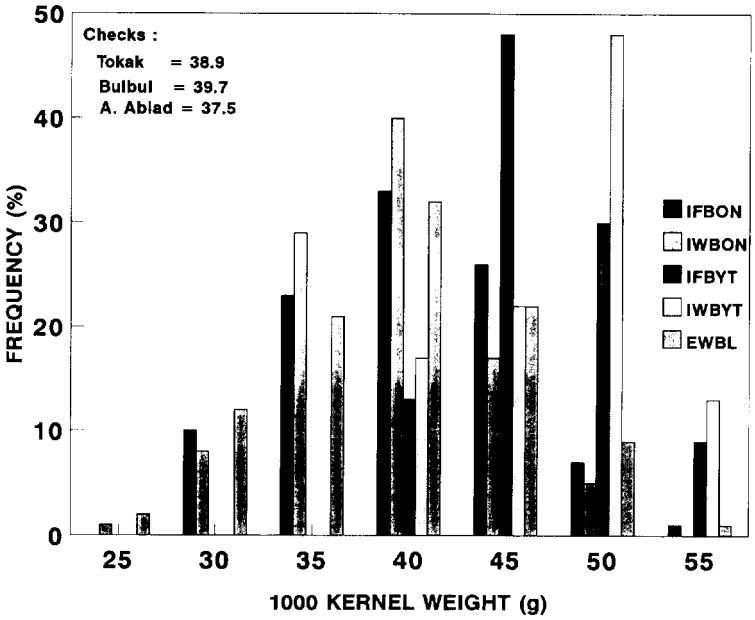




Fig. 2.2.2. Protein concentration and thousand-kernel weight distribtion in winter barley breeding material, 1993-94.

Majority of the tested material had better protein conrent and TKW than the checks. On the basis of higher protein content and TKW, respectively 1233 and 1087 lines were selected.

There is an increasing demand for malting and food barley, therefore, in the future germplasm development, quality evaluation for these characters will also be taken into account. **- F. Jaby El-Haramein and M. Tahir**

## 2.3. ICARDA/CIMMYT Barley project

### 2.3.1. Introduction

Since 1984, the barley breeding activities in Mexico have become a joint ICARDA/CIMMYT Program. The objectives are to produce improved barley germplasm for national programs with emphasis in Latin America. During the last 10 years, the main effort has been to incorporate disease resistance into agronomically good lines with high yield potential.

In Mexico during the winter months, the segregating barley populations and the yield trials of advanced lines are grown in the Yaqui Valley at the CIANO Experimental Station (38 meters elevation, $27^0$N latitude) located in the north-western part of the country. The summer plantings are made at two sites in the Central Mexico high plateau: El Batan Experimental Station (2,200 meters elevation, $19^0$N latitude) and Toluca Experimental Station (2,600 meters elevation, $19^0$N latitude).

### 2.3.2. New Barley Varieties

Kenya released **NGAO**, a two-row, early maturing barley, which is resistant to barley yellow dwarf virus (BYDV). It originated from the cross F7HJ33.86.1//8.2/4/As/Kristina/3/Apn/Dwarf21//Por/IB65/5/B1/Guajillo; CMSWB81A-425-A. It was released for malting purpose.

Canada released three varieties. **FALCON**, a hull-less barley, has superior digestible protein and energy contents and released for Alberta. Falcon was selected from a F2 population sent to Canada from Mexico from the cross:

11012.2/Tern//Tulelake Collection CMB76A-444. The varieties **TUKWA** and **SEEBE** are hulled varieties. They were also released in Alberta, and emanate from the crosses I7416/Hiproly and Masurca//Muller/Heydla, respectively. The crosses were made in Mexico and progenies selected in Alberta for their adaptation to Canadian conditions. Tukwa is a semidwarf feed trial, barley and Seebe is resistant to prevailing pathotypes of scald in the area.

### 2.3.3. Germplasm Development

Using the summer planting at the El Batan and Toluca, and winter season at CIANO, barley germplasm was advanced by two generations. Screening for resistant to stripe, leaf, and stem rusts and scald was done as mentioned in previous reports. Advanced lines that carry multiple disease resistance were yield-tested under rainfed conditions at El Batan, and under irrigation at CIANO. At El Batan, higher yields were observed due to good precipitation and cool weather. At CIANO, relatively high temperatures during early crop development resulted in lower yields (Table 2.3.1). Sen, a stiff-strawed cultivar with good lodging resistance, had low yield potential in previous yield trials. However, with the incorporation of Sen in the pedigree of the three top yielders at El Batan, it appears that the low yield linkage present in Sen has been broken, allowing for the production of high yielding genotypes with stiff straw.

At both locations, the experiments were conducted on beds separated by 0.75 m. The objective was to improve germination in plots at CIANO where irrigation followed by rains caused poor plant emergence. Planting in beds also uses less land than traditional basin planting.

In experiments that compared planting systems, beds resulted in less lodging but reduced yields. Arupo, a dwarf variety, yielded 8.1 t/ha in six-row plots in basins, and only 5.8 t/ha in beds. Robust//Gloria/Copal, a tall genotype, yielded 8.0 t/ha in basins compared to only 5.8 t/ha in beds. Although planting in beds reduced yield potential, the system discriminates well among low and high yielding genotypes and maintains the relative ranks obtained when planting in basins.

**Table 2.3.1. Yield (t/ha) of advanced barley lines at El Batan (summer-1993) and CIANO (winter-1993/94) in Central and Northern Mexico.**

| Cross and pedigree | El Batan | CIANO |
|---|---|---|
| Dc/Sen<br>CMB90A362-4M-1Y-1M-0Y | 8.0 | 4.8 |
| Arr/4*Boy/3/LB Iran/<br>UNA80/Lig640/4/Sen<br>CMB89A-987-J-1M-1Y-<br>1B-1Y-1M-0Y | 8.0 | 5.2 |
| Cen/Cal//Sen<br>CMB90-896-B-1B-1Y-1M-0Y | 7.6 | 4.4 |
| Maris Canon/Laurel//Aleli<br>CMB90-761-C-2Y-1M-1Y-2M-0Y | 7.6 | 5.2 |
| Gloria/Copal//IBTA80/3/<br>LB iran/UNA80//Lig 640<br>CMB88-658-A-3Y-1B-1Y-3M-0Y | 6.9 | 5.7 |
| Slo/Saida///Molle/3/Gloria/<br>Copal<br>CMB88A-945-C-12M-1Y-1M-0Y | 6.2 | 5.4 |

### 2.3.4. Hull-less Barley

The three main objectives for breeding hull-less barley are to: 1) increase the yield potential, 2) improve quality and 3) incorporate multiple disease resistance.

The yield potential of hull-less types was determined in yield trials at CIANO under irrigation. Two advanced hull-less lines yielded 5.1 t/ha, not significantly different from to the best covered check (5.6 t/ha). Protein content of hull-less grains is presented in Table 2.3.2.

Yield trials under two planting systems (basins and beds) will be conducted to reconfirm the yield performance of the best hull-less lines. The yield advantage of covered barleys over hull-less ones can be explained by the weights (12% of the total) of the lemma and palea. If a second year of trials shows that hull-less

could result in further expansion of hull-less barley production.

**Table 2.3.2. Yield and protein content of hull-less barley lines resistant to leaf, stripe and stem rusts at CIANO Experiment Station, Mexico.**

| Cross and Pedigree | Yield (t/ha) | % of hulled check | Grain protein (%) |
|---|---|---|---|
| CERRAJA<br>CMB91A-1142-C-11B-1-0B | 5.1 | 93 | 11.6 |
| CONGONA<br>CMB91A-542-A-1B-1Y-0B | 5.1 | 91 | 11.1 |
| CARRETILLA<br>CMB91A-1192-J-3B-1Y-0B | 4.8 | 87 | 11.5 |
| BASIL<br>CMB91A-937-T-7B-1Y-0B | 4.8 | 87 | 12.6 |
| CARRETILLA<br>CMB91A-1192-A0-1B-1Y-0B | 4.8 | 87 | 13.0 |
| CARRETILLA<br>CMB91A-1192-1B-1Y-0B | 4.8 | 87 | 12.2 |
| CARRETILLA<br>CMB91A-1192-AR-6B-1Y-0B | 4.7 | 85 | 11.8 |
| ESCANAL<br>CMB 91A-935-D-OM-1Y-0B | 4.7 | 85 | 11.9 |
| LINO/ROMERO<br>CMB91A-336-1M-1Y-0B | 4.7 | 85 | 11.1 |
| ISO<br>CMB91A-1143-J-1B-1Y-OB | 4.7 | 85 | 12.9 |
| AGAVE/BERMEJO//HIGO<br>CMB91A-996-D-3B-1Y-OB | 4.6 | 84 | 10.7 |

The top yielding hull-less entries, all six-rowed types, were affected by scab on the spike during the summer season at El Batan. Mycotoxins produced by the fungus are considered a major problem for using hull-less barleys as human food and animal feed.

The color of the grain's aleurone is an important trait to be considered when breeding hull-less barleys. White color is preferred over blue in the Andean region where barely is utilized as human food. Ecuador and Peru have indicated that segregation for aleurone color is a problem with two high- yielding covered barley types. Work in purification of the line V-5 has delayed its release in Ecuador. Although white grain color in wheat is related to grain sprouting in the spike no information is available on the influence of aleurone color in barley.

### 2.3.5. High Quality Hull-less Barely

The rapid increase in area sown to hull-less barleys in Alberta, Canada, can be explained by both the expanding international (mostly Japan) and national markets for such barleys that have superior digestible protein and energy contents. In 1993, hull-less barleys with good quality were sold at malting barley prices.

The main hull-less varieties in Canada are Condor and Falcon. These are being used in crosses to incorporate multiple disease resistance. A relatively large number of segregants in early generations, selected for resistance to rusts (stripe, leaf and stem), will be planted at CIANO for generation advance. An active interchange of germplasm is in progress with the Alberta program.

Feeding-quality evaluation of hull-less barleys for shrimp diets is being conducted in collaboration with the University of Sonora. In Canada, the feeding value of hull-less barleys has been tested in the diets of hogs.

### 2.3.6. Resistance to Biotic Stresses

#### 2.3.6.1. Development of Germplasm Resistant to *Helminthosporium sativum*

To develop barely for areas where its production is limited by *H. sativum*, several resistant lines were tested at the Poza Rica Experiment Station in coastal Mexico where the disease is endemic. The barley lines tested were selected

for their earliness and resistance reactions. However, an additional factor desired was heat tolerance, which would allow grain production in the tropics.

*H. sativum* is reported to cause different disease symptoms, i.e., crown rot, spot blotch on the leaves, and black point in the grains. The parental materials were classified for their reaction on the leaf, the coloration of the grain and agronomic performance under heat stress. Crosses among groups were made in the greenhouse and their F1's were planted in the greenhouse for F2 seed increase.

Plants from F2 populations were planted at CIANO (1993-94)and selected for leaf rust resistance and good agronomic (mainly high biomass) type. The F3's, planted at El Batan during the summer of 1994, were protected against stripe rust field infection with fungicide (Folicur) to advance one generation. The F4 will be planted next winter at Poza Rica and selected for resistance to *H. sativum* and heat stress. Plants with the best agronomic type and disease resistance will be sent to Vietnam, Thailand, Tanzania and Ecuador for further testing.

### 2.3.6.2. Inheritance of Scab Resistance

Scab (*Fusarium* spp.) is one of the most prevalent diseases of barley in the Yang Tze Basin in China. However, during the last two years, scab has surfaced in the main barley belt of the United States as well. Grain that has more than 4 ppm of vomitoxin is rejected at the elevator with a consequent reduction in price. Yield losses caused by the fungus are insignificant. Awareness of mycotoxins is lacking in most developing countries. For example in Mexico, scab infection is observed on barley sown in the high plateau but mycotoxin content is not measured in the grain.

A collection of infected spikes was made from several fields and *Fusarium* is being isolated and identified. The inheritance of scab resistance is being studied in a cross between Gobernadora, resistant to scab, and a susceptible malting line. F1 seed was sent to Oregon State University for the development of a doubled haploid population, which will be planted next year at Toluca, where heavy rains favor

scab development. The study is being conducted as a MS thesis project of Armando Gerns.

### 2.3.6.3. Russian Wheat Aphid

New barley lines resistant to the aphid *Diuraphis noxia*, derived from the cross Gloria/Come (resistant) and Esperanza (susceptible), were yield-tested under irrigation at the CIANO Experiment Station (Table 2.3.3). The lines are classified in two groups according to height,semidwarf and tall. It is believed that tall lines could be of more benefit because aphid infestation predominates in drought-prone areas where drought restricts plant height. Tall, aphid-resistant barley lines have been sent to Ethiopia for testing.

**Table 2.3.3. Yield of barley lines resistant to Russian Wheat Aphid at CIANO Experiment Station in Mexico.**

| Cross and Pedigree | Height (m) | Lodging score* (1-9) | Yield (t/ha) |
|---|---|---|---|
| Gloria/Come//Esperanza CMB90-312-55B-1B-47GH-0Y | 0.90 | 1 | 5.8 |
| Gloria/Come//Esperanza CMB90-312-56B-1B-150GH-0Y | 0.95 | 2 | 5.0 |
| Gloria/Come//Esperanza CMB90-312-82B-1B-138GH-0Y | 1.15 | 3 | 5.8 |
| Gloria/Come//Esperanza CMB90-312-51B-1B-67GH-0Y | 1.10 | 3 | 5.5 |

* Lodging score: 1=no lodging, 9=100% lodging.

### 2.3.6.4. Cataloging of Resistant Genes for Stripe Rust

Several NARSs in the Andean region have released barley varieties with resistance to stripe rust caused by *Puccinia striiformis* f.sp. *hordei* race 24. Some of these varieties have become popular with farmers, and the area under production has increased. However, the exact genetic

constitution that provides the stripe rust resistance in these varieties is not known.

In collaboration with Oregon State University (OSU), a project is underway to study the resistance genes present in some commercial varieties from Ecuador. The work involves making crosses in Mexico, production of doubled haploids (DH) by OSU and screening for stripe rust reactions under field conditions at Mexico. Work with molecular markers, i.e., Restricted Fragment Length Polymorphisms (RFLPs), is then conducted at OSU.

A sister line of the commercial varieties Calicuchima (Ecuador) and Kolla (Bolivia) was studied, which resulted in the identification of a major gene on chromosome 7 and a minor gene on chromosome 4. During the summer of 1994, 400 DH lines from four crosses involving three different resistant parents were screened at Toluca. The inheritance of the resistance to stripe rust from the Ecuadorian variety Shyri was determined to be polygenic, while the resistance of CI10587 and CI11958 was governed by a single gene. Studies using RFLPs are in progress to identify the exact chromosome location of these resistance genes. New doubled haploids are being produced with the stripe rust-resistant parents Shyri/Gloria//Copal/3/Shyri/Grit, Aleli, and Gloria/Copal for further testing.

The information generated will provide NARSs in the Andean Region with a better understanding of the number of genes operating for stripe rust resistance in their varieties. It will also serve as the basis to study the genetic variability already present to protect the barley crop from virulence changes of the fungus.

### 2.3.6.5. Leaf Rust Resistance Studies

A study of the inheritance to leaf rust caused by (*Puccinia hordei*) is underway in cooperation with the Virginia Polytechnic Institute in the USA. During the summer of 1994, the F2 and F3 populations from several crosses resistance and susceptible cultivars.

Inoculation of these populations will be done in Virginia, with the new race of *P. hordei* (race 30) that was able to overcome the resistance on Pa7 provided by Cebada

Capa. In Mexico, race 30 is not present and information on the genetic constitution of different genotypes used frequently in the program could be valuable. Complementary studies will be done in the field at CIANO during the winter 1994-95 to study the inheritance with races present in Mexico. In a separate study, variety Shyri was found to have a partial resistance for leaf rust.

#### 2.3.6.5. Screening of ICARDA Hull-less Collection for Leaf Rust Resistance

More than 1600 accessions of hull-less barley accessions from the ICARDA Germplasm Bank at Aleppo were screened for their reaction to leaf rust under field conditions at CIANO during the winter 1993-94. Except for three entries with low scores, the entire collection was susceptible to races of *P. hordei* present in Mexico. Growth habit classification resulted in 1109 spring, 93 winter, and 299 facultative types. Three entries (116455, 119750 and 119893) were discarded for contamination with Barley Stripe Mosaic (BSMV). From lines that headed, 108 were hooded.

### 2.3.7. Barley-Medic Rotation

During the summer of 1994 in the Mexican plateau, 16 hectares were under medic (*Medicago polymorpha*) that were grazed by lambs and cattle. Three seeding rates (4, 6 and 8 kg/ha) were used to establish the medic on new land. The lower rate resulted in poor stand establishment, while the 6 and 8 kg seed rates provided good establishment.

Planted the same day, an early maturing hooded barley (60 kg/ha seed rate) was used as a companion crop with the medic in two different planting schemes. This resulted in an increase in the total number of the grazing days for the season.

The animals began grazing the barley as early as 50 days after planting, when the plants started to head. The elimination of the barley plants early in the season by grazing animals allowed the medics to grow well since there was no longer competition for light, water and nutrients.

Hay was made on medic fields where there was heavy infestation of wild oats. Hay was readily sold at US$3/bale.

### 2.3.8. Barley For Animal Feed

In cooperation with INIFAP (the national agricultural research organization of Mexico) and farmers, the utilization of barley for uses other than malting is being promoted in three Mexican states (Sonora, Jalisco, Hidalgo). Experiments with grazing early maturity barley as a companion crop to ryegrass and medics (*Medicago polymorpha*) looked promising in verification trials conducted in farmers' field.

A breeding scheme to produce tall, hooded, early maturing barley for animal feed is in progress. Several lines selected for stripe rust resistance during the summer 1994 are being advanced as F4s in the Yaqui Valley, where selection for several traits including biomass and leaf rust resistance will be done. The best lines will be sent to the state of Aguas Calientes for adaptation testing.

Earliness is an important trait to overcome terminal drought in Aguas Calientes, as demonstrated by data collected over the last three years using the early maturity line Mora. Yields of Mora with only 250 mm of rain during 1993 reached 875 kg/ha. In 1994, 400 kg of grain were harvested in one hectare planted with Mora that received 150 mm of rain. **- H. Vivar**

## 2.4. Physiology/Agronomy

### 2.4.1. Boron Toxicity in Barley Seedlings in Relation to Soil Temperature

Boron (B) is an essential micronutrient in crop growth but its sufficiency range is narrow. Boron toxicity is a widespread problem in arid and semi-arid areas with cold weather. We investigated the effect of soil temperature (5, 10 and 15°C) on development of symptoms of B toxicity, plant growth and plant development, and on uptake and concentration of B in tissue of seedlings of four barley lines (Arabi Aswad, Tokak, Rihane-03 and Matnan 1) grown in soil with high

level of available B (12 mg $kg^{-1}$). Visual symptoms of toxicity were first observed in the high B soil concentration treatment at 5°C at 12 days after emergence. Concentration of B in tissue decreased with increasing soil-temperatures. There was no effect of soil temperature on B uptake or B concentration in plant tissue at the final sample (17 days after emergence). High soil B reduced seedling and leaf emergence rates, although the final seedling emergence and number of leaves were unaffected. Barley lines differed in concentration of B in tissues and visual toxicity symptom development. Adaptation to high B was either through maintaining low tissue B concentration or through tolerance to high tissue B concentration. While the investigated range of temperature does influence B toxicity in barley seedlings, it remains to be determined whether it affects crop yield. - **V. Mahalakshmi, S.K. Yau, J. Ryan, and J.M. Peacock**

### 2.4.2. Screening for Boron Toxicity Tolerance

Since treating the soil to remove or reduce the effect of B toxicity is not economically feasible, selecting crop cultivars with high tolerance to B toxicity is the most promising approach. The Program, therefore, started screening barley genotypes for tolerance of boron toxicity in 1992.

#### 2.4.2.1. Spring Barley

Out of the 394 advanced barley lines from the 1992-93 international nurseries screened last season, 18 lines with low B toxicity symptoms and low shoot B concentrations were grown in pots up to maturity under a plastic house. There were two treatments: control (0.4 ppm hot water extractable B) and +B (50 mg B/kg soil, giving a hot water extract of 18 ppm B).

The performance of the most B-toxicity tolerant lines is presented in Table 2.4.1. All the lines in Table 2.4.1 had lower or similar B-toxicity symptom scores than Galleon, the moderately tolerant Australian cultivar, at the seedling stage. They showed a substantial reduction in grain yield

under the +B treatment. The best line, Arar/Arabi Aswad, suffered a 26 % grain yield decrease. Three lines had a significantly lower grain yield reduction than Galleon. Relative to grain yield, the reduction in straw yield was much smaller. SLB 39-60, a selection from within a Syrian landrace, had a 23% increase in straw yield. The high soil B delayed heading, except for the lines Arar/Arabi Aswad and SLB 5-96. **- S.K. Yau, S. Ceccarelli, S. Grando, M.C. Saxena**

**Table 2.4.1. Performance of the most B-toxicity tolerant lines from the Spring Barley Project (in terms of least reduction in grain yield when grown in soil to which 50 mg B/kg soil [+B] was added, as compared to the control [-B]).**

| Name/cross | B toxicity symptom score[1] at +B | Difference in days to heading (+B to -B) | % difference over -B plants | |
|---|---|---|---|---|
| | | | Straw yield | Grain yield |
| Arar/Arabi Aswad | 2.0 | 0 | -17.3 | -26.2 |
| SLB 5-96 | 1.7 | 0 | -20.5 | -36.4 |
| SLB 39-60 | 2.5 | 2 | +23.5 | -41.6 |
| Sawsan/Badia//Arar | 3.2 | 9 | -20.5 | -44.7 |
| Tadmor | 3.0 | 1 | -43.3 | -45.1 |
| 9Cr.279-07/Roho | 2.5 | 5.5 | + 1.3 | -48.9 |
| Lignee 527/NK1272 | 1.7 | 8.5 | -21.6 | -49.0 |
| ER/Apm//Salmas | 3.2 | 1.5 | - 3.3 | -49.8 |
| Moderately tolerant check: | | | | |
| Galleon | 2.7 | 13 | - 6.7 | -59.7 |
| Susceptible check: | | | | |
| Pirate (winter) | 6.0 | no heading | -38.7 | no yield |
| Mean of 20 lines: | 2.9 | 7.7 | -12.1 | -53.1 |
| LSD (P=0.05) | 0.6 | 3.4 | 33.1 | 18.1 |

[1] 0-9 scale: 0 = no symptom, 9 = severe symptom. Scores taken at seedling stage.

### 2.4.2.2. Winter and Facultative Barley

Out of the 348 advanced barley lines from the 1992-93 international nurseries screened last season, 17 lines with low B-toxicity symptoms and low shoot B-concentrations were

grown under the same conditions as reported in previous section.

**Table 2.4.2. Performance of the most B-toxicity tolerant lines from the Winter and Facultative Barley Project (in terms of least reduction in grain yield when grown in soil to which 50 mg B/kg soil [+B] was added, as compared to the control [-B]).**

| Name/cross | B toxicity symptom score[1] at +B | Difference in days to heading (+B to -B) | % difference over -B plants | |
|---|---|---|---|---|
| | | | Straw yield | Grain yield |
| ZDM 477 (hooded) | 2.5 | -1 | - 4.5 | -26.4 |
| ZDM 3485 (naked) | 2.2 | 0 | -11.8 | -27.5 |
| ZDM 314 | 2.5 | 3.5 | -40.1 | -35.2 |
| Baluchistan | 3.2 | 1.5 | -22.2 | -36.7 |
| Tokak | 2.2 | -3 | -15.0 | -40.6 |
| 80-5144 | 2.0 | 3 | -38.4 | -43.9 |
| ZDM 939 | 3.5 | 0 | + 5.6 | -44.5 |
| ICB-100111 | 1.7 | 6 | -24.8 | -47.0 |
| ICB-104041 | 2.5 | 6 | +39.0 | -47.0 |
| Moderately tolerant check: | | | | |
| Galleon (spring) | 2.7 | 13 | - 6.7 | -59.7 |
| Susceptible check: | | | | |
| Pirate | 6.0 | no heading | -38.7 | no yield |
| Mean of 17 lines: | 2.5 | 4.3 | -14.6 | -50.6 |
| LSD (P=0.05) | 0.9 | 3.9 | 29.4 | 33.1 |

[1] 0-9 scale: 0 = no symptom, 9 = severe symptom. Scores taken at seedling stage.

The performance of the most B-toxicity tolerant lines are presented in Table 2.4.2. All of the 9 selected lines had lower or similar B-toxicity symptom scores than Galleon, the moderately tolerant Australian cultivar, at the seedling stage. The effects of B toxicity on yield and days to heading are similar to those found in spring barley. All lines had a substantial reduction in grain yield under the +B treatment. The best line, ZDM 477, had a 26 % yield decrease, which was significantly lower than that of Galleon. Relative to grain yield, the reduction in straw yield was much smaller. The line ICB-104041, a collection from Afghanistan, had a 39 % increase. The high soil B delayed

heading on average. But the line Tokak and ZDM 477 had earlier heading dates with -B than with +B treatment. **- S.K. Yau, M. Tahir, M.C. Saxena**

### 2.4.2.3. Iraqi Accessions

Iraqi soil samples were found to have the highest mean B concentration in a survey of 29 countries (Sillanpaa 1982)*. Since barley cultivation has a long history in Iraq, it is expected that good sources of tolerance to B toxicity can be found in Iraqi landraces. Fifty Iraqi barley accessions from the GRU collection were screened for B-toxicity tolerance in a plastic house to avoid the heterogeneity of B toxicity often present in the field. Seeds were sown in a tank of soil, which was mixed evenly with boric acid at the rate of 50 mg B/kg soil (giving a hot water extract of around 20 ppm B). Five seeds were sown for each entry. There were 3 replicates. None of the accessions had a higher symptom score than the two susceptible checks, Harmal and Pirate. Fifteen accessions had a symptom score lower than Galleon, the moderately tolerant barley check (Table 2.4.3). Among them, ten accessions had significantly lower shoot-B concentrations than the tolerant bread wheat check, Halberd. Accessions 108258 and 108477 had markedly lower B concentrations than the others, suggesting that they have a mechanism to restrict uptake of B or allow B to be easily removed by water running off the leaves. The findings that one-fifth of the accessions were tolerant, and the absence of susceptible accessions match well with the results of the soil survey conducted by Sillanpaa (1982)* that high soil B is common in Iraq. **- S.K. Yau, J. Valkoun (GRU), J. Ryan (FRMP), M.C. Saxena**

---

* Sillanpaa, M. (1982) Micronutrients and the Nutrient Status of Soils: A Global Study. FAO, Rome. FAO Soil Bulletin 48.

**Table 2.4.3. Boron-toxicity symptom and shoot-B concentration of selected Iraqi barley accessions 5 weeks after sowing in soil to which 50 mg B/kg soil was added.**

| ICARDA accession no. | Symptom score[1] | B conc. (ppm) | ICARDA accession no. | Symptom score | B conc. (ppm) |
|---|---|---|---|---|---|
| 108251 | 1.3 | 465 | 108253 | 2.3 | 510 |
| 108254 | 1.7 | 511 | 108258 | 2.2 | 267 |
| 108477 | 2.5 | 264 | 109415 | 1.8 | 520 |
| 109416 | 2.3 | 619 | 109418 | 2.2 | 456 |
| 109419 | 2.2 | 632 | 109420 | 2.2 | 481 |
| 121423 | 2.5 | 633 | 121426 | 2.7 | 483 |
| 121429 | 2.2 | 593 | 121430 | 2.0 | 548 |
| 121431 | 2.3 | 508 | | | |
| Tolerant checks: | | | | | |
| Galleon | 3.0 | 683 | Halberd (bread wheat) | 1.5 | 662 |
| Susceptible checks: | | | | | |
| Harmal | 5.0 | 774 | Pirate | 4.8 | 904 |

[1] 0-5 scale: 0 = no symptom, 5 = severe.

### 2.4.3. Zinc Deficiency Screening

A preliminary experiment showed that unlike Stork (durum wheat) and Mexipak (bread wheat), Harmal (barley) had a negative responsive to Zn application when grown in a low Zn soil (see section 3.4.2). **- S.K. Yau, J. Ryan (FRMP)**

### 2.4.4. Carbon Isotope Discrimination, Yield and Water use Efficiency in Barley under Field Conditions

Improving crop water-use efficiency as an integrated means to improve yield, has received increasing attention with the development of the $^{13}C$ discrimination theory in C3 plants. The theory suggested that $^{13}C$ dicrimination ($\Delta$), water use efficiency (W) and growth are linked together at the leaf level. Both $\Delta$ and W depend on the ratio of inetrcellular to atmospheric carbon dioxide concentrations (ci/ca). $^{13}C$ discrimination is high when stomata are widely open and ci is high. Under such conditions transpiration efficiency (ratio of photosynthesis/transpiration) is low. The net result is

that Δ should be negatively related to water use efficiency. $^{13}C$ discrimination is also viewed as an integrated measure of the efficiency of photosynthesis processes (the long term ci/ca) in response to the environmental conditions that prevail during the plant growth cycle prior to its estimation. Therefore, it can be used as a predictor of yield performance of plants in specific environmental conditions.

At ICARDA a major research project was initiated in 1988/89 season to examine the potential of $^{13}C$ technique in barley (and durum wheat) improvement under water limited conditions and extremes of temperature. Over 2500 samples for $^{13}C$ discrimination representing different plant parts and developmental stages were analysed in collaboration with Professor James Ehleringer and "The Stable Isotope Ratio Facility for Environmental Research" at the Derpartment of Biology, University of Utah, USA. In this section we report the results from the barley field study which were conducted over three years from 1989-1991.

The relationships among yield, carbon isotope discrimination (Δ) and water use efficiency (W) were investigated in a set of ten barley genotypes (Harnal, WI 2198, WI 2291/WI2269, Tadmor, Roho, ELB80, ELB37, ELB40, ELB11, and SBON96) under different moisture levels for three seasons in northern Syria. A line-source sprinkler irrigation system was used to create ten moisture levels ranging from natural rainfall to around 400 mm/growing season. Amount and distribution of rainfall and temperature differed substantially between seasons. Water use was estimated by the neutron probe method. Δ was measured in separate plant parts at several developmental stages and moisture levels.

### 2.4.4.1. Relation between Yield and Water Use Efficiency

Results show significant genotypic variations in yield, W and Δ measured in peduncles, grains and in flag leaves (Table 2.4.4).

Water use efficiency (W) increased slightly at low moisture levels in comparison with higher levels (Table 2.4.4). This indicates that water use and yield declined proportionally along the moisture gradient. Genotypic variation in W were statistically significant.

Across moisture levels( 1,3,5, & 10) water use efficiency correlated positively with above ground dry matter production (AGDM) and grain yield (GY), r for three seasons means were 0.47 and 0.44 respectively ($P<0.01$). Within each moisture level the relation between *W* and yield was stronger than across moisture levels, all correlations exceeded $r=0.90$ ($P<0.001$).

### 2.4.4.2. Relation between Δ and Yield

Across the moisture gradient, the correlation of Δ, measured for peduncles and grains, was both high and positive with AGDM and GY (Figure 2.4.1). Environments with a higher yield potential always had higher Δ values.

Within individual moisture levels the relation between Δ and yield was different from the ones observed across moisture gradient. For mean response over three seasons the relation between Δ and both AGDM and GY were significantly negative at both high and low moisture levels (Figure 2.4.2).

Within each season the relations were not consistently negative. At low moisture levels the relation between Δ and yield was significantly positive in 1989, and weakly negative in the other two seasons. While at high moisture level the relations were negative, but significant only in the 1991 season (data are not shown).

### 2.4.4.3. Relation between Δ and Water Use Efficiency (*W*)

Across moisture levels, Δ and *W* were weakly related. This was mainly due to the low variability in *W* across those moisture levels (Table 2.4.4).

Within individual moisture levels, mean values over three seasons showed a significant negative relation between Δ and water use efficiency for both low and high moisture levels ($r=-0.70$ and $-0.78$ respectively, $P<0.01$). However, within each season the relations were not consistent and followed a similar pattern to the relation between Δ and yield. The close resemblance of the relation between Δ and yield and between Δ and *W* suggested that the same controlling

factors influence both $^{13}C$ discrimination and water use efficiency.

We conclude from the observed relation, under field conditions, between $^{13}C$ discrimination, water use efficiency and yield that: First, a strong positive relation exists between water use efficiency and yield regardless of environmental conditions and moisture level. Second, a significant negative relation exists between $\Delta$ and both biological and grain yield and between $\Delta$ and water use efficiency in environments where temperature and moisture stresses are not dominant at critical stages of crop growth. In such environments selection for low $\Delta$ (either at high or at lower moisture levels) would be associated with higher water use efficiency, and consequently with higher yield potentials. Third, frost and low temperatures alone or in combination with low moisture availability may influence the expected negative relation and lead to a positive relation between yield and $\Delta$ and/or $W$ and $\Delta$. - **A.J. Dakheel, I. Naji, S. Ceccarelli, and J.M. Peacock**

## 2.5. International Nurseries

### 2.5.1. Spring Barley

International spring barley nurseries available for distribution from ICARDA, Syria, remained the same as last season (Table 2.5.1). Regarding trait-specific nurseries, there were three new germplasm pools containing net blotch, scald or powdery mildew resistant lines. A total of 308 nursery sets, nearly the same as last year, were distributed. There was no seed shortage, except for the Segregating Populations, but the number of observation nurseries requested by national programs decreased. More special yield trials, observation nurseries and segregating populations were sent to the five North African countries (Algeria, Egypt, Libya, Morocco and Tunisia) instead of the regular international nurseries. These are not included in the number given above. - **S.K. Yau, S. Ceccarelli, S. Grando, M.C. Saxena**

**Table 2.4.4. Mean values of above ground dry matter (AGDM), grain yield (GY), total water used by plants (W U), water use efficiency (W) and $^{13}C$ discrimination (Δ) measured in peduncles (P), grains (G) and leaves of 10 barley genotypes at the 5 leaf stage(L5) during three cropping seasons at low and high moisture levels.**

| Attribute | Low moisture (level 3) | | | | High moisture (level 8) | | | |
|---|---|---|---|---|---|---|---|---|
| | 1989 | 1990 | 1991 | Mean | 1989 | 1990 | 1991 | Mean |
| AGDM ($g.m^{-2}$) | 364 | 275 | 546 | 395 | 540 | 579 | 774 | 631 |
| SEM | 16 | 9 | 12 | 9 | 13 | 18 | 19 | 11 |
| GY ($g.m^{-2}$) | 148 | 68 | 209 | 142 | 248 | 238 | 345 | 275 |
| SEM | 5 | 4 | 7 | 5 | 9 | 10 | 10 | 6 |
| W U(mm) | 174 | 187 | 242 | 201 | 332 | 387 | 336 | 352 |
| SEM | 3.1 | 1.1 | 1.1 | 1.4 | 1 | 4.4 | 1.6 | 2 |
| $W_B$ | 2.1 | 1.47 | 2.26 | 1.94 | 1.63 | 1.5 | 2.3 | 1.8 |
| SEM | 0.08 | 0.05 | 0.04 | 0.04 | 0.04 | 0.05 | 0.06 | 0.04 |
| ΔL5 | 20.6 | | 21.3 | 20.96 | 20.7 | | 21.1 | 20.9 |
| SEM | 0.09 | | 0.10 | 0.09 | 0.10 | | 0.08 | 0.09 |
| ΔP | 16.7 | 16.8 | 18.7 | 17.4 | 18.4 | 18.0 | 19.5 | 18.7 |
| SEM | 0.08 | 0.29 | 0.07 | 0.1 | 0.14 | 0.17 | 0.13 | 0.10 |
| ΔG | 15.4 | 13.3 | 16.2 | 14.7 | 17.4 | 16.6 | 17.7 | 17.1 |
| SEM | 0.25 | 0.11 | 0.07 | 0.07 | 0.25 | 0.11 | 0.08 | 0.07 |

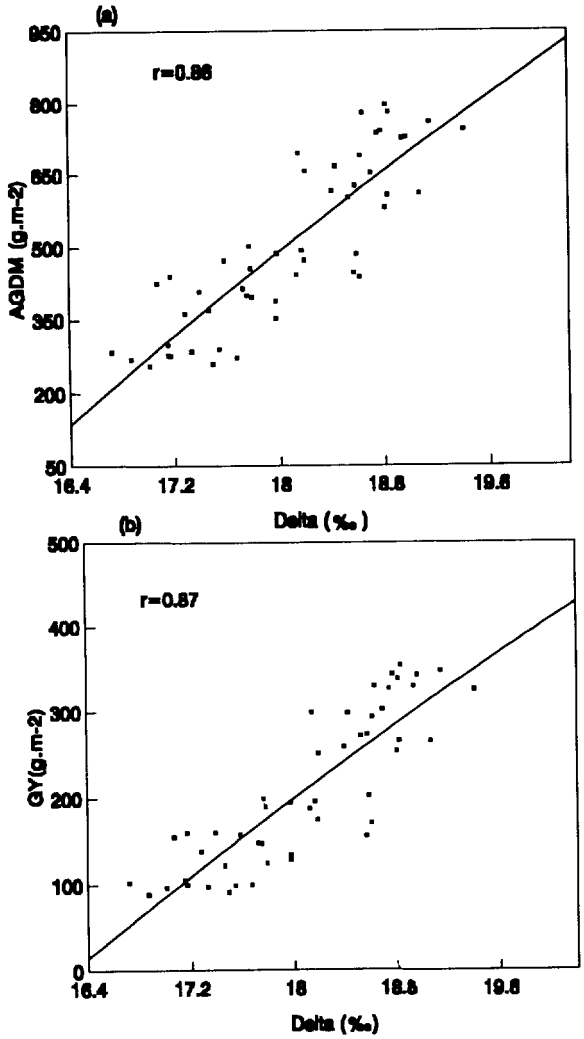



Figure 2.4.1. Relation between $^{13}C$ discrimination($\Delta$) measured in peduncles and above ground dry matter production (AGDM) (a) and grain yield (GY) (b) in 10 barley genotypes across five moisture levels. Values are means of three seasons.

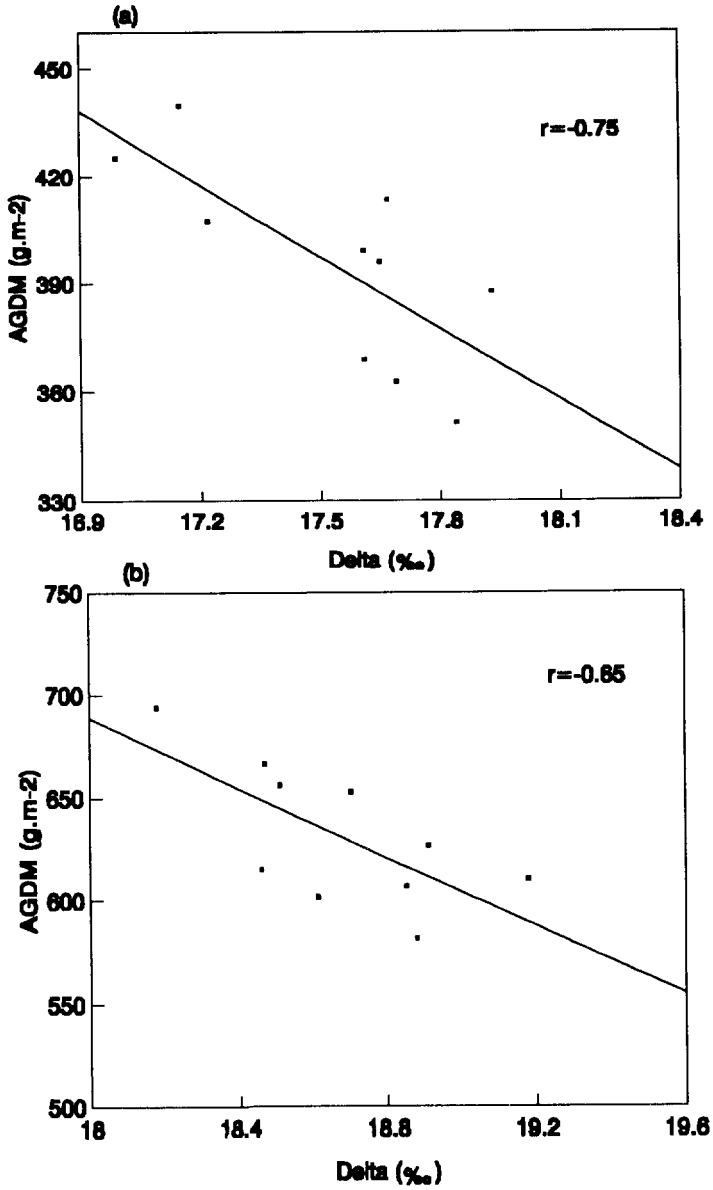



Figure 2.4.2. Relation between $^{13}C$ discrimination and above ground dry matter production (AGDM) at low moisture (level 3) (a) and high moisture (level 8) (b) in 10 barley genotypes. Values are means of three seasons.

**Table 2.5.1. International spring barley nurseries for 1994-95.**

| Nursery | Abbre-viation | No. entries | No. of sets distributed |
|---|---|---|---|
| **Regular Nurseries** | | | |
| Crossing Block | BCB | 71 | 25 |
| Segregating Populations | BSP | 139 | 20 |
| Observation Nurseries: | | | |
| - Low Rainfall (Mild Winter) | BON-LRA(M) | 113 | 22 |
| - Low Rainfall (Cool Winter) | BON-LRA(C) | 82 | 14 |
| - Moderate Rainfall | BON-MRA | 115 | 26 |
| Yield Trials: | | | |
| - Low Rainfall (Mild Winter) | BYT-LRA(M) | 24 | 33 |
| - Low Rainfall (Cool Winter) | BYT-LRA(C) | 24 | 20 |
| - Moderate Rainfall | BYT-MRA | 24 | 33 |
| **Germplasm Pools** | | | |
| Naked Barley | BN | 40 | 29 |
| BYDV Resistance | BYDV | 50 | 23 |
| Net Blotch Resistance | NB | 9 | 24 |
| Scald Resistance | SC | 22 | 17 |
| Powdery Mildew Resistance | PM | 18 | 22 |

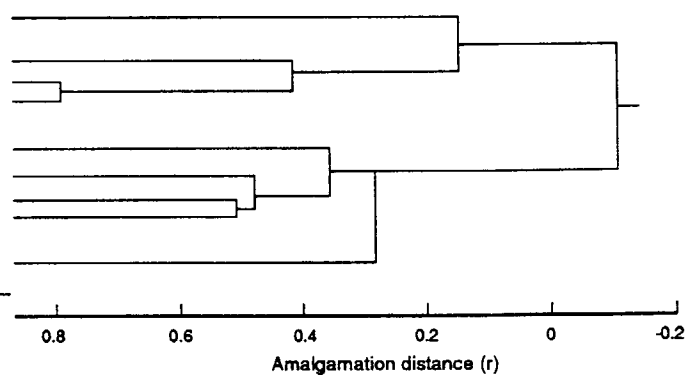
## 2.5.2. Winter/Facultative Barley

### 2.5.2.1. Barley High Elevation Adaptation Yield Trial

A collaborative project on specific adaptation of winter/facultative barleys in high-altitude areas of WANA was agreed upon between national programs of Algeria (ITGC, Setif), Iran (SPII, Karaj), Pakistan (AZRI, Quetta), Turkey (CRIFC, Ankara), and ICARDA. The participants agreed to conduct the Barley High Elevation Adaptation Yield Trial for three consecutive years in specific high-altitude locations. The trial consisted of facultative and winter barley lines/cultivars/accessions with different degrees of cold tolerance originating from WANA or elsewhere. In 1992-93, data of nine trials were received from the collaborators. The Turkish cultivar, Tokak, had the highest mean yield in the nine sites. Figure 2.5.1 presents the dendrogram obtained by a cluster analysis based on the entry mean grain yields at each site. Two main groups of sites were detected. One group consisted of Kazan (Ankara, Turkey), Haymana (Ankara, Turkey),

Fig. 2.5.1. Grouping of 9 sites by cluster analysis using grain yields of each of the 23 entries at each site (average linkage and correlation coefficient used for clustering).

| Location | Lat. (°N) | Long. (°E) | Elev. (m) |
|---|---|---|---|
| Sariab (Quetta) | 30.14 | 67.02 | 1702 |
| Maragheb | 37.15 | 46.15 | 1650 |
| Haymana (Ankara) | 39.15 | 32.47 | 1030 |
| Kazan (Ankara) | - | - | - |
| Setif | 36.09 | 05.21 | 1110 |
| Karaj (Reduced irrigation) | 35.50 | 50.58 | 1300 |
| Breda | 35.56 | 37.10 | 200 |
| Tel Hadya (Aleppo) | 36.01 | 36.56 | 284 |
| Terbol (Zahle) | 33.52 | 36.00 | 890 |



Maraghah (Iran) and Sariab (Quetta, Pakistan). The second group included Setif (Algeria), Karaj (Tehran, Iran), Breda (Aleppo, Syria), Tel Hadya (Aleppo, Syria) and Terbol (Zahle, Lebanon). This grouping is in broad agreement with previous experiences. The former group has colder winters than the latter, so barley lines with higher cold tolerance are necessary in the former group. **- S.K. Yau, M. Tahir, B. Amar (Algeria), M. Anwar Khan (Pakistan), N. Banisadr (Iran), H. Tosun (Turkey)**

### 2.5.2.2. Nursery Distribution

With the addition of the International Facultative Barley Yield Trial and International Facultative Barley Observation Nursery last year, six types of regular winter/facultative international barley nurseries were assembled by ICARDA (Table 2.5.2). Unlike last year, there was no major seed shortage to meet requests for nurseries. A total of 156 nursery sets were sent to national scientists. **- S.K.Yau, M. Tahir, M.C. Saxena**

**Table 2.5.2. International winter/facultative barley nurseries for 1994-95.**

| Nursery | Abbre-viation | No. entries | No. of sets distributed |
|---|---|---|---|
| **Regular** | | | |
| Crossing Block | IWFBCB[1] | 149 | 19 |
| Segregating Populations | IWFBSP | 150 | 20 |
| Observation Nurseries: | IWFBON | 150 | 29 |
| | IFBON[2] | 150 | 30 |
| Yield Trials: | IWFBYT | 24 | 26 |
| | IFBYT | 24 | 23 |
| **Special** | | | |
| Yield Trial | BHEAYT[3] | 24 | 9 |
| Total | | | 156 |

[1] IWF - International Winter and Facultative
[2] IF- International Facultative
[3] BHEAYT - Barley High Elevation Adaptation Yield Trial

## 2.6. Barley Pathology

Due to staff changes the research activities in the barely pathology project were limited during the 1993-94 season. The screening of breeding material against major diseases (scald, powdery mildew, covered smut) was carried out as usual.

Research on soil-borne diseases, a major activity in the last five years, was confined to testing a number of selected lines for resistance to two major root diseases of barely in Syria. Studies on the structure of disease resistance within Syrian landraces, an area which was emphasized because of the extended use of the breeding program of local selections, were stopped. The results in both areas of research will be reported in formal publications, after which an eventual follow-up can be considered.

### 2.6.1. Leaf Diseases

Screening for resistance to scald (*Rhynchosporium secalis*) is routinely carried out in field tests at Tel Hadya, using hill plots with at least two replications. Disease development is assisted by early sowing, a planting of a susceptible spreader next to each plot and inoculation with a mixture of Syrian scald strains just after plant emergence. In the past season most nurseries were as well planted at ICARDA's station at Terbol, Lebanon. The same methodology of planting was used, while the nurseries were inoculated with a mixture of Lebanese scald strains. In one nursery (the Key Location Disease Nursery) the effectiveness of artificial inoculation was compared with the use of scald infested straw, collected during the previous season.

Over the past years attempts were made to improve the reliability of seedling tests conducted in the greenhouse. Seedling tests allow the screening of material with a limited amount of seed under controlled conditions. It allows as well the use of homogenous, defined pathogen screened with the same mixture of scald strains as used in the field in order to compare field and seedling reactions.

Net blotch (*Pyrenophora teres*) and powdery mildew (*Erysiphe graminis*) are important diseases in barley growing environments with relatively warmer winters and moderate rainfall. Mild epidemics of powdery mildew occur naturally in all Tel Hadya nurseries every year. Continuous selection against susceptibility resulted in a moderate level of resistance in the ICARDA developed germplasm, which is adequate for some of our target areas.

Several attempts were made to initiate field screening for resistance to net blotch at Tel Hadya, but without success. In 1993 a program was started to compare the virulence of Syrian net blotch strains with exotic strains using seedling tests in contained environments. The Syrian strains appeared to have ample virulence, indicating that the failure of the field test is caused by a non conducive environment for disease in north Syria. Unfortunately the netblotch screening program had to be stopped because of staff cuts. It is hoped that the transfer of part of the breeding program to the Magreb counties will assist in an improvement of net blotch resistance in ICARDA developed germplasm.

### 2.6.1.1. Comparison of Effectiveness of Artificial Inoculation with the Spread of Straw in the Field

Table 2.6.1 shows the percentage of scald on check varieties in the BKL94. Each check was replicated four times both in the nursery that was inoculated as in the one in which scalded leaves of the previous season were spread. Analysis showed no significant difference in the scald development between both methods. Using straw is less labor intensive and larger numbers of nurseries can be tested, but through artificial inoculation it is possible to promote rapid shifts in the composition of inoculum, by selectively isolating the pathogen from lines with high levels of resistance. Frequent rains at the start of the 1993-94 season helped in the initiation of disease from infested debris.

**Table 2.6.1. Percentage scald on plant basis and top of check varieties in BKL94 after inoculation and after spread os scalded straw.**

| | Inoculated | | straw | |
|---|---|---|---|---|
| Name | basis | top | basis | top |
| Tadmor | 5 | 1 | 5 | 0 |
| Harmal | 46 | 8 | 41 | 2 |
| Rihane-03 | 59 | 5 | 41 | 2 |
| Arta | 55 | 7 | 48 | 8 |
| Faia | 58 | 4 | 58 | 2 |
| WI2281 | 55 | 8 | 55 | 7 |
| Morex | 68 | 9 | 50 | 3 |
| Roho | 70 | 18 | 50 | 3 |

The comparison of both methods should be continued over several years in order to conclude whether inoculation through use of straw is suitable for routine screening of germplasm under Tel Hadya conditions.

**2.6.1.2. Comparison of Scald Development at Tel Hadya and Terbol**

Disease development at Terbol was slightly less than at Tel Hadya (Table 2.6.2). Disease readings at Terbol are highly correlated with those at Tel Hadya (with artificial inoculation r = 0.57, with straw inoculation methods at r = 0.66), but the correlation is less than that among both inoculation methods at Tel Hadya (r = 0.75). Analysis of variance showed that the interaction component of entries with locations is not significant. It is therefore not likely that difference in virulence exist between the scald strains for inoculation.

**Table 2.6.2. Percentage scald averaged over all entries in four nurseries tested at Tel Hadya and Terbol.**

| | | Average percentage scald | |
|---|---|---|---|
| Nursery | Entries | Tel Hadya | Terbol |
| BKL94 | 117 | 22 | 15 |
| BNA94 | 151 | 24 | 18 |
| BPD94 | 570 | 27 | 16 |
| BID94 | 384 | 24 | 17 |

### 2.6.1.3. Level of Scald Resistance in ICARDA Germplasm

Figure 2.6.1 compares the level of scald development at Tel Hadya in four nurseries; Barley Key Location Disease Nursery (BKL94, 117 lines under advanced yield testing); North Africa Disease Nursery (BNA94, 151 lines selected for the Magreb countries); Preliminary Disease Nursery (BPD4, 570 lines under preliminary yield testing); Initial Disease Nursery (BPD94, 384 lines under initial yield testing). Entries are classified into four categories, resistant (< 7% scald), moderately resistant (7-15%), moderately susceptible (15-30%), susceptible (> 30%). Analysis of the distribution among these nurseries by Chi-Square test shows a highly significant difference, mainly caused by the greater frequency of highly resistant material in the BKL94.

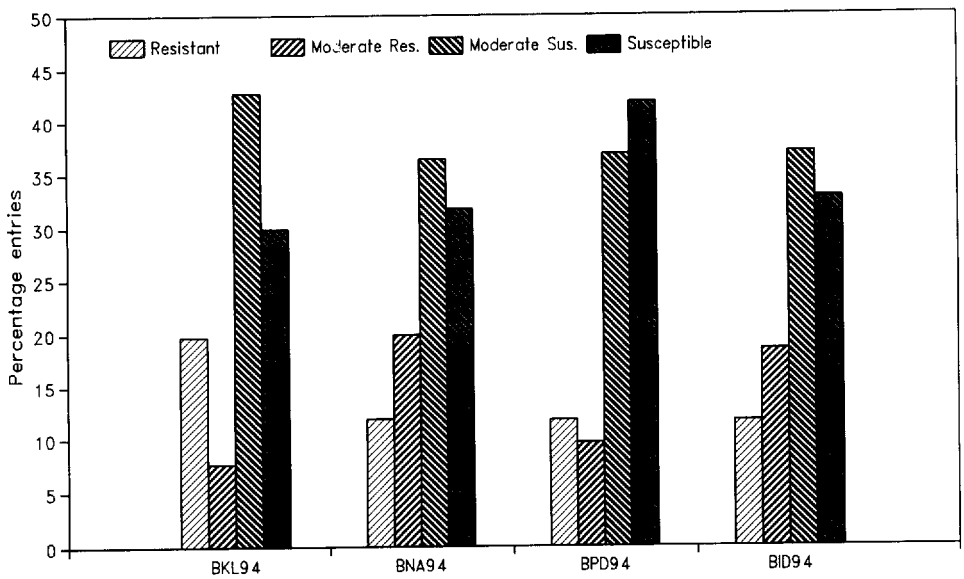



Fig. 2.6.1. Level of scald resistance in four barley nurseries at Tel Hadya, 1993/94.

### 2.6.1.4. Relation of Seedling Test with Field Rating

All entries in the BKL94 and the BNA94 were tested in seedling test in the greenhouse. Five seeds per entry were planted after germination on filter paper, moistened with a Ethyrimol solution to prevent the development of powdery mildew on the seedlings. The seedlings were inoculated with a mixture of Syrian scald strains on the moment the second leaf was fully extended. The plants were placed in a dew chamber for 24 h at 18°C in the dark after inoculation. Rating for scald was made 10 days after inoculation, using a 0-4 scale (0 = no disease, 4 = leaf completely scaled). The experiment was replicated twice. Table (2.6.3) compares the average rating in the seedling test with the performance in the field at Tel Hadya, using the same classification, resistant-susceptible as in the previous section. The use of the seedling test seems to be primarily in the detection of susceptibility: Out of the 49 entries with the highest (>3) score in the seedling test 46 rate moderate or fully susceptible in the field. A low rating (< 1) in the seedling test did not relate to a high level of resistance in the field; 58 out of 112 scored susceptible.

**Table 2.6.3.** Relation of seedling test with field rating 906 lines in DKL34 and BNA94, Tel Hadya, 1994.

| Seedling test Score | Field performance | | | |
|---|---|---|---|---|
| | Res. | Mod.-Res. | Mod.-Sus | Sus. |
| < 1 | 26 | 28 | 37 | 21 |
| > 1 - < 2 | 11 | 6 | 29 | 4 |
| > 2 - < 3 | 4 | 2 | 20 | 21 |
| > 3 | 0 | 3 | 18 | 27 |

### 2.6.2. Seed-borne Diseases

Field screening for resistance to covered smut (*Ustilago hordei*) is carried out every year, using a seed-inoculation

emphasis is given to screening in relatively early stage in the selection process. A total of 730 lines were tested during the 1993-94 season. Field testing for resistance to barely leaf stripe (*Pyrenophora graminea*) and loose smut (*Ustilago segetum*) is labor intensive and therefore restricted to the most advanced breeding material.

### 2.6.2.1. Interaction between Seed-borne Diseases

During the 1992-93 season a set of local landraces were tested both for resistance to scald and for covered smut. The latter screening was carried as usual by soaking seed in a solution of teliospores. In the scald nursery a number of entries were showing a high level of infestation by barley leaf stripe, while very few striped plants were observed on the same material in the covered smut nursery. Also, over years of disease screening and surveys of farmer's fields, we have never observed two different see-borne diseases (barley leaf stripe, loose or covered smut) on different tillers of the same plant.

During the 1993-94 season a small experiment was carried out to see whether inoculation with covered smut (CS) is suppressing the expression of barley leaf stripe (BS) and whether BS infested seed is less prone to CS infection. To acquire both stripe infested and clean seed, 7 landrace lines were harvested from two different nurseries. Seed from entries with an expected high level of BS infection was harvested from stripe-free tillers, grown close to striped tillers in the 1993 scald nursery. Seed from the same entries was as well harvested from smut-free plants in the covered smut nursery. As little or no stripe was observed in this nursery, this seed was expected to be free of infection. Seed from both sources was inoculated with covered smut. To avoid contamination of uninoculated entries during planting, a split-plot design was used with smut inoculation vs uninoculated as main plots. Entries and seed sources were planted as subplots. A subplot consisted of 2 rows of 1 m length in which 50 seed were hand sown.

Temperature optima of both diseases are different. A cold sowing bed is favoring stripe, while better smut development occurs at higher temperatures. To simulate

distinct conditions different sowing dates and pre-seeding treatments were used. The experiment was planted on two dates, 13 and 30 December. Pre-seeding treatments consisted of germination at 8°C (for 9 days) and at 20°C (for 3 days) on wet filter paper in dark incubators. Seeds from pre-seeding treatments were planted on 30 December, when coleoptiles were starting to emerge.

At flowering the number of plants with leaf stripe were noted while at maturity the number of plants with stripe and those with smut were counted as well as the number of infested tillers for both diseases. High levels of stripe were found on plants originating from seed of the heavily infested 1993 scald nursery. Stripe was as well found on plants from seed of the smut nursery, even though very few infested plants were present in this nursery in 1993. This could be an indication that only a limited amount of inoculum is necessary in a disease favorable year, or, alternatively, that the disease could be present in symptomless plants. Smut was only found on plants coming from inoculated seed.

Figure 2.6.2 shows the percentage of smutted plants from heavily and lightly stripe-infested seed for different sowing dates/pre-seedling treatments, averaged over the seven lines tested. Smut was clearly suppressed by stripe infection of the seed. There was no effect of the sowing date and only the pre-seeding germination at low temperature differed by slightly less smut.

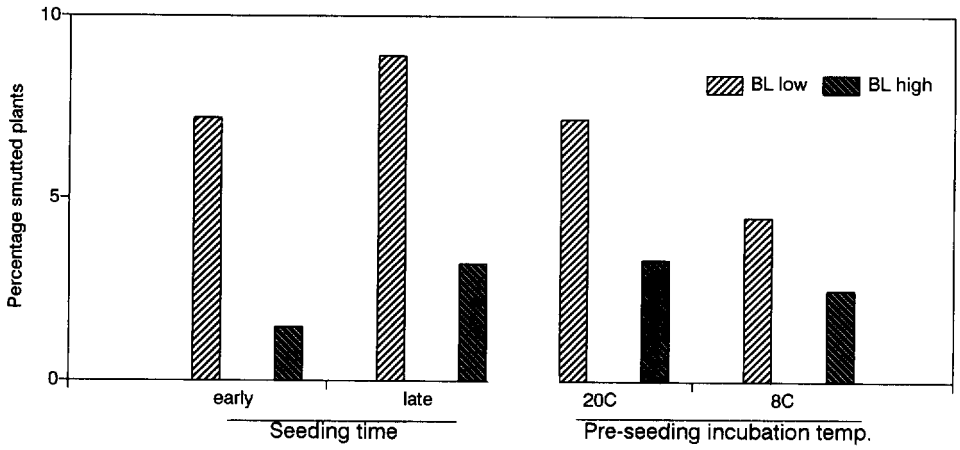



Fig. 2.6.2. Effect of barley leaf striped (BL) infection, seeding time and pre-seeding incubation temperature on the expression of covered smut.

Table (2.6.4) shows the stripe and smut percentages averaged over planting dates/pre-sowing treatments. For the three smut susceptible lines SLB 22-091, SLB 24-008 and SLB 24-034 the average percentage smutted plants from 'heavy' stripe infested seed is around one third of that from 'light' stripe infested seed. Interesting is that a similar level of suppression occurs on the two lines that seem to be rather resistant to stripe (22-091 and 24-034) as on the stripe susceptible line (24-008).

**Table 2.6.4. Percentage striped and smutted plants averaged over planting dates / pre-seeding treatments for seedlots with high and low stripe infestation with and without smut inoculation.**

| | low stripe infested seed | | | high stripe infested seed | | |
|---|---|---|---|---|---|---|
| | uninoc. | smut inoc. | | uninoc. | smut inoc. | |
| Line | % stripe | % stripe | % smut | % stripe | % stripe | % smut |
| 22-091 | 0.0 | 0.0 | 19.8 | 0.8 | 0.2 | 0.2 |
| 24 034 | 0.0 | 0.0 | 16.0 | 0.2 | 0.0 | 5.2 |
| 21-008 | 14.3 | 1.2 | 11.1 | 63.0 | 33.3 | 3.3 |
| 24-042 | 22.9 | 3.7 | 0.0 | 29.4 | 2.7 | 0.6 |
| 24-060 | 1.0 | 0.0 | 0.0 | 16.6 | 0.6 | 2.7 |
| 23-091 | 0.0 | 0.0 | 0.6 | 7.4 | 1.8 | 0.4 |
| 24-006 | 1.9 | 0.8 | 0.0 | 4.0 | 0.4 | 0.0 |
| AVG | 5.7 | 0.8 | 8.9 | 17.6 | 5.5 | 2.5 |

In Figure 2.6.3 the percentage of striped plants from both seedlots with and without smut inoculation is shown.

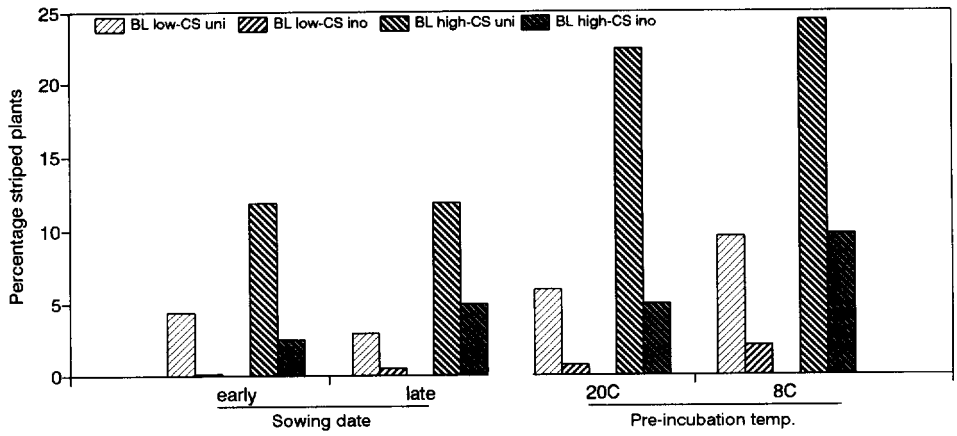



Fig. 2.6.3. Effect of covered smut inoculation, seeding time and pre-seeding incubation temperature treatments on the expression of barley leaf stripe.

The inhibition of stripe by covered smut inoculation is even larger than the inhibition of smut by stripe. The average reduction in the light infested seedlots (14%) is lees than in the high infested seedlots (31%), which is mainly caused by the heavily infested line SLB-24-008 (Table 2.6.4). Germinating the seed before planting increased the number of striped plants, especially at the lower temperature.

As noted previously, covered smut and leaf stripe could be found in the same plots, but not on the same plant. Both smuts and barley leaf stripe infest the growing point in an early stage of the plant development. In case inoculum is present of both diseases, the micro-environment during germination and the level of resistance of the cultivar will determine largely whether the initial infection will be by one pathogen or the other. Resistance to seedborne diseases acts at different stages during plant development, which can explain that lines with resistance to stripe are showing reduced smut infection, when exposed to stripe inoculum. Both diseases occur in farmer's fields in Syria and our previous work has shown that within local landraces large differences exist in resistance to both diseases. It is likely that the interaction between both pathogens together with the heterogeneity of resistance play in the suppression of both diseases.

### 2.6.2.2. Resistance to Barley Leaf Stripe in Iranian Germplasm

Barley leaf stripe is reported to be one of the most serious barley diseases in Iran. Previous testing of germplasm, both improved breeding lines and selections from landraces, showed that large differences in resistance exist and that under farmer's condition in barley growing environments with moderate rainfall this disease only becomes problematic if the cultivars are highly susceptible. In order to assess the level of resistance of the local Iranian germplasm, a collection of 100 barley landraces was obtained from the Iranian Germplasm bank at Karaj. The collection was randomly selected from different areas of the country. The material was increased in the isolation area at Tel-Hadya, where notes were taken on growth habit (1-5 scale, 1=early, 5=winter

type) and other characteristics. Out of 100 lines, 38 were early types (score 1 or 2) and only 18 lines were true winter types (score 4 and 5). Seed of all lines was as well rated for seed color (1-9 scale, 1=white, 9=black). Almost all collection were white (score 1 and 2) and only 4 lines had a dark [score 7] seed color. Testing for barley leaf stripe was done in a seedling test using artificial inoculation by germinating surface sterilized seed on mycelium of the pathogen at low temperature. The percentage striped plants was noted when the third leaf was fully extended. The test was replicated three times using 10 seed per replication. Collection sites of each accession were classified in 5 regions and 9 lines from each region were randomly selected for the test. Apart from the 45 accessions, four checks were used; two resistant lines [Betzes and Tokak], one susceptible [Arta] and one very susceptible [CI 6944]. Figure 2.6.4 shows the distribution for percentage of striped plants of the tested entries. The majority of the lines is more affected than the susceptible check Arta. However, four lines were more resistant than the highly resistant variety Betzes. Differences among regions was significant, with the central region having a larger number of susceptible accessions than the northern and eastern regions.

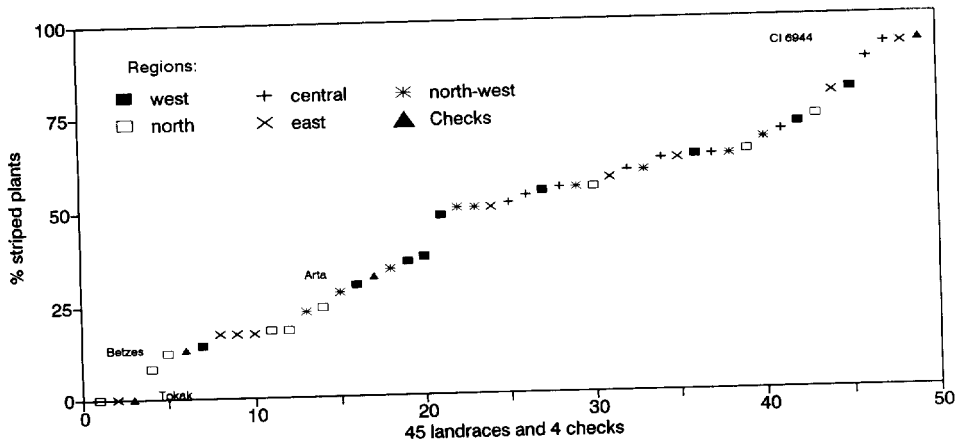



Fig. 2.6.4. Performance of barley landraces from five Iranian regions to aritficial inoculation with Pyrenophora graminea

A significant negative correlation was found between seed color and percentage striped plants, indicating that lines with a dark seed color tend to be more resistant. A similar relation was found in our work with Syrian landraces. No correlation was present between stripe resistance and growth habit.

The high proportion of susceptible lines in this random sample of Iranian landraces explains partly the frequent occurrence of barley leaf stripe in Iran. However, highly resistant entries are present, albeit in a low frequency, which should make selection of adapted resistant germplasm not too difficult a task. Furthermore, our testing was done on germplasm accessions, not on pure lines. Similar experiments using pure line selections of Syrian and Jordanian landraces showed that large differences in resistance may exist both within and among populations.

**- J. van Leur**

# 3. DURUM IMPROVEMENT

## 3.1. Durum Breeding

Durum is an important winter cereal crop in the Mediterranean region. Durum cultivated area in the WANA region covers more than 85% of the total area in the developing world. The durum grain yield per unit area and the area devoted to durum is increasing in most of the countries of the WANA region. The durum crop in WANA region is grown mainly under dryland conditions. These are characterized by drought, cold, terminal stress (drought and heat), and soil and nutrients problems (alkalinity, boron toxicity and micronutrients deficiency). In addition, almost all diseases, insects, and viruses that attack durum are prevailing and widespread in this region. The durum grain is used for making several food items which are locally produced and consumed, such as Burghul, Couscous, Pasta, and Durum Bread. The grain quality is an important factor in durum manufacturing industry. The durum manufacturing industry is gaining importance in the region. Several factories for Burghul, Couscous, and Pasta were established recently; some of them also founded joint ventures with pasta manufacturers from developed countries, particularly with Italy. The main objective of the joint ICARDA/CIMMYT durum project is to assist Mediterranean countries to enhance durum production in the dry areas by developing productive and adapted germplasm, resistant to abiotic and biotic stresses with good grain quality; improving dryland breeding methodology; and providing training.

Drought, cold, and terminal stress tolerant varieties with enhanced diseases and insects resistance are being released for large commercial production in many countries of the WANA region. Cham 3 is the most widely grown variety in Syria and was released in 1987. It has also been released in Jordan in 1990 (as Petra), Algeria in 1992 (as Korifla), in Libya in 1993 (as Zahra 5), and in Turkey in 1994 (as Firat-93). Heider, Kabir 1, Omrabi 9, Belikh 2 were released in Algeria. New durum genotypes with better resistance to

abiotic and biotic stresses are now considered for release. In Syria, Omrabi 3 is released as Cham 5, and in Turkey Omrabi "S" is released as Aydin 93. in Libya, Iraq, Iran, and Morocco Omrabi 5 is proposed for release, and in Tunisia Omrabi 3.

Improved durum genotypes were identified during the last season with enhanced tolerance to drought, cold, heat, and boron toxicity; resistance to Hessian fly, root rot, tan spot, powdery mildew, black point, leaf rust, and *Septoria tritici* in collaboration with NARSs in WANA. Progress was also made in widening the genetic base of resistance to Hessian fly and the three rusts through the use of durum landraces and wild relatives. The application of gliadin and glutenin components and molecular markers (PCR) techniques to screen for grain quality was also successfully incorporated as a routine tool in the breeding program, in collaboration with Tuscia University (Italy) and the biotechnology group at ICARDA. The development of molecular markers probes to test for abiotic stresses is now being established as a screening tool.

The joint ICARDA/CIMMYT durum breeding program has developed SEWANA (Southern Europe and West Asia-North Africa) durum research network with the scientists of NARSs and advanced institutions working on durum improvement to link and improve the durum research activities in the WANA region and South Europe. Following the establishment of SEWANA durum network, collaboartion with NARS and advanced institutions has increased to cover the different agro-ecological zones where durum is grown and now include a complimentary and integrated breeding research with NARSs for each zone. Joint research with NARS is based on comparative advantage (occurrence of specific environmental constraints, commitment of NARS, availability of funds, research infrastructure, and expertise). The current research activities within the durum network for each agroecological zone are as follows:

1) The aim of collaborative work for the Mediterranean Continental Areas (MCA) with NARSs of Syria and Jordan is to use the durum genetic diversity occurring in this zone, such as durum landraces and wild relatives, to improve tolerances to moisture stress, cold, and heat.

This work is associated with the ongoing basic research on moisture stress resistance with France and use molecular markers techniques with Italy and USA.

2) For the Mediterranean Temperate Areas (MTA), the collaborative breeding work with NARSs of Morocco and Tunisia aims at screening and developing resistances to Hessian fly, septoria tritici, root rot, tan spot, and powdery mildew.

3) For High Altitude Areas (HAA) the collaborative breeding work with Turkey, Algeria, and Morocco emphasizes cold tolerance. **- M.M. Nachit**

### 3.1.1. Widening Genetic Base of Durum

#### 3.1.1.2. Crosses Made in 1994

Several crosses were made between improved genotypes and landraces as well as wild relatives to incorporate additional resistance sources to biotic and abiotic stresses and to broaden the genetic base of durum. In the 1993/94 season, more than 300 crosses were made with landraces from the Mediterranean Islands, Syria, Jordan, Morocco, Algeria, Spain, Portugal, Turkey, and Ethiopia. The landraces from the Middle East region are used for enhancing the tolerance to drought, from Turkey and Algeria for incorporating cold tolerance, from Morocco-Iberia region for improving resistance to root rot and Hessian fly, and from Ethiopia for improving leaf rust resistance.

More than 250 crosses were made with durum wild relatives to introgress genes for resistance to abiotic and biotic stresses, particularly to Hessian fly and leaf rust. Durum recombinant lines (DRL) from the wild relatives introgression crossing program were tested for abiotic stress tolerance, disease resistance, and grain quality traits. Several DRLs showed promising performance under dryland conditions with high yield, resistance to leaf rust, tan spot, and septoria tritici, and improved grain quality.

### 3.1.1.2. Use of Recurrent Selection Methods

Recurrent selection populations (RSP) for Mediterranean durum landraces were developed To get durum populations with desirable traits by crossing landraces and wild relatives with stable and high yielding genotypes. These populations are: Middle East (ME-RSP), Maghreb-Iberia (MI-RSP), Kyperounda (Kyp-RSP), *T. dicoccoides* (Td-RSP), *Aegilops* (Ae-RSP); *T. monococcum* (Tm-RSP), *and T. carthlicum* (Tc-RSP), and salt tolerance population (salt-RSP). Lines from these populations are selected under different abiotic and biotic stresses. The ME-RSP is targeted to continental Mediterranean dryland areas, whereas the MI-RSP to temperate dryland areas. These RSPs are in the fourth cycle. Improvements were shown in earliness for ME-RSP, MI-RSP, Tm-RSP, and Ae-RSP. All RSPs showed improvement in fertile tillering ability except for Tm-RSP. Only in the Kyp-RSP and Tc-RSP populations, significant improvements were made in spike fertility. Height was reduced in all RSPs. Agronomically promising lines were selected at Tel Hadya and Breda stations. During the summer cycle at Tel Hadya and Terbol stations, several RSP lines were selected for tolerance to heat and resistance to leaf and stem rusts. - **M.M. Nachit, A. Asbati, M. Azrak, Z. Yunis, and N. Rbeiz**

### 3.1.1.3. Introgression of Resistance Genes for Abiotic and Biotic Stresses from *T. dicoccoides*

Several crosses between high yielding durum genotypes and *T. dicoccoides* were made to improve grain quality and resistance to *Septoria tritici* and yellow rust. Backcrosses were made to durum eliminate undesirable traits. In 1993/94, 23 crosses were made with *T. dicoccoides*. In the segregating populations, plants were selected for resistance to drought, heat, yellow rust, leaf, and stem rust. In the advanced populations, crosses with *T. dicoccoides* showed high levels of resistance to tan spot, heat, and cold. Several lines from these crosses are now included in the international trials. - **M.M. Nachit, A. Saleh, M. Maali, A. Asbati, M. Azrak, Z. Yunis**

### 3.1.1.5. Introgression of Quality Genes from *T. dicoccoides*

Variation in gluten elasticity and strength is usually attributed to differences between the gluten subunits. These proteins include high molecular weight (HMW) or A subunits and low molecular weight (LMW) subunit; this latter group is subdivided into B, C, and D subunits, according to their mobility in sodium dodecyl sulfate (SDS)-PAGE and their relative isoelectric point. In durum, a consistent relationship has been found between the B group of LMW glutenin subunits, coded by genes at the complex *Glu-B3* locus, and gluten quality. Two main types of LMW glutenin subunits, designated as LMW-1 and LMW-2, have been detected at this locus in the durums. They are related to poor and good gluten viscoelasticity, respectively.

Within the SEWANA durum network, joint work with Tuscia University, the Middle East countries, and ICARDA, storage protein analysis of *T. dicoccoides* has shown that this species is highly variable for HMW glutenin subunits encoded at the *Glu-A1* and Glu-B1 loci and for B subunits of glutenins. The electrophoretic analyses have shown that *T. dicoccoides* alleles at the Glu-A1, Glu-B1, and Glu-B3 loci are uncommon among cultivated durums. The effects of A and B subunits of glutenin on gluten properties were evaluated in F6 progenies of durum x *T. dicoccoides*. These progenies have allelic variants at the Glu-A1, Glu-B1, Gli-B1, and Glu-B3 loci, which are not usually present in durums. The results showed that the F6 progenies with the best quality contained the Glu-A1 allele from *T. dicoccoides* and the Glu-B3 allele (LMW-2) from durum. **- M. Ciaffi, A.M. Gallo, D. Lafiandra M.M. Nachit, A. Saleh, M. Maali, A. Asbati, M. Azrak**

### 3.1.1.5. Introgression of Genes for Abiotic and Biotic Stresses from Durum Wild Relatives

Introgression from *T. dicoccum* and *T. polonicum* produced promising lines under dry and heat conditions, in addition to leaf and stem rust resistance (Table 3.1.1). Crosses with *T. polonicum* performed well under terminal stress conditions; and crosses with *T. carthlicum* under cold conditions.

Crosses with *T. monococcum* were made to improve rust

resistance, earliness, and early growth vigor. Introgression from *T. monococcum* are important in widening the genetic base for resistance to stem and leaf rust, and enhance drought tolerance. From these crosses, several lines were advanced and tested in the different durum nurseries.

Furthermore, 177 crosses were made with different *Aegilops species* which were earlier selected for yellow rust, Hessian fly, and Russian Wheat Aphids resistance. Several *Aegilops*-RCLs are now in the advanced generations and show promising performance under dryland conditions. Crosses with Hessian fly resistant *Aegilops* were given high priority during 1994 crossing program. Recombinant lines with *Aegilops* and other wild relatives will be screened for Hessian fly resistance. **- M.M. Nachit, A. Asbati, M. Jarrah, M. Azrak, Z. Yunis, A. Saleh**

**Table 3.1.1. Percentage of selection for different biotic and biotic stresses in segregating and advanced populations involving crosses with durum wild relatives.**

| Species | Winter 1993/94 | Summer 1994 |
|---|---|---|
| | YR, ST, WSSF, C, D | LR, SR, H |
| *Aegilops Spp.* | 40.5% | 63.0% |
| *T. monococcum* | 31.2% | 55.0% |
| *T. dicoccoides* | 57.9% | 38.5% |
| *T. dicoccum* | 81.0% | 32.0% |
| *T. carthlicum* | 62.1% | 32.0% |
| *T. polonicum* | 20.3% | 33.3% |
| *T. araraticum* | 15.7% | 25.0% |
| *T. persicum* | 39.3% | 12.5% |

YR= yellow rust, ST= Septoria tritici, WSSF= Wheat stem sawfly, C= cold, D= drought, LR= leaf rust, SR= stem rust, H= heat.

### 3.1.1.6. Introgression of Genes for Resistance to Hessian Fly from *Aegilops* spp.

More than 140 *Aegilops* accessions from the ICARDA collection were screened for Hessian fly resistance by staff of INRA, Morocco. Nineteen accessions were identified as resistant to Hessian fly. Techniques for embryo-rescue was established at ICARDA and used to develop RCLs with recalcitrant *Aegilops*.

A cut stem method was developed in which spikes from durum and *Aegilops* are kept under controlled temperature conditions and media, to extend the crossing period and increase the efficiency of rescuing the *Aegilops* x durum hybrids. At ICARDA, more than 200 crosses with different *Aegilops* were made including the 19 resistant to Hessian fly. The hybrids are backcrossed to durums with different desirable traits, particularly, leaf rust and septoria tritici resistance. Similarly, at IAVH2, Morocco, six accessions of *Aegilops ovata*, 3 *Aegilops triuncialis*, and one *T. monococcum* were crossed with several durum genotypes. The embryo-rescue technique was also used and plantlets were obtained. The plants were treated with colchicine and at anthesis backcrossed to durums. The durum x *Ae. ovata* crosses were more successful than those with durum x *Ae. triuncialis*. - **M. Bouhssini, O. Benlhabib, A. Comeau, M.M. Nachit, M. Baum, A. Asbati, and M. Azrak**

### 3.1.2. Selection for Multiple Resistance to Abiotic and Biotic Stresses

Development of durum improved germplasm with multiple resistance to abiotic stresses (drought, cold, and heat) and to biotic stresses (diseases and insects) is required to respond to the erratic occurrence of environmental stresses in the WANA region. During the 1993/94 winter season the screening for resistance to drought, heat, cold, diseases, and insects in the Double Gradients Selection Techniques (DGST) was effective, see previous annual reports of Cereal Program at ICARDA. In the 1994 summer season (beginning of July at Tel Hadya, and beginning of August at Terbol), segregating populations and advanced lines were selected for heat tolerance and vernalization requirement at Tel Hadya, and for leaf and stem rust resistance at Terbol station. Resutls of the screening are included in the specific stresses, mentioned later. - **M.M. Nachit, and M. Azrak, N. Rebeiz**

### 3.1.3. Use of Molecular Markers Techniques in Durum Breeding

In 1993-94, RFLPs, gliadin, quality traits, and pedigree data were analyzed for 81 durum accessions that represent most of the important germplasm for durum improvement in the Mediterranean region. Similarity matrices based on the different types of traits were compared. In addition, individual gliadin and RFLP bands were analyzed for association with quality traits. The goal of this activity is to develop an information base for this germplasm pool consisting of agronomic and quality traits and diseases resistance reaction, as well as molecular and biochemical markers, their chromosome location, and their linkage to loci affecting those traits. Within the SEWANA durum network, analyses will be completed for stress tolerance traits including C12/13 discrimination, diseases and insects resistance, gliadin and glutenin components, boron toxicity, pasta and bread making.

#### 3.1.3.1. Marker Assisted Selection

Because of the difficulty in creating artificial screening conditions, traits, such as Hessian fly, leaf rust, and common bunt are potential candidates for marker-assisted selection. Markers correlated with drought resistance will be developed at ICARDA and tested in the mapping populations. We have constructed primers for the following clones which will be available for mapping and marker-assisted selection in durum: BCD21, BCD120, BCD450, BCD1426, BCD1434, CDO64, CDO431, BCD249, CDO482, CDO786, CDO795, DGG12. Most of these are also associated with preharvest sprouting resistance. CDO482 is linked with leaf rust and Hessian fly resistance.

#### 3.1.3.2. Development of Populations for QTL Analysis

The mapping populations of Jennah Khetifa/Cham 1, Omrabi 5/ *T. dicoccoides* 600545//Omrabi 5, and Korifla/*T. dicoccoides* 600806//Korifla were further advanced. The first cross includes Jennah Khetifa, a landrace with good quality traits, common bunt resistance, but with low yield and high

susceptibility to yellow rust; and Cham 1 with high yield and resistance to yellow rust, but low grain quality. In the backcross material the parents used were Omrabi5 and a *T. dicoccoides*; Omrabi 5 is drought tolerant with good adaptation to dryland; and *T. dicoccoides* 600545 is resistant to *septoria tritici* and yellow rust and has good grain quality. The F5-plants are now under increase and F6 seed will be available for running the RFLPs mapping. Development of mapping populations: Cama di Abbou x Cham1 for the Temperate areas, Kunduru x Cham 1 for Turkey, and Selbera X Cham 1 for the Atlas mountains is in progress. -
**M.M. Nachit, M. Baum, A. Asbati, and M. Jarrah**

### 3.1.3.3. Use of Molecular Markers for Desirable Traits

Molecular marker techniques for LMW-2 glutenin was initiated to test marker-assisted selection for efficiency in the durum breeding program using the Cham 1/Cham 3//Cham 1 backcross F1 population. Oligonucleotides for Plymerace Chain Reaction (PCR) amplification of the appropriate DNA sequence were used to screen the backcross progeny in each generation prior anthesis. These primers were successfully used in 1993/94 to screen the advanced durum genotypes for grain protein related to quality.

Within the SEWANA durum network, DNA molecular markers (PCR primers) were sequenced and amplified in collaboration with Tuscia University, Italy, for g gliadins (45 and 42), low molecular weight (LMW-1 and LMW-2), and high molecular weight (HMW) glutenin subunits. The primers used for the amplification are:

**γ-gliadin 42/45 primer sequence**
5'ATG AAG ACC TTA CTC ATC CT 3'
ACA TAC ACG TTG CAC ATG G
**Glutenin LMW-1&2 primer sequence**
5'ATG AAG ACC TTC CTC GTC TT 3'
CAA CGC CGA ATG GCA CAC TA
**Glutenin HMW primer sequence**
5'TCT CAA GAT CCT ATG TTA AT 3'
TGC CCA TAT TGT CTT GCG AC

The amplification of γ-gliadin showed the presence of 5 major bands, ranging between 750 and 1000 base pairs (bp). The bands 800, 830, and 970 bp were not polymorphic, while 900 and 950 were polymorphic. Genotypes with 900 bp correspond to γ-42 gliadin genotypes (e.g. Cham 1) and with 950 bp to γ-45 genotypes (Omrabi 5).

The amplification of LMW glutenin sequences showed the presence of 3 bands, ranging between 900 and 1200 bp. The two smaller fragments were present in all genotypes. The size of the long fragment differed between genotypes possessing LMW-1 or LMW-2 glutenin subunits. The amplification product of LMW-2 genotypes (Omrabi 5) was about 50 bp longer (larger) than that obtained in LMW-1 genotypes (Cham 1). Further, the primers used for amplification of HMW-glutenins revealed one band only at about 900 bp which was monomorphic for all analyzed genotypes.

The genotypes with the highest gluten strength quality, such as Omrabi 5, Haurani, and Korifla (Cham 3) showed DNA-glutenin (LMW-2 and γ-45 gliadin). In contrast, the genotypes with weak gluten strength quality, such as Cham 1 showed DNA-glutenin with LMW-1 and γ-42 gliadin. Thus the use of PCR amplification for the identification of LMW-1 or LMW-2 permits to select the lines with the potential for good grain quality without any of environmental effects. The technique will be expanded to screen for other important quality traits such as yellow pigment and vitreousness. -
**M. Labhilili, R. D'Ovido, M. Sorrells, M. Baum, M.M. Nachit**

### 3.1.3.4. Development of Molecular Markers for Resistances to Abiotic Stresses

Durum genotypes that are resistant and susceptible to drought, cold, and heat stresses in the field are tested to determine DNA markers that are associated with resistances to these stresses. Several cDNA or genomic clones are identified and that can be specific for one or more abiotic stresses. In durum, six cDNA dehydrin clones were characterized. In addition to these clones, new specific clones for Mediterranean environmental conditions, will be used to screen for the abiotic stress tolerance in durums.

For this purpose, eleven genotypes with contrasting

tolerance to the main abiotic stresses were tested. Samples were taken in different growth stages (germination, 3-leaves stage, tillering, and anthesis). The chlorophyll fluorescence inhibition technique was used to quantify the effect of the stress. The expression of dehydrins was also followed by studying mRNA. From the samples collected, cDNA library will be synthesized and clones isolated and characterized. Some of these clones will be used to identify molecular markers related with abiotic stress tolerance.
**- M. Labhilili, M. Baalabaki, A. Asbati, M. Jarrah, M. Baum, M.M. Nachit**

### 3.1.4. Progress in Mediterranean Continental Environment

#### 3.1.4.1. Testing and Use of Durum Landraces and Wild Relatives

In collaboration with the NARSs of Syria, Lebanon, and Jordan, morphophysiological traits associated with durum productivity in Mediterranean continental environment (MCA) were assessed for landraces from Syria, Iraq, Jordan, Cyprus, and Turkey at 3 different environments in Syria: Tel Hadya, Hypo, and Mjarja. The preliminary results show that the most traits associated with high productivity were early growth vigor and fertile tillering ability. Crosses for the continental areas in 1994 season were made with improved genotypes and landraces from Syria, Jordan, Iraq, and Lebanon. Crosses with landraces and *T. dicoccoides* from Jordan and Syria were also made and advanced populations were tested at: Rabba in Jordan; Tel Hadya, Lattakia, and Breda in Syria; and Terbol in Lebanon.

#### 3.1.4.2. Abiotic Stress Tolerance

**Drought:** All Segregating populations for the Mediterranean continental areas were screened for performance under dry conditions of Tel Hadya and Breda sites. The total seasonal precipitation was 373 and 291 mm, respectively at these two sites. The mean percent of selection ranged from 38% for F3 to 61% for F6. The selection average was 53% for all

segregating populations. Under the dry conditions of Breda site, grain yields ranged between 768 and 2385 kg/ha. Several lines outyielded the checks Cham 1 (1733 kg/ha), Haurani (1848 kg/ha), Cham 3 (1889 kg/ha), and Omrabi 5 (1939 kg/ha).

**Table 3.1.2. Grain yield (kg/ha) of entries in Advanced Durum Yield Trials (ADYT) at Breda for last 9 years, compared with Haurani.**

| Season | Rainfall | Grain yield (kg/ha) | | |
|---|---|---|---|---|
| | | ADYT Entries | | Haurani |
| | (mm) | Mean | Max. | |
| 1985/86 | 218 | 1224 | 1697 | 1014 |
| 1986/87 | 245 | 1127 | 2500 | 1066 |
| 1987/88 | 408 | 3608 | 4372 | 3066 |
| 1988/89 | 186 | 758 | 1237 | 503 |
| 1989/90 | 179 | 494 | 1420 | 695 |
| 1990/91 | 181 | 930 | 1248 | 846 |
| 1991/92 | 270 | 1324 | 1936 | 1150 |
| 1992/93 | 284 | 2447 | 3166 | 2385 |
| 1993/94 | 291 | 1860 | 2610 | 1848 |
| Mean | 251 | 1816 | 2523 | 1572 |

These results demonstrate progress made in drought tolerance. A comparison was made of the highly adapted and drought tolerant landrace (Haurani) with the recently developed drought tolerant durum genotypes. Table 3.1.2 shows the grain yields achieved at Breda, over last 9 seasons.

The yields of the best lines under dry conditions at Breda are presented in Table 3.1.3. The best lines were crosses with local landraces, mainly Haurani. These lines represent the new generation of germplasm developed from crosses with local material and selected under Mediterranean continental conditions for multiple abiotic stress resistance. The use of the double gradient selection technique is an important tool in incorporating multiple stress tolerance.

**Table 3.1.3. Grain yield of some promising drought tolerant lines for continental dryland conditions at Breda, 1993/94**

| No. | Cross/entry | Grain yield (kg/ha) | Percent of Haurani | Percent of Cham 3 |
|---|---|---|---|---|
| 512 | Omrabi 6 | 2610 | 137 | 130 |
| 513 | Omrabi 3 | 2410 | 126 | 120 |
| 812 | Wadalmez 6 | 2327 | 122 | 116 |
| 614 | GdoVZ512/Cit// Ruff/Fg/3/Haucan | 2294 | 120 | 115 |
| 809 | Massara 1 | 2260 | 118 | 113 |
| | Haurani | 1908 | 100 | - |
| | Cham 3 | 2000 | - | 100 |
| | LSD(0.05) | 537 | | |

The morphophysiological traits that were most associated with grain yield in this year under dry conditions, were early growth vigor ($r = 0.54$, $p = 0.01$), fertile tillering ($r = 0.51$, $p = 0.01$), and spike fertility ($r = 0.43$, $p = 0.01$).

Within the SEWANA durum network activities, chlorophyll fluorescence inhibition and proline accumulation were studied to screen for drought tolerance in France. Under dry conditions, genotypic fluorescence inhibition increased by 44.5% and proline accumulation 15.7 times, when compared with nonstress conditions. Positive association was found between fluorescence inhibition and proline accumulation ($r^2=0.79$). A large variation could be observed for proline accumulation among genotypes, ranging from 68.4 $\mu g\ g^{-1}$ and 183.0 $\mu g\ g^{-1}$; and for fluorescence inhibition from 31 to 71% of the nonstressed treatment. Drought tolerant genotypes, such as Omrabi 5 and Korifla (Cham 3) showed an average fluorescence inhibition of 34% and the drought susceptible genotypes, such as Gezira 17 and Po an average fluorescence inhibition of 61%. Similarly, for drought tolerant genotypes the average proline accumulation was 166 $\mu g\ g^{-1}$ and for the drought susceptible genotypes 126 $\mu g\ g^{-1}$.

Chlorophyll fluorescence inhibition and proline accumulation were significantly and positively correlated with drought tolerance in the Mediterranean continental areas (Breda) for grain yield ($r^2 = 0.62$; 0.59) and biological

yield($r^2$ = 0.59; 0.49), respectively. Leaf water potential (LWP) was also significantly associated with chlorophyll fluorescence inhibition ($r^2$ = 0.56). More than 62.4% of the drought tolerance of the analyzed durum genotypes was explained by chlorophyll fluorescence inhibition; and 59.3% by proline accumulation. These results illustrate the usefulness of these markers as a tool to identify drought resistant durum genotypes. However, additional studies are required to study the genetics and GE interactions of these traits. **- T. Ali-Dib, P. Monneveux, M.M. Nachit, M. Azrak, A. Asbati**

**Cold:** The early planting method of the double selection gradients technique was used to screen the segregating populations for cold tolerance at Tel Hadya. The susceptible checks (Stork and Cham 1) showed severe cold damage in contrast to Haurani and Omrabi 5. More than 65% all segregating populations showed tolerance to cold. Selection for performance under cold conditions was made under Tel Hadya (early planting conditions) and Terbol. Grain yield ranged between 462 and 4494 kg/ha. Among the checks, Omrabi 5 showed the highest yield (3475 kg/ha), followed by Haurani (3080 kg/ha), Cham 1 (1774 kg/ha), and Stork (1648 kg/ha). The highest yielding lines were crosses with durum germplasm originated from the continental areas of the WANA region (Table 3.1.4).

**Table 3.1.4. Grain yield of some promising lines under cold conditions in comparison with cold susceptible checks, Tel Hadya, 1993/94.**

| No. | Cross/entry | Grain yield (kg/ha) | Percent of Cham 1 | Percent of Stork |
|---|---|---|---|---|
| 323 | Awl2/Bit | 4494 | 253 | 273 |
| 1808 | Cham1/Brach | 4357 | 246 | 264 |
| 422 | Awl1/Sbl4 | 4356 | 245 | 264 |
| 1912 | Omrabi6 | 4350 | 245 | 264 |
| | Cham 1 | 1774 | 100 | |
| | Stork | 1648 | | 100 |
| | LSD(0.05) | 491 | | |

Most of these lines yielded more than twofold of the yield of

cold susceptible check. A cross with Cham1 was developed with cold tolerance (Cham1/Brach). These results show progress made for cold tolerance in the continental areas.

**Resistance to Terminal Stresses:** The late and summer sowing of the DSG-technique are used to identify material resistant to terminal stress (drought + heat) (Table 3.1.5). The landraces Haurani and Kyperounda are the best source for terminal stresses. Lahn x Haurani crosses are also showing good adaptation under these environmental conditions. These results corroborate earlier findings, in which Omrabi x Lahn (Omlahn) crosses were identified as tolerant to heat. It is of interest to note that these material show also good tolerance to cold.

**Table 3.1.5. Grain yield of some promising lines under terminal stress conditions in comparison with checks at Tel Hadya, Late planting, 1993/94.**

| No. | Cross/entry | Grain yield (kg/ha) | Percent of Cham 3 | Percent of Haurani |
|---|---|---|---|---|
| 520 | Omrabi 6 | 2035 | 161 | 302 |
| 513 | Omrabi 3 (Cham 5) | 1698 | 134 | 252 |
| 312 | Omrabi3/Lahn | 1639 | 130 | 243 |
| 517 | Blk2/Kbr8 | 1638 | 130 | 243 |
| 404 | Wadalmez3 | 1567 | 124 | 233 |
| | Cham 3 | 1263 | 100 | |
| | Haurani | 673 | | 100 |
| | LSD(0.05) | 412 | | |

Table 3.1.5 shows the five highest yielding lines compared to checks for drought and heat tolerance. The mean grain yield of this trail was 1209 kg/ha and ranged from 344 to 1908 kg/ha. Fertile tillering ability ($r = 0.53$, $p = 0.01$), earliness ($r = -0.39$, $p = 0.01$), and peduncle length ($r = 0.33$, $p = 0.01$) were highly associated with grain yield under terminal stress tolerance. Selections under summer and late planting conditions at Tel Hadya and summer conditions at Terbol facilitate the identification of germplasm with combined resistance to leaf and stem rusts and to heat and terminal stresses.

### 3.1.4.3. Biotic Stresses

**Disease Resistance:** Several crosses were made to upgrade resistance to septoria tritici, common bunt, leaf rust, stem rusts, and BYDV. All crosses had at least one parent resistant to yellow rust. Crosses with *Triticum dicoccoides* were used to widen the genetic base for resistance to septoria tritici and yellow rust.

The segregating populations were screened for resistance in winter cycle to yellow rust and wheat stem sawfly; and in summer cycle to leaf and stem rusts, in addition to abiotic stresses. Thirty-three percent of all segregating populations were advanced to the 1994/95 winter cycle, after selection for resistance to the above mentioned stresses. The continental durum material possesss high levels of resistance to yellow rust and common bunt (Table 3.1.6) and good adaptation.

**Table 3.1.6. Reaction of advanced durum lines to yellow rust and common bunt, ADYT-NCA, 1994.**

| Disease | Average | Min. | Max. |
|---|---|---|---|
| Yellow rust (ACI*) | 4.1 | 0.2 | 44.0 |
| Common bunt (%) | 25.6 | 1.4 | 66.2 |

* ACI = Average Coefficient of Infection

Durum gene-pools with resistance to common bunt (*Tilletia foetida* and *T. caries*), septoria tritici (Mycosphaerella graminicola), yellow rust (*Puccinia striiformis*), leaf rust (*Puccinia recondita*), and stem rust (*Puccinia graminis*), powdery mildew (*Erysiphe graminis*), and BYDV were formed. **- M.M. Nachit, O. Mamluk, M. Azrak, A. Asbati, and M. Jarrah.**

**Stem Sawfly:** Several crosses were made for resistance to stem sawfly. All segregating populations were exposed to natural attack by stem sawfly at Breda and Tel Hadya. In addition, crosses with solid stem landraces were made with the stress tolerant genotypes and subjected to screening for resistance to other biotic and abiotic stresses. Most of the advanced populations and newly developed genotypes have upgraded levels of resistance.

### 3.1.4.4. Grain Quality

All genotypes included in the yield trials targeted to Mediterranean Continental Areas (MCA) were analyzed for protein content, sedimentation test, yellow pigment, and kernel weight. They were also analyzed for DNALMW glutenin subunits which are highly related to the technological quality of durum for making endproducts. Table 3.1.7 shows some of the quality parameters for DNA-LMW-2 and DNA-LMW-1 lines at Breda and Tel Hadya late planting conditions. Of all lines developed for MCA, 90.8% were having LMW-2 and the remaining 9.2% had LMW-1 subunits, clearly reflecting the improvement in quality in our breeding lines for these areas. Haurani, Omrabi 5, and Cham 3 were used as good quality checks (LMW-2 type), while Cham 1 was used as poor quality check (LMW-1 type). The results in Table 3.1.7 show that quality traits estimated by conventional methods (i.e. protein content (%), sedimentation test, and sedimentation index) are highly affected by environment and are not able to reveal the real genetic difference in technological quality as the differences in these traits between LMW-2 and LMW-1 lines were rather low. Thus, the use of DNA-LMW screening will facilitate and enhance efficiency for technological quality. **- M.M. Nachit, F.J. El-Haramein, A.S. Saleh**

**Table 3.1.7. Some quality traits of advanced durum lines developed for the Mediterranean continental areas having different low molecular weight glutenin subunits (LMW-2 and LMW-1) when grown at Breda and Tel Hadya (LP = late planting conditions), 1993/94.**

| Conventional quality traits | Location | Values for lines having | | Difference |
|---|---|---|---|---|
| | | LMW-2 | LMW-1 | |
| Protein content (%) | | | | |
| | Breda | 12.6 | 12.1 | 0.5 |
| | Tel Hadya LP | 19.7 | 19.6 | 0.1 |
| Sedimentation test (ml) | | | | |
| | Breda | 27.7 | 25.4 | 2.3 |
| | Tel Hadya LP | 46.4 | 44.6 | 1.8 |
| Sedimentation index | | | | |
| | Breda | 2.2 | 2.1 | 0.1 |
| | Tel Hadya LP | 2.4 | 2.3 | 0.1 |

### 3.1.4.5. Productivity and Yield Stability

The performance of stable yielding durum genotypes combining yield potential with abiotic and biotic stress resistance are shown in Table 3.1.8, from the results of RDYT-LR (Continental Areas) conducted at 11 locations in the Mediterranean dry areas in 1993/94. This material was developed for erratic environmental conditions common in WANA region. The durum advanced material generated in the joint ICARDA/CIMMYT durum breeding program showed high performance and stability in the Mediterranean region. The mean productivity of newly developed ICARDA/CIMMYT durum genotypes was 34.1% better than that of Cham 1, the standard check. The stability of these lines and Cham 1 was much better than the stability of CIMMYT/Mexico developed genotypes tested in this trial. - **M.M. Nachit**

**Table 3.1.8. Durum genotypes with stable productivity in the Mediterranean continental areas, RDYT-LR, 1993/94.**

| Entry | | Mean grain yield | Stability | | |
|---|---|---|---|---|---|
| No. | Name | (kg/ha) | MDMYL | Percent of Cham 1 | Rank |
| ICARDA/CIMMYT genotypes with highest yield and stability: | | | | | |
| 8 | Omrabi 5 | 3053 | 0.122 | 188 | 2 |
| 11 | Massara | 3000 | 0.120 | 192 | 1 |
| 4 | Genil 3 | 2956 | 0.146 | 157 | 3 |
| 10 | Omrabi 3 | 2925 | 0.158 | 146 | 4 |
| 2 | Omruf 2 | 2824 | 0.212 | 108 | 5 |
| CIMMYT/Mexico genotypes included in RDYT-LR1993/94: | | | | | |
| 22 | Stn/Agia | 2542 | 0.327 | 70 | 18 |
| 21 | Altar/Somo//Auk | 2528 | 0.346 | 66 | 19 |
| 23 | Altar84/Sh177 | 2511 | 0.323 | 71 | 17 |
| 19 | Boy/Yav// PI330551 | 2305 | 0.421 | 55 | 23 |
| | Cham 1 | 2803 | 0.230 | 100 | 7 |
| | LSD(0.05) | 334 | | | |

MDMYL = Mean of difference from maximum highest yielder at each Location divided by location mean. Relative stability(%) = (MDMYL of Check Entry/MDMYL of Test Entry) x 100.

### 3.1.4.6. On-farm Trials, Large Scale Testing, and Seed Multiplication

In Syria, the national program has released Omrabi 3 as Cham 5 for commercial production. This variety is a cross between Haurani and Jori C69 which went through the selection strategy developed by the joint ICARDA/CIMMYT durum breeding program. Later it was also tested through the international nurseries in the WANA region. Omrabi 3 showed high productivity and yield stability in the MCA. It was included in the Syrian onfarm trials and the large scale testing for 4 years. Omrabi 3 combines high productivity with resistance to drought and cold. It also possesses good quality traits making for Burghul and durum bread in Syria. It shows better performance than Haurani, Cham 1 and Cham 3 in stressed and nonstressed conditions. More than 1.5 tons of certified seed were given to the Syrian Organization for Seed Multiplication for seed increase and distribution to farmers. Omrabi 3 is also performing well under the continental environment of Tunisia, in Elkef province, and is considered for release.

A sister line of Omrabi 3 was also released in Turkey under the name of Aydin-93 for the continental areas (South-East Anatolia, Diyarbakir). Another sister line, Omrabi 5 was selected and proposed for release in Iran. Omrabi 5 also showed high performance and good adaptation to stressed conditions in Iraq, Algeria and Lebanon.

Several lines were also tested in the on-farm trials in different countries, such as Omruf, Omsnima, and Genil lines, showing better performance and adaptation than Omrabi 3.

## 3.1.5. Progress in Mediterranean Temperate Environment

### 3.1.5.1. Germplasm Testing

For the temperate or maritime environments more than 450 crosses were made, mainly with parental material carrying resistance to Hessian fly, root rot, leaf rust, and BYDV. The promising inbred lines developed for Hessian fly resistance and landraces with root rot resistance were also used in this cycle. The segregating populations were screened for stem sawfly, drought, and terminal stress in

winter cycle, and for heat, leaf, and stem rust in summer. The selected material was advanced for further tests and selection in 1994/95 season. - **A. Asbati, M. Azrak, M.M. Nachit**

**Screening for Hessian Fly and Root Rot Resistance:** Screening of 1132 durum accessions from ICARDA's world collection was made at Jemaa Shaim station, in collaboration with the scientists from INRA. The durum accession No.829 was identified as resistant to Hessian fly where dead larvae were found on the plants. The resistant durum populations (F4 generation) developed by the joint program confirmed their resistance and are advanced for further testing and multiplication and use in the hybridization program.

The accessions tested for Hessian fly resistance were also tested for root rot resistance. Inoculation was made by spraying the fungal suspension (*Fusariun culmorum and Heminthosporium sativum*) on the seeds which were left to dry before sowing. Data were taken on emergence, number of tillers and spikes, and on white heads percentage. The weather was not conducive for disease development and hence no conclusive results were obtained. However, the towel paper screening for root rot, a lab test with highly repeatable results, was developed and will be used in the future, as additional tool for resistance screening to root rot. - **N. Nsarellah, M. Mergoum, M. Bouhssini, A. Asbati, M. Azrak, M.M. Nachit**

**Screening for Powdery Mildew Resistance:** During the 1993/94 season, more than 1400 accession were screened in collaboration with Moroccan colleagues at the IAVH2, Guich station, Morocco, for resistance to powdery mildew. Resistance to powdery mildew was mainly found in the durum landraces originated from Morocco, Algeria, and Tunisia. Jennah Khetifa was resistant to powdery mildew at Guich station. This cultivar is used to develop a durum population for genome mapping and QTL analysis. During the 1994/95 season the following selections will be used for crosses to upgrade the resistance to powder mildew:

ICDW 7196 (Morocco)
ICDW 7199 (Morocco)
ICDW 9535 (Morocco)

ICDW 10329 (Morocco)
ICDW 6835 Biskri Glabre AC 2 (Algeria)
ICDW 6837 Biskri Glabre AP 2 (Algeria)
ICDW 7020 Mahmoudi (Tunisia)
ICDW 9795 BD 1548 (Tunisia)
ICDW 6856 Jennah Khetifa Ap4 (Tunisia)

**- A. Ouassou, A. Asbati, M. Azrak, M.M. Nachit**

### 3.1.5.2. Abiotic Stress Tolerance

**Drought:** Characterization of durum cultivars and wild relatives from the Middle East and the Maghreb region for moisture stress and other studies on stress resistance are undertaken in collaboration with ENSA-INRA Montpellier, within the framework of the SEWANA durum network. The moisture stress tolerance traits such as osmotic adjustment, relative water content (RWC), and photochemical activities (net photosynthesis, internal $CO_2$ concentration, stomatal conductance, chlorophyll fluorescence inhibition) in combination with root traits (depth, length, density, number of seminal roots) are investigated. The preliminary results show that Cham 1 and some *T. dicoccoides* lines can make high levels of osmotic adjustment; and *T. polonicum* having high values for RWC under moisture stress. Analysis of lines originating from crosses with tetraploid species *(T. dicoccum, T. polonicum, T. carthlicum)* with Cham 1, Korifla, and Omrabi 5 showed that several root traits (number, volume, and dry weight) and above ground growth are related. The heritability for RWC was found to high (h2 = 0.73). The inheritance of RWC displayed in several crosses transgressive inheritance. **- A. Alhakimi, R. Djamila, A. Asbati, M. Jarrah, P. Monneveux, M.M. Nachit**

The yields of the best lines under dry conditions at Breda are in Table 3.1.9. The best lines were crosses with durum germplasm from Mediterranean temperate areas such as Hadj-Mouline from Morocco, a parent of the genotype Moulsabil 2, targeted and selected for Mediterranean temperate areas (MTA).

**Table 3.1.9. Grain yield of drought tolerant promising lines for Mediterranean Temperate Areas (MTA), Tel Hadya, 1993/94**

| No. | Cross/entry | Grain yield (kg/ha) | Percent of Omrabi 5 | Percent of Cham 3 |
|---|---|---|---|---|
| 1813 | Gerbrach-1 | 2385 | 123 | 126 |
| 1519 | Moulsabil-2 | 2351 | 121 | 125 |
| 1724 | Gerbrant | 2335 | 120 | 124 |
| 1223 | Genil-4 | 2318 | 119 | 123 |
| 1723 | Zeina-1 | 2268 | 117 | 120 |
| | Omrabi 5 | 1939 | 100 | - |
| | Korifla (Cham 3) | 1885 | - | 100 |
| | LSD(0.05) | 324 | | |

**Terminal Stress and Heat Tolerance:** In the MTA, the landraces Haurani and Kyperounda were the best sources for the terminal stresses (drought and heat). Lahn x Haurani crosses are also showing good adaptation under these conditions. These results corroborate earlier findings, in which Omrabi x Lahn (Omlahn) crosses were identified as rpomising for heat resistance. Table 3.1.10 shows the highest yielding lines compared to checks for terminal stress tolerance.

**Table 3.1.10. Grain yield of promising durum lines under terminal stress conditions for MTA, Tel Hadya late planting, 1993/94.**

| No. | Cross/entry | Grain yield (kg/ha) | Percent of Cham 1 | Percent of Stork |
|---|---|---|---|---|
| 1513 | Krf/Haucan | 1908 | 157 | 155 |
| 1022 | Omsnima | 1820 | 150 | 148 |
| 1508 | Lahn/Haucan | 1748 | 144 | 142 |
| 1509 | Lahn/Haucan | 1744 | 143 | 142 |
| | Cham 1 | 1215 | 100 | - |
| | Stork | 1231 | - | 100 |
| | LSD(0.05) | 588 | | |

### 3.1.5.3. Biotic Stresses

**Hessian Fly:** In contrast to bread wheat where Hessian fly

resistance is available and several varieties are already released in Morocco and grown by farmers, resistance in durum is not found, although the whole durum world collection was screened. Several- simple and back-crosses were made with different Hessian fly resistance genes originating from different *Triticum* species. Within the durum network activities, crosses and advanced populations, after screening for several biotic and abiotic stresses, particularly, yellow and leaf rusts and septoria tritici at ICARDA, were further tested for Hessian fly resistance by INRA/Morocco. Resistant lines are now in advanced populations and are the first durum plants to carry genetic resistance to Hessian fly in Morocco.

In 1994 summer planting, 46% of the segregating populations with resistance to Hessian fly were also selected for leaf and stem rust resistance to get combined resistance to Hessian fly and leaf rust with tolerance to terminal stresses.

Screening of *Aegilops* spp. collected from the areas where Hessian fly is endemic; showed that several *Aegilops* spp. were resistant (possibly different genes than the ones already known) to Hessian fly. The *Aegilops* populations showing resistance were crossed with durum genotypes adapted to Temperate dryland conditions. More than 300 crosses were made to upgrade the Hessian fly resistance in durum. Embryo rescue technique was employed. The advanced populations of the Hessian fly crossing program were also subjected to screening for other biotic and abiotic stresses and grain quality tests. - **M.M. Nachit, A. Asbati, M. Azrak, Nsarellah, M. Bouhssini, M. Baum, O. Benlhabib, A. Comeau**

**Leaf Rust and Septoria Tritici Blotch:** Until recently, durum germplasm had low resistance to leaf rust. Most of the sources of leaf rust resistance reported in durums, are ineffective in the Middle East. Therefore, emphasis was placed on broadening the genetic base for leaf rust resistance through the use of resistances from diverse sources in durums and wild relatives. Results are encouraging as resistance to leaf rust has started to build up in the program. The level of resistance of advanced lines shows that the average cofficient of infection (ACI) to leaf rust is 25.2 where more than 12% of all the advanced lines had an ACI less than 10 (Table 3.1.11).

As for septoria tritici blotch, the most important disease of durum in the Mediterranean region, particularly, the temperate areas, resistance is at acceptable levels (Table 3.1.11). Almost 90% of advanced lines show levels below 5. The septoria tritici resistant durum material is widely utilized by NARSs, particularly, by INRAT, Tunisia. - **M.M. Nachit, O.F. Mamluk, M. Azrak, A. Asbati, M. Jarrah**

**Table 3.1.11. Reaction of advanced durum lines to leaf rust and septoria tritici blotch in ADYT-MTA, 1994.**

| Disease | Average | Min. | Max. |
|---|---|---|---|
| Leaf rust (ACI) | 25.2 | 1.5 | 48.3 |
| Septoria tritici rating (1-9 scale) | 3.7 | 2.0 | 6.5 |

After the successful introduction of resistance to septoria tritici blotch in the durum genotypes targeted for the MCA, a need was also felt to increase the resistance to Septoria tritici in the germplasm targeted to the MTA. This was done by decentralizing the work to the Tunisian durum program of INRAT with provision of resistant durum material and funds to incorporate resistance in the germplasm for the Tunisian favorable areas and similar areas in other Maghreb countries. Sources of resistance to septoria tritici are already identified and crosses were made during spring 1994 to high yielding material and to widely grown commercial varieties and promising lines. A Tunisian septoria nursery was assembled and will be distributed in the Maghreb region. The lines included in the nursery originated from the ICARDA/CIMMYT joint breeding program, ICARDA septoria nursery, and from the Tunisian INRAT durum breeding program. The development of productive genotypes with good resistance to septoria tritici blotch, good quality, and good adaptation to favorable conditions is the objective of this activity. Because of the extreme drought in 1993/94 crop season in Tunisia, incidence of septoria tritici blotch was low in all sites where the material was planted. However, agronomically well adapted lines and populations were selected and advanced for screening in 1995. - **M.S. Gharbi, A.R. Maamouri, M.M. Nachit, A Asbati, M. Azrak, Y. Zuhair**

### 3.1.5.4. Grain Quality

The genotypes included in the yield trials targeted to Mediterranean Temperate Areas (MTA) were also analyzed for several quality traits. Table 3.1.12 shows mean and ranges for protein content (%), gluten strength parameters, kernel weight, and vitreousness. The range for most of the traits was large, except for vitreousness. LMW-2 glutenin subunit was present in 69.3% of the lines included in the advanced yield trials (Table 3.1.13). However, this percentage is below the one found in the lines included in the Mediterranean Continental Areas.

**Table 3.1.12. Quality traits in the durum advance lines targeted to Mediterranean Temperate Areas, Breda, 1993/94.**

| Quality trait | Mean | Range |
|---|---|---|
| Protein content (%) | 12.7 | 9.6-16.5 |
| Sedimentation test (SDS, ml) | 27.0 | 18.0-37.0 |
| SDS index[1] | 2.1 | 1.6-2.6 |
| Modified SDS index[2] | 3.5 | 1.8-5.9 |
| 1000 kernel weight (g) | 39.7 | 32.6- 49.7 |
| Vitreousness | 99.7 | 91.0-100.0 |

[1])= Sedimentation test / protein content (%)
[2])= Sedimentation test X protein content (%) / 100

**Table 3.1.13. Frequency of LMW-1 and LMW-2 in the durum advance lines targeted to Mediterranean Temperate Areas (MTA), 1993/94.**

| | Number of lines | |
|---|---|---|
| Glutenin subunit | Total | % |
| LMW-1 | 44 | 30.8 |
| LMW-2 | 99 | 69.3 |

**- M.M. Nachit, A.S. Saleh, A Asbati, M.Azrak, Y. Zuhair**

### 3.1.5.5. Productivity and Yield Stability

Durum genotypes combining high productivity with yield stability are shown in Table 3.1.14. The data from 11 sites

from the Middle region and Tunisia were used to determine productivity and yield stability of the genotypes included in the regional yield trial (RDYT-MR). This material is targeted for the areas with favorable conditions and irrigation, however abiotic stresses, such as drought and extreme temperatures (cold and heat) do occur. The stable productivity of the best ICARDA/CIMMYT genotypes developed was 30.7% more than that of Cham 1 and much higher than that of the material coming from CIMMYT/Mexico. The results of the RDYT-MR for favorable areas, similar to the results of RDYT-LR, again demonstrate the importance of using local germplasm and selection under the environmental conditions of the targeted production area.

**Table 3.1.14. Durum genotypes with stable productivity in the Mediterranean favorable areas, RDYT-MR, 1993/94.**

| Entry | | Mean grain yield | Stability | | |
|---|---|---|---|---|---|
| No. | Name | (kg/ha) | MDMYL | Percent of Cham 1 | Rank |
| ICARDA/CIMMYT genotypes with highest yield and stability: | | | | | |
| 9 | Omrabi-6 | 4096 | 0.105 | 213 | 1 |
| 8 | Omrabi-5 | 3891 | 0.150 | 149 | 2 |
| 2 | Genil-3 | 3962 | 0.160 | 140 | 3 |
| 11 | Heider//Mt/Ho | 3929 | 0.178 | 126 | 4 |
| 10 | Massara 1 | 3858 | 0.183 | 122 | 5 |
| CIMMYT/Mexico genotypes included in RDYT-MR1993/94: | | | | | |
| 23 | Stn/3/Hui/Carc// Chto/4/Altar84 | 3722 | 0.252 | 89 | 14 |
| 19 | Qfn/Kill | 3595 | 0.281 | 80 | 19 |
| 21 | Somo/4/D7224/ Vic//Stk/3/Auk | 3434 | 0.349 | 64 | 21 |
| 22 | Stn/Agia | 3291 | 0.377 | 59 | 22 |
| | Cham 1 | 3859 | 0.224 | 100 | 9 |
| | LSD(0.05) | 289 | | | |

MDMYL = Mean of Difference from maximum highest yielder at each Location divided by location mean. Relative stability(%) = (MDMYL of Check Entry/MDMYL of Test Entry) x 100.

The germplasm originated from the joint ICARDA/CIMMYT durum breeding program for favorable areas of WANA has more resistance to abiotic stresses and to the prevailing diseases and insects of WANA region, particularly to yellow and leaf rust and stem sawfly, than the CIMMYt/Mexico material and thus has higher stability in the productivity in this region.
**- M.M. Nachit, M. Jarrah, and M. Azrak, A. Asbati, Y. Zuhair**

### 3.1.5.6. On-farm Trials, Large Scale Testing, and Seed Multiplication

High yielding genotypes for the MTA were produced in collaboration with NARSs. However, the adoption of durum germplasm in some major durum producing countries was slow, because of the occurrence of Hessian fly. Hessian fly had hampered the speed of release of drought tolerant genotypes in Morocco. In the areas where Hessian fly is not a limiting factor, durum genotypes targeted to MTA were released (Libya, Iraq, and Iran). Omrabi 5 and Genil 5 are among the best performing genotypes in these areas. Table 3.1.15 shows the performance of Omrabi 5 in comparison to Waha and the local check Abu Ghraib in Iraq. These results demonstrate again the productivity of the abiotic stress tolerant durum material, such as Omrabi 5. In Iran, Genil 5 was identified as highly adapted genotype for the dry areas.

**Table 3.1.15. Mean Yield of Omrabi 5 and Waha in onfarm trials under different sowing dates and irrigation treatments, Iraq, 1993/94.**

| Variety | Yield (kg/Ha) | % of check |
|---|---|---|
| Omrabi 5 | 2025 | 302 |
| Waha-Iraq | 1502 | 224 |
| Abu Ghraib (Check) | 670 | 100 |

### 3.1.6. Progress in Mediterranean High Altitude Environment

Crosses for high altitude areas were made in 1993/94 mostly with Turkish cold resistant durum landraces. Crosses with *T. dicoccoides* and Turkish landraces showed good adaptation and

resistance to the constraints encountered in the high altitude areas. The cold screening for advanced lines was made at Tel Hadya (using early planting), Terbol (Lebanon), Annaceur (Atlas mountains of Morocco), and at Haymana and Ulas (Anatolian plateaux of Turkey). All segregating and advanced lines were tested for performance under dryland conditions at Tel Hadya. Testing for performance under dryland conditions was also made at Tel Hadya.

The screening for yellow rust and stem sawfly was done at Tel Hadya/Syria and Terbol (winter sowing), for tan spot resistance at Annaceur (Morocco), and for leaf and stem rust resistance at Terbol (summer-sowing). After selection, 25% of the total segregating populations targeted to high altitude areas were advanced for 1994/95 cycle.

### 3.1.6.1. Grain Quality

Durum lines showing promise in high altitude areas of Lebanon were analyzed for grain quality traits. The results showed that all other genotypes had band γ-45 gliadin and LMW-2, except Waha (Cham 1) had γ-42 gliadin and glutenin LMW-1. High gluten strength is associated with high sedimentation values and indices and with the presence of band γ-45 gliadin and glutenin LMW-2, and low values with γ-42 gliadin and glutenin LMW-1. Most genotypes showed higher values for sedimentation test (above 20 ml) and sedimentation index (above 1.5) as compared to Waha (16 ml and 1.1, respectively).

The results showed that in Lebanon no significant differences among varieties and sites were found for protein content; except for the site Kfardan. The values for protein content are low (not more than 12%). Most of the durum cultivars showed acceptable values for yellow pigment (6ppm), except Sebou (4ppm). Sebou was produced through crossing *T. polonicum*, a wild tetraploid relative of durum, with a high yielding durum line from CIMMYT (Crane). The highest values were found at Kfardan (7ppm), a highland site, while the lowest values were found in Sour (4ppm), a lowland site. All varieties and sites showed mean values exceeding 40 grams for kernel weight and 78 for hectoliter weight. This study was made within the framework of a degree thesis, in

collaboration with the Lebanese Agricultural Research Center (ARC) of the Ministry of Agriculture and Faculty of agricultural sciences the Lebanese University. - **N. Hussain, A. Jawad, W. Debs, M. Abiantun, N. Rebeiz, A. Alsaleh, M.M. Nachit**

### 3.1.6.2. Productivity and Yield Stability

Many of the lines included in RDYT-HA showed resistance to cold and gave high grain yields in high elevation areas where vernalization requirement is satisfied. Stable or consistent productive durum genotypes combining yield potential with cold, yellow rust and common bunt resistance are shown in Table 3.1.16 based on results from 5 locations.

**Table 3.1.16. Durum genotypes with stable productivity in the Mediterranean high altitude areas, RDYT-HAA, 1993/94.**

| Entry | | Mean grain yield | Stability | | |
|---|---|---|---|---|---|
| No. | Name | (kg/ha) | MDMYL | Percent of Cham 1 | Rank |
| 11 | Metm/ymh// TDcds-SY20021 | 4525 | 0.184 | 435 | 1 |
| 9 | ICDH86-0027 | 4226 | 0.262 | 306 | 2 |
| 13 | Raspinegro/ TDurum//Cham 1 | 4070 | 0.344 | 233 | 5 |
| 23 | ICDH83-0792 | 4033 | 0.346 | 231 | 6 |
| 18 | ICI86-0089 | 3777 | 0.343 | 233 | 4 |
| | Cakmak | 3336 | 0.512 | 156 | 14 |
| | Cham1 | 2603 | 0.801 | 100 | 24 |

DMYL = Mean of difference from maximum highest yielder at each location divided by location mean. Relative stability(%) = (MDMYL of Check Entry/MDMYL of Test Entry) x 100.

Some of the promising durum genotypes for high altitude areas are crosses with WANA landraces and wild relatives, particularly with *T. dicoccoides*. The stable productivity of high altitude genotypes was 187.6% better than that of Cham 1, whereas that ofCakmak, the leading Turkish variety, was 56% better than Cham 1. The results are encouraging and demonstrate again the importance of using local germplasm and

selection under environmental conditions similar to those of the production area.

## 3.2. Physiology/Agronomy

### 3.2.1. Tiller Development and Contribution to Yield under Different Moisture Regimes in two *Triticum* species

The number of productive tillers is an important yield component in wheat and it is affected by water stress and genetic factors. A greenhouse experiment was conducted during spring 1992 at Tel Hadya, Syria, with eight genotypes representing two *Triticum* species (*Triticum turgidum* L. ssp. *durum* and *Triticum aestivum* L. ssp. *aestivum)* under four soil-moisture regimes (95%, 75%, 55%, and 35% field capacity) to study the effect of water deficit on tiller development and tiller contribution to grain yield.

In the highest watering regime appearance of Tiller 1 was delayed in both species (Table 3.2.1). Also Tiller 2 (95% field capacity) was suppressed in this treatment in *durum*, while its appearance was delayed in *aestivum*. In the driest treatment, a majority of the tillers were suppressed and the ones which emerged were delayed. In *durum*, the heat units required to produce successive leaves on the tillers were higher than that for the main stem and increased with increasing water stress, causing a high rate of tiller abortion (Table 3.2.2). In *aestivum*, each tiller, once produced, developed leaves at the same rate as on the main stem. Phyllochron of tillers as well as main stem was not affected by water stress in *aestivum*. In *aestivum*, contribution by tillers to yield was higher than that of *durum* in all treatments (Table 3.2.3). Results indicate that early appearance of tillers and faster rate of leaf appearance under water stress result in higher tiller survival and greater tiller contribution to final yield. Hence, tiller dynamics under water stress, may be used as a selection criterion for breeding for drought tolerance. Effcts of moisture supply on grain yield and water use efficiency are presented in the section 4.2.2. - **M.G. Mosaad, G. Ortiz-Ferrara, M.M. Nachit, V. Mahalakshmi and J.M. Peacock**

**Table 3.2.1. Percentage of plants producing various tillers (T1 to T4) and their time of appearance (°C days ) in two *Triticum* species**

| | | Water regime (% field capacity) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 95 | | 75 | | | | 55 | | 35 | | | |
| Genotype | | T1 | T2 | T0 | T1 | T2 | T3 | T1 | T2 | T1 | T2 | T3 | T4 |
| *Triticum turgidum* ssp. *durum* | | | | | | | | | | | | | |
| Omrabi 5 | % | 100 | 50 | 42 | 100 | 75 | -- | 92 | 58 | 25 | 08 | -- | -- |
| | °C days | 342 | 406 | 300 | 262 | 382 | -- | 277 | 385 | 322 | 558 | -- | -- |
| Kabir 1 | % | 100 | -- | -- | 100 | 100 | 83 | 100 | 75 | -- | 75 | 33 | -- |
| | °C days | 293 | -- | -- | 249 | 367 | 565 | 332 | 438 | -- | 507 | 597 | -- |
| Stork | % | 100 | -- | -- | 83 | 75 | -- | 42 | 25 | -- | -- | -- | -- |
| | °C days | 354 | -- | -- | 343 | 398 | -- | 338 | 424 | -- | -- | -- | -- |
| Gallareta | % | 100 | -- | -- | 92 | 92 | -- | 92 | 33 | -- | -- | -- | -- |
| | °C days | 351 | -- | -- | 336 | 430 | -- | 340 | 429 | -- | -- | -- | -- |
| *Triticum aestivum* | | | | | | | | | | | | | |
| Cham 6 | % | 50 | 92 | -- | 67 | 92 | 33 | 33 | 75 | -- | -- | 8 | 8 |
| | °C days | 272 | 390 | -- | 256 | 403 | 577 | 320 | 398 | -- | -- | 436 | 599 |
| Dorghal | % | 92 | 100 | -- | 92 | 100 | 42 | 67 | 75 | -- | 50 | -- | -- |
| | °C days | 353 | 446 | -- | 334 | 427 | 565 | 376 | 456 | -- | 458 | -- | -- |
| Yamama | % | 83 | 50 | -- | 75 | 67 | -- | 33 | 50 | -- | -- | 8 | -- |
| | °C days | 298 | 500 | -- | 271 | 412 | -- | 344 | 520 | -- | -- | 676 | -- |
| Debeira | % | 92 | 67 | -- | 100 | 75 | -- | 58 | 25 | -- | -- | -- | -- |
| | °C days | 357 | 505 | -- | 287 | 436 | -- | 334 | 435 | -- | -- | -- | -- |

| | T1 | T2 |
|---|---|---|
| Tiller appearance | | |
| SE for watering regimes | 7.1 | 7.7 |
| SE for genotypes | 10.1 | 10.9 |
| SE for watering regimes x genotypes | 20.2 | 21.9 |

**Table 3.2.2. Heat units (°C days) needed to produced successive leaves on main stem (MS) and tillers in the two *Triticum* species.**

| | Water regime (% field capacity) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 95 | | | 75 | | | | | 55 | | | 35 | | | | |
| Genotype | MS | T1 | T2 | MS | T0 | T1 | T2 | T3 | MS | T1 | T2 | MS | T1 | T2 | T3 | T4 |
| *Triticum turgidum* ssp. *durum* | | | | | | | | | | | | | | | | |
| Omrabi 5 | 117 | 108 | 166 | 120 | 177 | 141 | 162 | -- | 119 | 139 | 180 | 131 | 161 | 136 | -- | -- |
| Kabir 1 | 123 | 134 | -- | 121 | -- | 148 | 151 | 160 | 135 | 135 | 136 | 135 | -- | 132 | 134 | -- |
| Stork | 111 | 106 | -- | 118 | -- | 122 | 137 | -- | 116 | 143 | 149 | 124 | -- | -- | -- | -- |
| Gallareta | 114 | 107 | -- | 116 | -- | 116 | 136 | -- | 117 | 128 | 165 | 119 | -- | -- | -- | -- |
| *Triticum aestivum* | | | | | | | | | | | | | | | | |
| Cham 6 | 106 | 114 | 97 | 106 | -- | 119 | 109 | 100 | 106 | 112 | 104 | 111 | -- | -- | 108 | 69 |
| Dorghal | 118 | 101 | 105 | 120 | -- | 108 | 119 | 142 | 128 | 108 | 120 | 129 | -- | 138 | -- | -- |
| Yamama | 111 | 122 | 110 | 114 | -- | 131 | 119 | -- | 117 | 108 | 113 | 129 | -- | 105 | 76 | -- |
| Debeira | 123 | 118 | 107 | 120 | -- | 132 | 129 | -- | 124 | 127 | 145 | 143 | -- | -- | -- | -- |

| | MS | T1 | T2 |
|---|---|---|---|
| SE for watering regimes | 0.6 | 2.1 | 3.6 |
| SE for genotypes | 0.8 | 3.0 | 5.2 |
| SE for watering regimes x genotypes | 1.7 | 6.0 | 10.3 |

**Table 3.2.3. Effect of four watering regimes on grain yield (g/plant) of main stem (MS) and tillers (T) and the contribution (%) of the tillers to the total grain yield per plant in two *Triticum* species.**

| | Water regime (% field capacity) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 95 | | | 75 | | | 55 | | | 35 | | |
| Genotype | MS | T | % | MS | T | % | MS | T | % | MS | T | % |
| *Triticum turgidum* ssp. *durum* | | | | | | | | | | | | |
| Omrabi 5 | 1.9 | 1.0 | 35 | 1.8 | 0.7 | 28 | 1.3 | 0.5 | 28 | 0.8 | 0.0 | 0 |
| Kabir | 1.3 | 1.3 | 50 | 1.6 | 0.6 | 27 | 1.1 | 0.4 | 25 | 0.8 | 0.0 | 0 |
| Stork | 1.7 | 1.5 | 47 | 1.4 | 0.7 | 33 | 1.3 | 0.6 | 33 | 0.7 | 0.0 | 0 |
| Gallareta | 1.7 | 0.9 | 35 | 1.4 | 0.8 | 36 | 1.1 | 0.2 | 15 | 0.8 | 0.0 | 0 |
| Mean | 1.6 | 1.2 | 43 | 1.5 | 0.7 | 32 | 1.2 | 0.4 | 25 | 0.8 | 0.0 | 0 |
| *Triticum aestivum* | | | | | | | | | | | | |
| Cham 6 | 1.4 | 2.2 | 61 | 1.2 | 1.4 | 54 | 1.2 | 1.0 | 48 | 0.9 | 0.3 | 25 |
| Dorghal | 1.7 | 1.5 | 47 | 1.7 | 1.2 | 41 | 1.6 | 0.9 | 36 | 1.2 | 0.0 | 0 |
| Yamama | 1.4 | 1.4 | 50 | 1.3 | 1.2 | 48 | 1.1 | 0.8 | 42 | 0.8 | 0.1 | 11 |
| Debeira | 1.2 | 2.1 | 64 | 1.4 | 1.6 | 53 | 1.3 | 1.0 | 44 | 0.9 | 0.1 | 10 |
| Mean | 1.4 | 1.8 | 56 | 1.4 | 1.3 | 48 | 1.3 | 0.9 | 41 | 0.9 | 0.1 | 10 |

| | Total | MS | T | % |
|---|---|---|---|---|
| SE for watering regimes | 0.06 | 0.03 | 0.04 | 1.1 |
| SE for genotypes | 0.08 | 0.04 | 0.06 | 1.6 |
| SE for watering regimes x genotypes | 0.17 | 0.09 | 0.11 | 3.1 |

### 3.2.2. Effect of Vernalization and Photoperiod on Phenology and Canopy Development in Durum Wheat

An understanding of how environment controls the phenology and canopy development of durum wheat is required to understand the adaptation of the crop. The aim of this study was to determine the effect of vernalization and photoperiod on days to anthesis, total number of leaves at anthesis, and phyllochron in sixteen improved cultivars and four lines selected from locally adapted landraces of durum wheat (*Triticum turgidum* L. ssp. *durum*) under greenhouse conditions. The experiment was conducted during spring 1992 at Tel Hadya, Syria, in all combinations of three photoperiods (8, 12 and 16 h daylength) and two vernalization treatments (vernalized and unvernalized). Differences in response to photoperiod and vernalization and genetic variation independent of vernalization and photoperiod (intrinsic earliness), affecting anthesis date of durum wheat were identified. Days to anthesis was positively related to number of leaves at anthesis (Tables 3.2.4 and 3.2.5). Days to anthesis and number of leaves at anthesis decreased with increasing photoperiod in the photoperiod-sensitive genotypes. Vernalization sensitive genotypes were earlier and had less number of leaves in the vernalized plants compared with the unvernalized. Most of the lines selected from landraces were sensitive to both vernalization and photoperiod. Improved genotypes were different in their sensitivity to vernalization and photoperiod. Phyllochron decreased with increasing daylength and this was more pronounced in photoperiod-sensitive genotypes (Table 3.2.6). These results suggest that phenology and number of leaves of durum wheat is affected by photoperiod and vernalization while phyllochron was affected by photoperiod. - **M.G. Mosaad, V. Mahalakshmi, G. Ortiz-Ferrara, M. Nachit and J.M. Peacock**

**Table 3.2.4. Days to anthesis of twenty durum wheat genotypes under vernalized (V) and unvernalized (0) treatments, with long (L) (16 h) and short (S) photoperiod (12 h) and the main effect of vernalization (ΔV), photoperiod (ΔP) and their interaction.**

| | | Days to anthesis | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Genotype | Type | VL | OL | VS | OS | ΔV | ΔP | V x P |
| Insensitive to V and P | | | | | | | | |
| Genil -3 | I | 48 | 48 | 49 | 48 | -1 | 1 | 4 |
| Lahn//Gs/Stk | I | 47 | 47 | 48 | 47 | 1 | 1 | 6 |
| Stork | C | 46 | 47 | 49 | 47 | 1 | 3 | 5 |
| Mrb 3/Tun D.7 | I | 47 | 47 | 50 | 47 | 1 | 4 | 8 |
| Cham -1 | I | 48 | 48 | 54 | 48 | 1 | 6 | -3 |
| Korifla | I | 47 | 48 | 54 | 48 | 1 | 7 | 1 |
| Gallareta | I | 49 | 53 | 54 | 53 | 4 | 5 | -5 |
| Syrica -1 | I | 47 | 51 | 52 | 51 | 4 | 5 | 4 |
| Om Rabi - 5 | I | 48 | 46 | 58 | 60 | -2 | 11 | 4 |
| Mean | | 47 | 48 | 52 | 56 | 1 | 5 | 3 |
| Sensitive to V and insensitive to P | | | | | | | | |
| Lahn | I | 48 | 62 | 56 | 60 | 14 | 8 | -9 |
| Insensitive to V and sensitive to P | | | | | | | | |
| Bicre | I | 47 | 50 | 82 | 82 | 3 | 35 | -3 |
| Tensift -1 | I | 48 | 52 | 77 | 81 | 3 | 29 | 0 |
| Rufom -7 | I | 48 | 52 | 80 | 79 | 4 | 32 | -5 |
| Kavarna 6933 | SL | 62 | 58 | 87 | 103 | -4 | 25 | 20 |
| Rufom -5 | I | 48 | 48 | 72 | 77 | 0 | 24 | 6 |
| Omtel -1 | I | 48 | 53 | 72 | 67 | 4 | 23 | -9 |
| Mean | | 50 | 52 | 78 | 82 | 2 | 28 | 2 |
| Sensitive to V and P | | | | | | | | |
| Kabir -1 | I | 48 | 81 | 72 | 81 | 33 | 25 | -25 |
| Biskri 7056 | SL | 57 | 73 | 91 | 91 | 16 | 34 | -15 |
| Oued Zenati 368 | SL | 54 | 64 | 87 | 87 | 10 | 33 | -10 |
| Belady 12202 | SL | 53 | 62 | 83 | 106 | 8 | 30 | 15 |
| Mean | | 53 | 70 | 83 | 91 | 17 | 30 | -9 |

I = improved; SL = selected from landrace; C = check

**Table 3.2.5. Effect of photoperiod and vernalization on number of leaves on the main stem at anthesis in twenty durum wheat genotypes under plastic-house conditions at Tel Hadya, 1992.**

| | 8h | | 12h | | 16h | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Genotypes | V | 0 | V | 0 | V | 0 | ΔV | ΔP | PxV |
| Insensitive to V and P | | | | | | | | | |
| Genil-3 | 8 | 10 | 7 | 7 | 7 | 7 | 0 | 0 | 1 |
| Lahn//Gs/Stk | 9 | 11 | 7 | 8 | 7 | 7 | 0 | 0 | 0 |
| Stork | 8 | 9 | 6 | 8 | 7 | 7 | 0 | -1 | 1 |
| Mrb 3/Tun D.7 | 10 | 12 | 8 | 9 | 7 | 8 | 1 | 1 | 0 |
| Cham 1 | 10 | 10 | 7 | 8 | 7 | 7 | 1 | 0 | 0 |
| Korifla | 8 | 10 | 7 | 8 | 7 | 7 | 1 | 0 | 0 |
| Gallareta | 9 | 10 | 7 | 9 | 6 | 8 | 2 | 1 | 0 |
| Syrica -1 | 9 | 12 | 7 | 9 | 6 | 8 | 2 | 1 | 0 |
| Om Rabi -5 | 12 | 13 | 8 | 9 | 7 | 7 | 1 | 1 | 1 |
| Mean | 9 | 11 | 7 | 8 | 7 | 7 | 1 | 0 | 0 |
| Sensitive to V and insensitive to P | | | | | | | | | |
| Lahn | 9 | 12 | 7 | 10 | 7 | 10 | 3 | 1 | -1 |
| Insensitive to V and sensitive to P | | | | | | | | | |
| Bicre | 15 | 14 | 10 | 11 | 7 | 8 | 1 | 3 | 0 |
| Tensift -1 | 13 | 14 | 10 | 12 | 7 | 9 | 2 | 3 | -1 |
| Rufom -7 | 13 | 14 | 9 | 11 | 6 | 7 | 1 | 3 | 0 |
| 6937 Kavarna | 15 | 14 | 13 | 13 | 9 | 10 | 1 | 4 | -1 |
| Rufom -5 | 14 | 14 | 9 | 10 | 7 | 7 | 0 | 2 | 1 |
| Omtel -1 | 14 | 15 | 10 | 10 | 7 | 8 | 1 | 3 | 0 |
| Mean | 14 | 14 | 10 | 11 | 7 | 8 | 1 | 3 | 0 |
| Sensitive to V and P | | | | | | | | | |
| Kabir -1 | 13 | 13 | 9 | 10 | 7 | 13 | 6 | 2 | -4 |
| 7056 Biskri | 14 | 14 | 12 | 13 | 8 | 10 | 2 | 4 | -1 |
| Oued Zenati | 15 | 14 | 11 | 13 | 8 | 11 | 3 | 3 | -2 |
| 12202 Belady | 13 | 14 | 10 | 14 | 7 | 10 | 3 | 3 | 0 |
| Mean | 14 | 14 | 11 | 12 | 8 | 11 | 4 | 3 | -2 |

**Table 3.2.6. Effect of photoperiod and vernalization treatment combinations on phyllochron (°C day leaf$^{-1}$) in twenty durum wheat genotypes. Values in parantheses denote ± S.E.**

| Genotype | 8 h | | 12 h | | 16 h | |
|---|---|---|---|---|---|---|
| | V | 0 | V | 0 | V | 0 |
| Insensitive to V and P | | | | | | |
| Genil -3 | 115(1.4) | 108(1.1) | 92(1.1) | 99(1.8) | 87(1.6) | 90(1.6) |
| Lahn//Gs/Stk | 114(2.0) | 110(1.4) | 92(2.2) | 97(1.6) | 91(1.4) | 92(1.3) |
| Stork | 119(1.5) | 107(1.2) | 108(1.8) | 100(1.0) | 95(1.3) | 94(1.0) |
| Mrb 3/Tun D.7.. | 111(1.9) | 108(1.1) | 97(1.2) | 105(2.1) | 92(1.9) | 90(1.1) |
| Cham 1 | 120(1.8) | 117(0.9) | 108(1.5) | 93(1.6) | 98(1.5) | 93(1.2) |
| Korifla | 125(1.6) | 121(1.2) | 111(1.6) | 106(1.3) | 98(1.9) | 89(1.4) |
| Gallareta | 118(1.5) | 114(1.3) | 103(2.2) | 92(1.8) | 97(1.1) | 90(1.6) |
| Syrica -1 | 121(2.9) | 115(1.2) | 104(2.4) | 102(1.5) | 104(1.3) | 95(1.4) |
| Om Rabi -5 | 122(1.4) | 121(0.8) | 110(1.9) | 100(1.3) | 92(1.5) | 89(1.5) |
| Group mean | 118 | 113 | 103 | 99 | 95 | 91 |
| Sensitive to V and insensitive to P | | | | | | |
| Lahn | 114(2.3) | 106(1.2) | 105(1.3) | 98(1.7) | 96(1.4) | 94(1.6) |
| Insensitive to V and sensitive to P | | | | | | |
| Bicre | 126(1.5) | 125(2.1) | 119(1.5) | 104(1.9) | 103(1.8) | 88(1.9) |
| Tensift -1 | 130(1.6) | 125(1.4) | 110(2.0) | 112(1.5) | 95(1.8) | 87(1.1) |
| Rufom -7 | 133(2.1) | 127(2.1) | 124(2.8) | 111(2.4) | 161(1.3) | 98(1.4) |
| 693 Kavarna | 122(1.7) | 118(1.9) | 106(1.6) | 112(1.1) | 108(1.2) | 93(1.8) |
| Rufom -5 | 130(2.2) | 129(2.1) | 121(1.8) | 116(1.6) | 98(1.4) | 91(2.2) |
| Omtel -1 | 122(2.2) | 113(1.5) | 110(1.5) | 103(1.2) | 87(1.4) | 82(1.9) |
| Group mean | 127 | 123 | 115 | 110 | 101 | 90 |
| Sensitive to V and P | | | | | | |
| Kabir -1 | 129(1.8) | 125(0.9) | 116(1.5) | 122(1.2) | 99(2.4) | 110(0.9) |
| 7056 Biskri | 130(1.5) | 128(1.6) | 119(1.4) | 116(1.7) | 116(1.1) | 107(1.0) |
| Oued Zenati | 120(1.9) | 122(1.6) | 111(2.2) | 112(1.5) | 97(1.7) | 97(1.7) |
| 12202 Belady | 133(1.6) | 111(2.1) | 117(2.0) | 103(1.8) | 87(0.9) | 99(1.5) |
| Group mean | 128 | 126 | 114 | 117 | 104 | 103 |

### 3.2.3. Micronutrient Studies

#### 3.2.3.1. Boron Toxicity Tolerance

**Differential Yield Responses:** Nineteen durum wheat landraces, cultivars or advanced lines of different origin in WANA were evaluated for their B-toxicity tolerance at the seedling stage in a plastic house in 1992-93. Significant differences in foliar-symptom scores were observed. To test if seedling performance corresponds to yield performance, nine of the entries were grown in pots up to maturity in a plastic house under low N fertility in three replicates. Three soil B levels were created by adding 0 (B0), 25 (B25) and 50 (B50) mg B/kg soil, giving a hot water extract of 0.3, 7.1 and 17.4 ppm B, respectively.

Gezira (old Syrian cultivar) and Oued Zenati (Algerian landrace) were the most B-toxicity tolerant durum entries (Table 3.2.7) having low B-toxicity symptom scores and low shoot-B concentrations at B25 and B50, slight delay in heading, and small or no reduction in grain and straw yields at B50 as compared to B0. When compared with the tolerant Australian bread wheat cultivar, Halberd, delay in heading and reduction in yields were similar, but they had higher symptom scores and B concentrations. Boron-toxicity symptom score taken at seedling stage showed non-significant (P 0.001) correlation with seedling shoot-B concentration (confirmation of last year's results), delay in heading and yield reductions. Shoot-B concentration had a significant correlation with delay in heading (r=0.75) and reduction in grain yield (r=0.69). By considering shoot B concentration, delay in heading and reduction in grain yield, Omrabi 5 (sister line of Cham 5, the latest released cultivar in Syria) has higher B-toxicity tolerance than Cham 3 (released in 1987 in Syria), which in turn has higher tolerance than Cham 1 (released in 1984 in Syria). - **S.K. Yau, M.M. Nachit, J. Ryan (FRMP), J. Hamblin (CLIMA, Australia)**

**Table 3.2.7. Mean B-toxicity symptom score and shoot-B concentration at B25 and B50 treatments, delay in heading, and reduction /increase in grain and straw yield from B0 to B50 treatment for durum wheat test entries and bread wheat checks.**

| Name/cross | B toxicity symptom score[1] | Shoot B conc. (ppm) | Delay in days to heading | %difference in Straw yield | %difference in Grain yield |
|---|---|---|---|---|---|
| Gezira | 0.7 | 282 | 3.7 | +34.6 | - 2.8 |
| Omrabi 5 | 0.8 | 240 | 6.0 | -15.6 | -10.4 |
| Haurani | 1.3 | 334 | 7.0 | -11.6 | -31.7 |
| Oued Zenati | 1.1 | 245 | 2.0 | - 6.7 | - 1.4 |
| Cham 3 | 2.3 | 329 | 7.7 | -11.8 | -14.7 |
| Jordan 21 | 1.1 | 356 | 8.0 | -16.6 | -25.6 |
| Deraa | 1.3 | 380 | 8.0 | -13.1 | -11.9 |
| Cham 1 | 1.3 | 391 | 11.3 | + 5.0 | -29.0 |
| Cakmak | 2.8 | 347 | 4.3 | -19.3 | -30.0 |
| Tolerant bread wheat check | | | | | |
| Halberd | 0.3 | 203 | 2.3 | + 1.4 | - 6.1 |
| Susceptible bread wheat check | | | | | |
| Schomburgk | 0.8 | 225 | 4.7 | - 9.8 | -16.0 |
| Mean | 1.4 | 323 | 6.4 | - 6.1 | -17.5 |
| LSD (P=0.05): | 0.3 | 77 | 4.2 | 20.8 | ns |

[1] 0-5 scale: 0 = no symptom, 5 = severe symptom. Scores taken at seedling stage.

**Testing Last Season's Selection:** Out of the 246 advanced lines from the 1992-93 regional nurseries screened last season, 15 lines with low B-toxicity symptoms and low shoot-B concentration were grown in pots up to maturity under a plastic house. There were two treatments: control (0.4 ppm hot water extractable B) and +B (50 mg B/kg soil, giving a hot water extract of 18 ppm B).

The performance of the most B-toxicity tolerant lines is presented in Table 3.2.8. All lines showed a substantial reduction in grain yield under the +B treatment. The best line, Awl 1//Memo/Goo (= Awalbor), suffered a 10 % yield decrease, which was lower than that of Halberd, the tolerant Australia bread wheat cultivar, but higher than that of Greek G61450, the highly tolerant bread wheat check. Relative to grain yield, the reduction in straw yield was much smaller, and Awl 1//Memo/Goo had a 24% increase.

**Table 3.2.8. Performance of the most B-toxicity tolerant durum wheat lines (in terms of least reduction in grain yield when grown in soil added with 50 mg B/kg soil [+B] relative to the control [-B]).**

| Name/cross | B toxicity symptom score[1] at +B | Difference in days to heading (+B to -B) | % difference over -B plants | |
|---|---|---|---|---|
| | | | Straw yield | Grain yield |
| Awl 1//Memo/Goo[2] | 2.0 | 10.5 | +23.7 | y-10.6 |
| Awl 2/Bit[3] | 2.0 | 8 | +16.5 | -25.6 |
| Awl 2/Bit[4] | 2.0 | 10 | +14.8 | -29.6 |
| T.A73-74/D.Coll-01.1y/3/Pg/Chap//21563/4/Crosby[5] | 2.0 | 4.5 | -13.3 | -33.0 |
| Tolerant bread wheat check | | | | |
| Halberd | 1.0 | 6.5 | -14.4 | -36.4 |
| Highly tolerant bread wheat check | | | | |
| Greek G61450 | 0.7 | 4.5 | +17.0 | + 2.4 |
| Susceptible bread wheat check | | | | |
| Zidane | 3.0 | 7.5 | -36.3 | -39.9 |
| Mean of 15 lines | 2.0 | 7.6 | -16.8 | -43.6 |
| LSD (P=0.05) | 0.2 | 2.3 | 34.5 | 24.3 |

[1] 0-9 scale: 0 = no symptom, 9 = severe symptom. Scores taken at seedling stage.
[2] = Awalbor
[3] = Awalbit B-1
[4] = Awalbit B-2
[5] = ICA84-1555-B

Excessive soil B delayed heading, and all of the selected lines had higher B-toxicity symptom scores than Halberd at the seedling stage. **- S.K. Yau, M.M. Nachit, M.C. Saxena**

**Seedling Test:** Seedlings of 134 advanced CIMMYT/ICARDA durum lines from the 1993-94 Regional Observation Nursery for High Altitude Areas were tested in a plastic house in soils mixed evenly with boric acid (50 mg B/kg soil, giving a hot water extract of around 20 ppm). Most lines had a higher mean symptom score than the Australian bread wheat check, Schomburgk. Four lines with the lowest B toxicity symptoms are presented in Table 3.2.9. These lines are derived from crosses with landraces or wild relatives. **- S.K.Yau, M.M. Nachit, M.C. Saxena**

**Table 3.2.9. Durum lines in the 1993-94 DON-HAA having least B-toxicity symptoms 6 weeks after sowing in soil to which 50 mg B/kg soil was added.**

| Ent. no. | Name/cross | Symptom score[1] |
|---|---|---|
| 14 | Kristal | 1.7 |
| 21 | Bd 272/T.dic.Sy 20101//Cham 1/3/Cham 1 | 1.7 |
| 30 | CD 21760/T.dic.-1Q 55132//Cham 1/3/Tourus-1/4/Shwa/Pt1 | 1.7 |
| 132 | Hau/A.Kots-Sy 20224//Cham 1 | 1.7 |
| Tolerant check | | |
| | Halberd (bread wheat from Australia) | 1.0 |
| Susceptible check | | |
| | Schomburgk (bread wheat from Australia) | 2.0 |

[1] 0-9 scale: 0=no symptom, 9=severe symptoms

### 3.2.3.2. Zinc Deficiency

Zinc deficiency is a wide-spread micronutrient problem in West Asia. In the world soil survey conducted by Sillanpaa (1982), Iraq had the lowest levels of mean soil Zn concentration among the countries studied, followed by Turkey. For Syria, Sillanpaa (1982) suggested that the most likely micronutrient problems are shortages of Zn and Mn.

Before embarking on screening for Zn deficiency tolerance, a preliminary experiment was initiated in a plastic house. Stork durum wheat, Mexipak bread wheat and Harmal barley were grown in triplicate in pots of a Zn deficient soil thoroughly mixed with and without $ZnSO_4$ (0.4 vs 3.2 ppm Zn). Grain and straw yields did not respond to Zn application for the durum wheat, but a positive response in bread wheat and a negative response in barley were observed.
**- S.K. Yau, J. Ryan (FRMP), M.M. Nachit**

## 3.3. International Nurseries

Regional durum wheat nurseries assembled by the joint CIMMYT/ICARDA durum wheat project at ICARDA are given in

Table 3.3.1. There were 11 different nurseries. The Crossing Block, which is prepared every 2-3 years, was assembled this year. A nursery consisting of segregating populations for high altitude areas was made available for the first time. The nursery 'Segregating Populations from Crosses with Wild Relatives' was not prepared due to seed shortage. The three germplasm pools for sources of resistance to yellow rust, stem rust or common bunt, which had been made available over the last two consecutive years, were discontinued as scheduled. In response to requests of national scientists, the number of lines included in the 'Observation Nursery for Favorable Areas' was reduced to a more manageable level. A total of 285 sets of regular nurseries were distributed this year, representing a slight reduction over last year. - **S.K. Yau, M.M. Nachit, M.C. Saxena**

**Table 3.3.1. Regional durum wheat nurseries for 1994-95.**

| Nursery | Abbre-viation | No. of entries | No. of sets distributed |
|---|---|---|---|
| **Mediterranean Coastal and Continental Areas:** | | | |
| **Regular Nurseries** | | | |
| Crossing Block | DCB | 100 | 27 |
| Segregating Populations | DSP | 96 | 35 |
| Observation Nurseries: | | | |
| - Semi-arid Areas | DON-SA | 180 | 25 |
| - Favorable Areas | DON-FA | 152 | 32 |
| Yield Trials: | | | |
| - Semi-arid Areas | DYT-SA | 24 | 23 |
| - Favorable Areas | DYT-FA | 24 | 41 |
| **Specific-trait Observation Nurseries** | | | |
| Drought & Heat Tolerance | DHTON | 48 | 32 |
| Drought & Cold Tolerance | DCTON | 48 | 23 |
| **Mediterranean Highland Areas:** | | | |
| Segregating Populations | DSP-HAA[1] | 62 | 9 |
| Observation Nursery | DON-HAA | 94 | 23 |
| Yield Trial | DYT-HAA | 24 | 15 |
| Total | | | 285 |

[1] HAA - High Altitude Areas

# 4. SPRING BREAD WHEAT IMPROVEMENT

## 4.1. Spring Bread Wheat Breeding

### 4.1.1. Introduction

The weather conditions during 1993-94 crop season at Tel Hadya and Breda (our main experimental stations in Syria), are reported in other sections of this annual report. Extensive damage by drought, cold, heat, and biotic stresses such as yellow rust and Hessian fly were reported from most of the dry production areas of West Asia and North Africa (WANA). This annual report presents data of progress made in developing germplasm with tolerance to these important stresses. We describe the revision in the research priorities in our breeding efforts for rainfed Mediterranean environments. We present: a) our activities in evaluating and using non-conventional material to enhance the biodiversity in our germplasm; b) results of our research on photoperiod and vernalization and the phyllochron response to these two factors in elite bread wheat germplasm; c) the research progress of our collaboration with national program scientists of Morocco in producing and evaluating double haploids for Hessian fly; and d) the progress made in jointly identifying germplasm with national programs of WANA and the potential impact of these developments for the sustainability of the farming systems for the resource-poor farmers of the region. **- G. Ortiz Ferrara**

### 4.1.2. Research Priorities for Bread Wheat Improvement

A detailed description of the three major agroecological zones where bread wheat is grown in WANA has been reported in ICARDA's annual report of 1988. This included geographical area, production, and the main stresses limiting yields. The low rainfall environments of the region continue to receive highest priority.

The CIMMYT/ICARDA spring bread wheat improvement project continues to evolve and adjust its priorities based on: a) new experiences and developments occurring in the

project, b) medium term plans of the two sister International Centers and, c) NARS's demands. Because of that, during 1994, the project further assessed and modified its research priorities (Table 4.1).

**Table 4.1. List of research priorities in the CIMMYT/ICARDA spring bread wheat improvement program (1994-2000).**

| Research activity | Production zone | | |
|---|---|---|---|
| Priority | LRT (<400 mm) | MRT (400-600 mm) | IRR |
| **Breeding** | | | |
| Yield | **** | * | D |
| Yield stability | **** | * | D |
| **Abiotic stresses** | | | |
| Terminal drought | **** | * | D |
| Cold | **** | * | D |
| Heat | *** | * | D |
| Salinity | D | * | D |
| **Methodology** | | | |
| Selection methods | **** | * | D |
| Multilocation testing | **** | * | D |
| Strategies | **** | * | D |
| **Pathology** | | | |
| Foliar diseases | * | **** | D |
| Seed borne diseases | *** | D | D |
| **Entomology** | | | |
| Insect pests | **** | * | D |
| **Agronomy** | *** | D | D |
| **Physiology** | **** | D | D |
| **Quality** | | | |
| Bread making | **** | * | D |
| Nutritional | **** | * | D |
| **Training** | **** | ** | D |
| **Regional activities** | **** | **** | **** |

LRT= Low rainfall-low temperature areas; MRT= Moderate rainfall with moderate to high temperature areas; IRR= Irrigated areas.
Priority: * Low; ** Medium; *** High; **** Very High.
D = Discontinued.

Continued emphasis was placed in the development of improved, adapted germplasm for the variable and unpredictable rainfed environments of the region, with special emphasis on low-rainfall areas (less than 400 mm annual rainfall). Research this year was concentrated on the

identification of parental material and advanced lines possessing high grain yield and stability, with tolerance to abiotic stresses such as terminal drought, cold and terminal heat, and to biotic stresses such as yellow rust, septoria, common bunt, sawflies, Hessian fly, suni bugs and aphids. Breeding activities in the irrigated and high rainfall areas were discontinued. These modifications will result in a reliance on CIMMYT's main station breeding program for irrigated areas and increased support by the joint CIMMYT/ICARDA project to NARS activities in the drought-prone wheat production zones. **- G. Ortiz Ferrara**

### 4.1.3. Breeding for Abiotic Stress Resistance

The breeding strategies used in our program, to develop and identify genetic material with tolerance to the abiotic and biotic stresses of WANA, has been published elsewhere (Ortiz Ferrara and Deghais 1988. Ortiz Ferrara et al. 1989)*. Using these methodes, the project has identified genetic material with tolerance to the principal stresses. This material is made available to national programs in the region for either direct use or further incorporation in their own breeding programs.

Terminal drought, cold, and terminal heat are the main abiotic stresses responsible for reduced yields in the rainfed-Mediterranean environments of the region. In selecting and identifying germplasm with tolerance to these stresses, the project emphasizes the use of multilocation testing. This is done at two different levels: (1) international multilocation testing, in which data from 50 to 75 locations in the region is obtained through the CIMMYT/ICARDA International Nurseries System, and (2) regional multilocation testing, five different environments at ICARDA sites in Syria and Lebanon. The latter constitutes

---

* Ortiz Ferrara, G. and Deghais, M. 1988. Modified bulk: a selection method for enhancing disease resistance and adaptation in rainfed wheat. Pages 1149-1153 in: Proceedings of the Seventh International Wheat Genetics Symposium, Cambridge, England.

the hub of the screening program in which segregating populations and advanced lines are tested and selected under different moisture and temperature conditions.

The yield levels of advanced bread wheat lines tested for two consecutive years in three of these environments are shown in Table 4.2.2. Both years were extremely dry (less than 300 mm rainfall) at Breda (BR), a location used to screen germplasm for terminal drought resistance under low fertility conditions. Similarly, high temperatures and moisture stress were also experienced in both years in Tel Hadya Late Planting (TH-LP), which was used to screen for terminal heat stress during the reproductive period. The environmental conditions at Terbol (TB) site in Lebanon, which is used by the project to screen for cold and disease resistance under optimum moisture and fertility conditions, were similar in the two years and resembled long-term average except for the rainfall which was low in 1994. Despite the low rainfall, the grain yield of the top performing line, the mean of the best ten lines, as well as the mean yield of lines in the trials were substantially higher in 1994 in the three environments. The mean yield of the local checks was only slightly higher in 1994 than in 1993. These trends in yield increases reflect progress made by the project in breeding for terminal drought, terminal heat, and cold stress. **- G. Ortiz Ferrara, M.A. Moussa, M.G. Mosaad, and N. Rbeiz**

### 4.1.4. Enhancing Disease Resistance

Yellow rust, leaf rust, stem rust and septoria tritici blotch are the main foliar diseases in WANA. During the past two seasons, some countries in West Asia such as Iran, Lebanon and Syria, have experienced yield reductions due to yellow rust. This is believed to be due to the following reasons: a) the possible presence of a new race of the pathogen, b) unusually favorable weather conditions for yellow rust development (cool and rainy) at the end of the season, c) wide spread use of the varieties susceptible Yr9 gene associated with the 1B/1R translocation and, d) lack of enough seed of resistant varieties to replace the susceptible ones.

**Table 4.2. Trends in yield levels of advanced spring bread wheat lines over two years and three environments: terminal drought (BR); terminal heat (TH-LP); and cold stress (TB). Advanced yield trials, 1993 and 1994.**

| | Grain yield (kg/ha) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Highest yielding line | | | Ave. of best ten lines | | | Ave. of all lines | | | Ave. local check | | |
| Year | BR | TH-LP | TB | BR | TH-LP | TB | BR | TH-LP | TB | BR | TH-LP | TB |
| 1993 | 2366 | 1955 | 5116 | 2290 | 1824 | 4208 | 1957 | 1264 | 3317 | 1816 | 1204 | 3137 |
| 1994 | 2933 | 2305 | 6433 | 2770 | 2040 | 5876 | 2264 | 1312 | 4981 | 1902 | 1198 | 3204 |
| % increaese in 1994 | 124 | 116 | 126 | 121 | 112 | 140 | 116 | 104 | 150 | 104 | 100 | 102 |

BR = Breda .(< 300 mm in both years); TH-LP = Tel Hadya late planting (total rainfall plus supplementary irrigation, 300 mm); TB = Terbol, Lebanon (total rainfall plus supplementary irrigation, 664 mm in 1993 and 475 mm in 1994). Number of lines tested N = 216 in 1993 and 288 in 1994.

Because of the possibility of the presence of a new race of yellow rust, the project has placed increased efforts to select and evaluate germplasm with different genetic sources of resistance to this pathogen. Evaluation of disease reaction is based on the use of multilocation testing, the modified bulk method of selection, artificial inoculations and a close cooperation with the pathologists.

This strategy has increased the level of disease resistance in bread wheat germplasm. As an example, due to the increased selection pressure excercised for yellow rust resistance during the last two seasons, the percentage of resistant families has increased in each sccessive generation (Fig. 4.1). Many families in the resistant segregating material combine one or two genes for yellow rust resistance. In cooperation with the pathologist, the project is planing to conduct race virulence analysis and gene identification in elite germplasm. The project is also aiming at incorporating different sources of yellow rust resistance from distant sources such as Ae. geniculata, Ae. neglecta and Ae. triuncialis.

In cooperation with national programs in the region, the project has identified several lines that combine high grain yield, and yield stability with good sources of yellow rust resistance. Table 4.3 shows six bread wheat lines that had higher grain yield and better yellow rust resistance than the national check variety in three of the countries that have reported substantial damage during 1993 and 1994 from yellow rust. These lines are currently under extensive testing and seed multiplication. Seed of these lines would be provided to those NARS in 1995. **- G. Ortiz Ferrara, O.F. Mamluk, M.A. Moussa and M.G. Mosaad.**

### 4.1.5. Use of Double Haploids to develop Hessian Fly Resistance

In cooperation with senior scientists in Morocco and with the biotechnology group at ICARDA, the project evaluated during 1993-94 a series of double haploids developed with Hessian fly resistance parental material. The technique of production and the details of the trial were reported in the Cereals Program Annual Report for 1993.

**Table 4.3. Grain yield and yellow rust reaction (YR) of promising bread wheat lines in selected countries of West Asia, RWYT-SA 1993-94.**

| Cross | Iran (Moghan) Grain yield | | YR | Syria (Izraa) Grain yield | | YR | Lebanon (Kfardan) Grain yield | | YR |
|---|---|---|---|---|---|---|---|---|---|
| | kg/ha | % of NC | | kg/ha | % of NC | | kg/ha | % of NC | |
| Tevee-2 | 5134 | 183 | R | 2760 | 107 | R | 3111 | 114 | |
| Buc'S'/Mn 72253 | 4610 | 164 | 5MS | 2680 | 104 | R | 3000 | 110 | R |
| Florkwa-1 | 4265 | 152 | 5MR | 2613 | 101 | R | 2955 | 109 | 5MR |
| Kacino | 4150 | 148 | R | 2560 | 99 | R | 2738 | 101 | TMR |
| Caskor | 3740 | 133 | R | 2533 | 98 | 10MR | 2833 | 104 | R |
| Kaby | 3575 | 127 | TMS | 2626 | 102 | R | 2833 | 104 | TMR |
| Mexipak (LC) | 3257 | 115 | 20S | 2346 | 90 | 100S | 2266 | 83 | 100S |
| Natl.Check(NC) | 2808 | 100 | 30MS | 2586 | 100 | 40M | 2722 | 100 | 100S |
| Site mean | 3954 | - | - | 2548 | - | - | 2530 | - | - |
| LSD .05 | 1108 | - | - | 749 | - | - | 632 | - | - |
| CV (%) | 15.3 | - | - | 17.8 | - | - | 15.2 | - | - |

The yield trial with the Hessian fly double haploids was planted at Jma't Shaim, Morocco during the 1993-94 crop season. This is a hot spot where high infestations of this insect pest occur every year under natural conditions. Table 4.4 presents five of the highest yielding double haploids (DH) in the trial. The grain yields of these DH lines were substantially higher than those of the Hessian fly resistant and susceptible parents. These DHs combine Hessian fly resistance with other desirable traits such as resistance to yellow rust, and septoria tritici blotch and tolerance to drought. This trial is currently planted for a second year in Morocco. The DH lines and the resistant parents are under seed multiplication at Tel Hadya. - **G. Ortiz Ferrara, P. Lashermes, M. El Bouhssini, M. Merghoum, M. Jlibene, A. Amri, F. Weigand, S. Weigand, O.F. Mamlouk, and M.S. Mekni**

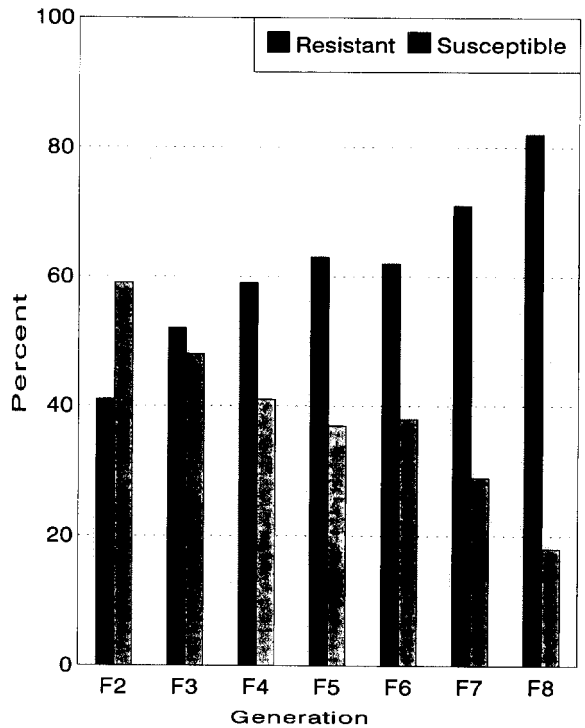



Figure 4.1. Percentage of resistant or susceptible bread wheat families to yellow rust in various generations at Tel Hadya during 1993/94 under the artificial epiphytotics created with mixed inoculum of the disease.

**Table 4.4. Performance of double haploid-Hessian fly resistant bread wheat lines under natural infestation and dry conditions at Jma't Shaim, Morocco, 1993-94.**

| Line | Grain yield (kg/ha) | % of HFRP | % of HFSP |
|---|---|---|---|
| Shi#4414/Crow//Gomam | 2975 | 121 | 153 |
| Shi#4414/Crow//Gomam | 2933 | 119 | 151 |
| Shi#4414/Crow//Gomam | 2883 | 117 | 148 |
| Tsi/Vee//Shi#4414/Crow | 2775 | 113 | 129 |
| Vee's'/Saada | 2650 | 108 | 124 |
| Shi#4414/Crow (HFRP) | 2458 | 100 | |
| Saada (HFRP) | 2458 | | |
| Tsi/Vee's' (HFSP) | 2158 | | |
| Vee's' (HFSP) | 2141 | | 100 |
| Gomam (HFSP) | 1942 | | |
| Site mean | 2214 | | |
| LSD (0.05) | 632 | | |
| CV (%) | 14.0 | | |

HFRP=Hessian fly resistant parent; HFSP=Hessian fly susceptible parent.

### 4.1.6. Evaluation of Landraces for Stress Resistance Breeding

The utility of particular traits as selection criteria in a breeding program depends on the ease and cost of screening, the reliability of observations and the genetic variability available for that trait. Moss et al. (1974) indicated that the information to guide plant breeders in developing higher yielding varieties by selecting for specific physiological traits controlling stress resistance was not available. They recommended close cooperation between physiologists, physical scientists and plant breeders in defining stress related traits, in discovering genetic variability for these traits and in incorporating desirable traits into new varieties.

The breeding/physiological approach to abiotic stresses including the techniques followed by the project to identify easily measurable traits associated with yield under stress conditions, and the amount of genetic variability available for those traits, was presented by Ortiz Ferrara et al. (1989). In that study, eleven morphological, physiological

and/or phenological traits were used to evaluate eighty four advanced bread wheat lines under terminal drought, terminal heat and cold stress conditions. Increased leaf rolling, longer peduncle length, increased plant height, early heading and maturity and higher number of tillers/$m^2$ proved important under terminal drought and heat stress. Conversely, with the exception of leaf temperature, all other characters responded differently under cold stress. It was concluded that sufficient variability exists within the eighty four lines for these traits to warrant further studies of their use as selection tools.

To identify additional sources of genetic variability for stress-related traits, evaluation was done of 96 accessions of bread wheat landraces collected in WANA. Tables 4.5 and 4.6 confirm that adequate variability exists among this type of material to justify its exploitation and use for stress resistance breeding. During the past five years, about 20% of our crossing program has been directed at the incorporation of this material in our breeding project.

**Table 4.5. Genetic variation among 96 accessions of bread wheat landraces for several morphological and physiological characters evaluated under terminal drought stress (183 mm total seasonal rainfall) in the landraces yield trial 1989-90, Breda, Syria.**

| Character | Maximum | Minimum | Mean | GCV (%) |
|---|---|---|---|---|
| Grain yield (kg/ha) | 1177 | 133 | 585 | 35.7 |
| Growth habit (GH) | 5 | 1 | 3.3 | 14.2 |
| Seedling vigor (SV) | 5 | 1 | 3.0 | 20.9 |
| Leaf rolling (LR) | 5 | 1 | 3.2 | 22.3 |
| Days to heading | 159 | 138 | 150 | 1.5 |
| Days to maturity | 185 | 167 | 176 | 0.8 |
| Plant height (cm) | 50 | 25 | 35 | 18.9 |
| Frost resistance score (FRS) | 5 | 2 | 4.0 | 12.1 |
| Leaf temperature (°C) | 37 | 32 | 34.9 | 3.2 |

GCV = genotypic coefficient of variation. Scale for SV, LR, and FRS: 1 = low, 5 = high. GH: 1 = erect, 5 = prostrate.

**Table 4.6. Genetic variation among 96 ccessions of bread wheat landraces for several morphological and physiological characters evaluated under cold stress (minimum temp.-10°C) in the landraces yield trial 1989-90, Tel Hadya, Syria.**

| Character | Maximum | Minimum | Mean | GCV (%) |
|---|---|---|---|---|
| Grain yield (kg/ha) | 3555 | 133 | 1788 | 29.9 |
| Growth habit (GH) | 5 | 1 | 3.1 | 13.2 |
| Seedling vigor (SV) | 5 | 1 | 3.5 | 14.0 |
| Leaf rolling (LR) | 5 | 1 | 2.9 | 23.7 |
| Days to heading | 194 | 165 | 177 | 1.2 |
| Days to maturity | 229 | 211 | 218 | 1.0 |
| Plant height (cm) | 90 | 55 | 69 | 10.4 |
| Frost resistance score (FRS) | 5 | 1 | 2.9 | 13.9 |
| Leaf temperature (°C) | 33 | 19 | 24.6 | 5.2 |
| Tillering (1 mtr) | 280 | 49 | 96.2 | 28.1 |
| Peduncle length (cm) | 56 | 19 | 30.4 | 20.2 |

GCV = genotypic coefficient of variation. Scale for SV, LR, and FRS: 1 = low, 5 = high. GH: 1 = erect, 5 = prostrate.
- **G. Ortiz Ferrara, M.A. Moussa, M.G. Mosaad, and J. Valkoun.**

### 4.1.7. Research on Potoperiod, Vernalization and Phyllochron Response

Screening techniques that allow the characterization of large numbers of breeding lines for vernalization and photoperiod response in wheat are needed to enhance the adaptation of the crop. In this experiment, twenty bread wheat lines were evaluated for their response to vernalization and photoperiods under two controlled environments and high ambient air temperatures under field conditions. Vernalized and unvernalized seedlings were transplanted to pots and placed in three photoperiods (8, 12 and 16 h of light) in the plastic house or in growth chambers.

Days to anthesis decreased with increasing photoperiod and vernalized plants flowered earlier than unvernalized (Ortiz Ferrara et al. 1994).

.7. Correlation coefficients between the values for basal vegetative period (BVP), e to vernalization (ΔV), and response to photoperiod (ΔP) obtained in plastic house (PH) se obtained in growth chamber (C) and the correlation of those values with the growth GH), vernalization response (VR) and days to heading (DHE) as recorded under heat- d field (F) conditions, (n=23).

| | Plastic house | | | Growth chamber | | | Field | | |
|---|---|---|---|---|---|---|---|---|---|
| | BVP | ΔV | ΔP | BVP | ΔV | ΔP | GH | VR | DHE |
| | - | 0.15 | -0.12 | 0.70*** | 0.13 | 0.16 | 0.19 | 0.33 | 0.40 |
| | | | 0.41* | -0.09 | 0.92*** | 0.28 | 0.75*** | 0.87*** | 0.91*** |
| | | | | 0.00 | 0.43* | 0.71*** | 0.16 | 0.17 | -0.29 |
| | | | | | -0.27 | 0.06 | 0.00 | 0.07 | 0.26 |
| | | | | | | 0.41* | 0.65*** | 0.73*** | 0.74*** |
| | | | | | | | 0.08 | 0.17 | -0.07 |
| | | | | | | | | 0.87*** | 0.84*** |
| | | | | | | | | | 0.95*** |

0.001; ** P<0.01; * P<0.05

Table 4.7 shows the correlation coefficients between basal vegetative period, main effect of vernalization, and main effect of photoperiod in plastic house and growth chamber with agronomic traits under heat-stressed field conditions. Days to anthesis data were significantly correlated between the plastic house and the growth chamber (r =0.88***). Basal vegetative period and effect of vernalization and photoperiod from the two screening techniques were also positively correlated. Growth habit, vernalization requirement and heading date in the field were highly correlated with the main effect of vernalization in the two controlled environments. The results of this research indicated that selection for vernalization response of a large number of genotypes can be achieved under high ambient air temperatures in the field and selected material can subsequently be screened for photoperiod response under plastic house conditions.

An understanding of how the environment controls the initiation and development of the wheat leaf is required to construct dynamic crop simulation models. A plastic house experiment was conducted to determine the effect of vernalization and photoperiod on total number of leaves at anthesis,leaf emergence rate, and phyllochron in 20 spring bread wheat genotypes. All combinations of three photoperiods (8, 12, and 16 h daylength) and two vernalization treatments (vernalized and unvernalized) were tested.

Total number of leaves on the main stem at anthesis decreased with increased photoperiod. Vernalization reduced the total number of leaves on main stem at anthesis in the vernalization-sensitive genotypes (Mosaad et al. 1994)*.

Table 4.8 presents the effect of photoperiod and vernalization on phyllochron interval ($^{\circ}C$ day $leaf^{-1}$) in different spring bread wheat genotypes under plastic house conditions. Leaf number on the main stem was linearly (r =0.99) related to accumulated growing degree days ($^{\circ}C$ d).

---

* Mosaad, M.G., Ortiz Ferrara, G., Mahalakshmi, M., and Fischer, R.A. 1994. Phyllochron response to vernalization and photoperiod in spring wheat. Crop Science. (In press).

Genotypes differed in leaf emergence rates. Leaf emergence rate increased with increasing photoperiod. Phyllochron decreased with increased daylength from 124 °C day leaf$^{-1}$ at 8 h to 97 °C day leaf$^{-1}$ at 16 h photoperiod. These results suggest that, to model leaf appearance and canopy development in bread wheat, genotypic coefficients of phyllochron need to be determined in relation to photoperiod.

**Table 4.8. Effect of photoperiod and vernalization on phyllochron interval (°C day leaf $^{-1}$) in different spring bread wheat genotypes under plastic house conditions in Tel Hadya, Syria, 1992.**

| Genotype | 8 h | | 12 h | | 16 h | |
|---|---|---|---|---|---|---|
| | Ver | Non-ver | Ver | Non-ver | Ver | Non-ver |
| 1 Zargoon | 127 | 116 | 109 | 114 | 107 | 100 |
| 2 HTYT90-108 | 119 | 123 | 115 | 106 | 100 | 98 |
| 3 Dorghal | 124 | 114 | 107 | 100 | 108 | 102 |
| 4 HTYT90-218 | 122 | 115 | 105 | 109 | 99 | 100 |
| 5 Zidane 89 | 115 | 110 | 104 | 110 | 102 | 91 |
| 6 HTYT90-302 | 121 | 137 | 98 | 109 | 91 | 108 |
| 7 Sudan #1 | 130 | 109 | 119 | 104 | 102 | 96 |
| 8 HTYT90-311 | 118 | 105 | 93 | 119 | 94 | 91 |
| 9 HTYT90-403 | 112 | 103 | 98 | 97 | 102 | 101 |
| 10 DTL-19 | 147 | 115 | 108 | 112 | 105 | 103 |
| 11 RHYT92-5 | 117 | 123 | 111 | 98 | 108 | 97 |
| 12 RHYT92-6 | 120 | 117 | 105 | 100 | 96 | 96 |
| 13 Debeira | 157 | 160 | 146 | 118 | 112 | 106 |
| 14 RHYT92-8 | 122 | 120 | 105 | 89 | 105 | 96 |
| 15 Yamama | 127 | 138 | 106 | 105 | 102 | 99 |
| 16 RHYT92-17 | 118 | 114 | 97 | 104 | 96 | 93 |
| 17 Gomam | 126 | 111 | 109 | 105 | 107 | 100 |
| 18 RHYT92-18 | 123 | 120 | 99 | 101 | 95 | 91 |
| 19 RHYT92-19 | 123 | 130 | 111 | 103 | 103 | 92 |
| 20 Cham 6 | 115 | 128 | 92 | 99 | 87 | 85 |
| CV (%) | | | 7.8 | | | |
| LSD (0.05) for Photoperiod at the same level of Vernalization | | | | | 2.37 | |
| LSD (0.05) for Vernalization at the same level of Genotype | | | | | 6.11 | |
| LSD (0.05) for Genotype at the same level of vernalization | | | | | 6.12 | |

Additionally, the effect of vernalization at inductive photoperiods on the phyllochron in genotypes adapted to heat-

prone tropical environments needs further study. - **G. Ortiz Ferrara, M.G. Mosaad, V. Mahalakshmi, R.A. Fischer, and M.A. Moussa.**

### 4.1.8. Breeding for High Yield and Stability

In WANA, bread wheat is usually grown at precipitation levels ranging from 250 to 650 mm. The spring bread wheat project continued to select and identify breeding material for this wide range of precipitation and to disseminate it in the region through the CIMMYT/ICARDA international nurseries system.

Grain yield and yield stability are the most important objectives in the dry areas of WANA. Table 4.9 presents the yield and stability of promising bread wheat germplasm compared to improved check in the Regional Wheat Yield Trial for Low Rainfall Areas (RWYTT-LRA) conducted at at least 18 dryland locations (200 to 350 mm) in WANA over a period of five years. The top yielding entry (TYE) differed each year. The results allow the comparison of yield and yield stability of the TYE with the improved check Cham 6. - **G. Ortiz Ferrara, S.K. Yau, M.A. Moussa, M.G. Mosaad and National Program Scientists**

### 4.1.9. Adaptation of Improved Bread Wheat Germplasm

Since 1983, The Syrian national program has released six improved bread wheat varieties. These are: Bohouth 2, 4, and 6; and Cham 2, 4, and 6. The amount of seed produced by Government Organization for Seed Multiplication (GOSM) of Syria for the most recently released varieties is presented in Figure 4.2. Assuming a seed rate of 150 kg/ha, this would amount to a coverage of approximately 241,000 ha during 1992-93 crop season, about 200,000 ha during 1993-94, and about 279,000 ha in 1994-95 with the improved bread wheat varieties. The actual area covered may be more because many farmers in Syria retain their own seed for the next crop cycle. During the last three years, the improved bread wheat varieties have replaced the local wheat variety Mexipak 65. Cham 4, an improved bread wheat variety released by Syrian

national programs in collaboration with CIMMYT/ICARDA joint project has become the leading variety grown by farmers (Figure 4.2).

**Table 4.9. Grain yield in kg/ha (GY), rank and yield stability parameters of the top yielding entry (TYE) of bread wheat in comparison with the improved check genotype in the low-rainfall (<400 mm) areas of West Asia and North Africa in RWYT-LRA, 1988-1992.**

| Year | | TYE | Cham 6 (check) | No. of sites |
|---|---|---|---|---|
| 1988 | GY | 2850 | 2845 | 35 |
| | Rank | 1 | 2 | 35 |
| | b Coef. | 1.042 | 1.056 | 25 |
| | $d^2$ | 154454 | 168662 | 25 |
| 1989 | GY | 2808 | 2771 | 24 |
| | Rank | 1 | 2 | 24 |
| | b Coef. | 1.198 | 1.074 | 24 |
| | $d^2$ | 51680 | 154595 | 24 |
| 1990 | GY | 2886 | 2878 | 18 |
| | Rank | 1 | 2 | 18 |
| | b Coef. | 1.082 | 1.138 | 18 |
| | $d^2$ | 64349 | 45732 | 18 |
| 1991 | GY | 3626 | 3417 | 26 |
| | Rank | 1 | 8 | 26 |
| | b Coef. | 1.102 | 0.919 | 26 |
| | $d^2$ | 166837 | 54225 | 26 |
| 1992 | GY | 3847 | 3543 | 40 |
| | Rank | 1 | 14 | 40 |
| | b Coef | 1.137 | 0.977 | 26 |
| | $d^2$ | 94023 | 53536 | 26 |

Collaborative research with the Syrian national program is attempting to develop bread wheat cultivars with better yield, yield stability, disease resistance and tolerance of abiotic stress than Cham 4. Results from our joint on-farm verification yield trials in Syria show two new promising bread wheat lines Ghurab-2 (SWM 11623-9AP-3AP-7AP-2AP-1AP-0AP), and Dorrage (ICW 80-0745-4AP-1AP-3AP-0AP), which are higher yielding and have better disease resistance than the local check. They are currently being tested in farmers fields. **- G. Ortiz Ferrara, A. Shehade, M. Michael, M.A. Moussa, and M.G. Mosaad.**

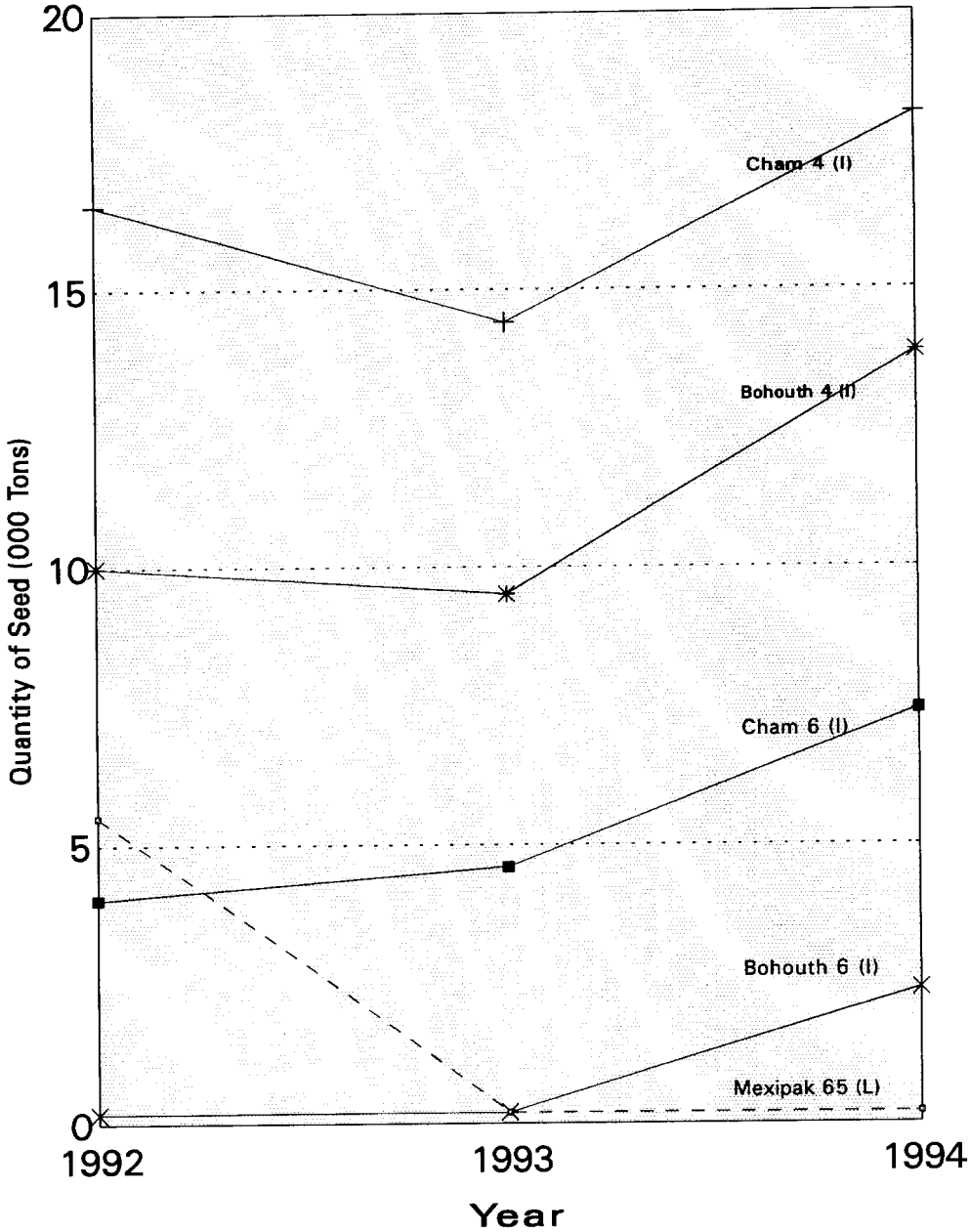



Fig.4.2. Seed of improved (I) and local (L) bread wheat varieties produced by the Government Organization for Seed Multiplication (GOSM) of Syria and distributed to farmers during the last 3 years (1992-94).

## 4.2. Physiology/Agronomy

A comparison of controlled environment and field condition evaluation of response of wheat and photoperiod and vernalization is already reported in section 4.1.7. Other studies are reported here.

### 4.2.1. Vernalization and Photoperiod Response of Adapted Wheats from the Mediterranean Region

Forty nine local and improved wheat cultivars from the Mediterranean region in West Asia and North Africa were analysed for their response to photoperiod and vernalization under controlled environment conditions. Differences in response to photoperiod and vernalization and genetic variation independent of vernalization and photoperiod (intrinsic earliness), affecting anthesis date of wheat were identified (Table 4.2.1). Long photoperiod (16 h) separated unvernalized plants into three distinct groups, corresponding to commonly recognized winter, facultative, and spring types. Most old local cultivars were sensitive to both vernalization and photoperiod. All the improved genotypes were insensitive to photoperiod. Responses to vernalization were generally small under short photoperiods (10 h & 13 h) but were more pronounced in long photoperiod (16 h), particularly in winter and facultative types from northern latitudes. The opposite reaction was found in spring-type cultivars adapted to low latitude whose response to vernalization was smaller in long photoperiod compared to short photoperiods. In conclusion, these results should help to classify cultivar responses to photoperiod and vernalization and their interaction. This should help breeders target their genetic improvement work and improve its efficiencies. **- M.G. Mosaad, G. Ortiz-Ferrara, V. Mahalakshmi, I. Naji, J.M. Peacock and S. Rajaram**

**Table 4.2.1. Days to anthesis of local and improved wheat varieties, adapted in various countries of West Asia and North Africa, under vernalized (V) and unvernalized (0) treatment under long (L) (16 h) and short (S) photoperiod (10 h) and the main effects, of vernalization (ΔV), photoperiod (ΔP) and their interaction V x P.**

| | | | | Days to anthesis | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No. | Cultivar | Type | Origin | VL(BVP) | 0L | VS | 0S | ΔV | ΔP | V x P |
| *Insensitive to V and P* | | | | | | | | | | |
| 10 | Sakha 69 | I | Egypt | 48 | 46 | 60 | 66 | -2(-) | 12(-) | 8 |
| 1 | Mexipak 65 | I | Syria | 50 | 55 | 59 | 71 | 5(-) | 9(-) | 7 |
| 45 | Jupateco 73 | I | Check | 55 | 61 | 64 | 77 | 6(-) | 9(-) | 7 |
| 39 | Jouda | I | Morocco | 46 | 50 | 57 | 66 | 4(-) | 11(-) | 5 |
| 2 | Cham 6 | I | Syria | 45 | 50 | 59 | 69 | 5(-) | 14(-) | 5 |
| 37 | Saada | I | Morocco | 50 | 46 | 56 | 57 | -4(-) | 6(-) | 5 |
| 49 | Anza | I | Check | 50 | 49 | 63 | 67 | -1(-) | 13(-) | 5 |
| 48 | Siete Cerros | I | Check | 49 | 51 | 61 | 67 | 2(-) | 12(-) | 4 |
| 31 | Tanit 80 | I | Tunisia | 51 | 54 | 58 | 64 | 3(-) | 7(-) | 3 |
| 47 | Sonora 64 | I | check | 55 | 52 | 63 | 62 | -3(_) | 8(-) | 2 |
| 14 | Sohag 2 | I | Egypt | 50 | 46 | 57 | 54 | -4(-) | 7(-) | 1 |
| 38 | Merchouch | I | Morocco | 47 | 49 | 59 | 59 | 2(-) | 12(-) | -2 |
| 28 | Bohoth 111 | I | Libya | 45 | 49 | 55 | 57 | 4(-) | 10(-) | -2 |
| 11 | Giza 160 | I | Egypt | 43 | 48 | 54 | 78 | 5(-) | 11(-) | 19 |
| 17 | Debeira | I | Sudan | 55 | 50 | 67 | 80 | -5(-) | 12(-) | 18 |
| 15 | Sohag 3 | I | Egypt | 54 | 56 | 61 | 80 | 2(-) | 7(-) | 17 |
| 18 | El - Nilein | I | Sudan | 47 | 50 | 57 | 77 | 3(-) | 10(-) | 17 |
| 43 | Tejo | I | Portugal | 54 | 53 | 64 | 78 | -1(-) | 10(-) | 15 |
| 24 | Sonalika | I | Yemen | 45 | 51 | 49 | 67 | 6(-) | 4(-) | 12 |
| 16 | Condor | I | Sudan | 46 | 50 | 57 | 71 | 4(-) | 11(-) | 10 |
| 40 | L -22 | L | Morocco | 49 | 52 | 58 | 71 | 3(-) | 9(-) | 10 |
| *Sensitive to V and insensitive to P* | | | | | | | | | | |
| 46 | Pitic | I | Check | 52 | 73 | 62 | 89 | 21(+) | 10(-) | 6 |
| 34 | Zidane 89 | I | Algeria | 56 | 76 | 70 | 96 | 20(+) | 14(-) | 6 |
| 13 | Giza 164 | I | Egypt | 54 | 71 | 69 | 91 | 17(+) | 15(-) | 5 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 19 | Sasarieb | I | Sudan | 53 | 74 | 64 | 86 | 21(+) | 11(-) | 1 |
| 35 | Zidi Okba | I | Algeria | 47 | 58 | 59 | 71 | 11(+) | 12(-) | 1 |
| 6 | Mokhtar | I | Yemen | 52 | 71 | 65 | 81 | 19(+) | 13(-) | -3 |
| 25 | Aziz | I | Yemen | 50 | 66 | 54 | 91 | 16(+) | 4(-) | 21 |
| 29 | Florence Aurora | L | Tunisia | 41 | 50 | 54 | 83 | 9(+) | 13(-) | 20 |
| 30 | Byrsa | I | Tunisia | 51 | 80 | 59 | 101 | 29(+) | 8(-) | 13 |
| 3 | Gomam | I | Syria | 47 | 62 | 60 | 88 | 15(+) | 13(-) | 13 |
| 27 | L -33 | L | Yemen | 51 | 74 | 63 | 97 | 23(+) | 12(-) | 11 |
| 7 | Bolal | I | Turkey | 53 | NF | 60 | NF | > 50(+) | 7(-) | -- |
| 42 | Centauro | I | Portugal | 54 | NF | 62 | NF | > 50(+) | 8(-) | -- |
| *Insensitive to V and sensitive to P* | | | | | | | | | | |
| 9 | Giza 155 | L | Egypt | 55 | 56 | 76 | 87 | 1(-) | 21(+) | 10 |
| 22 | L -23 | L | Ethiopia | 46 | 49 | 64 | 70 | 3(-) | 18(+) | 3 |
| 8 | L -66 | L | Turkey | 65 | 61 | 119 | 113 | -4(-) | 54(+) | -2 |
| 23 | L -17 | L | Ethiopia | 50 | 53 | 68 | 66 | 3(-) | 18(+) | -5 |
| *Sensitive to V and P* | | | | | | | | | | |
| 32 | L -56 | L | Tunisia | 62 | 77 | 98 | 115 | 15(+) | 36(+) | 2 |
| 6 | Gerek | L | Turkey | 49 | 77 | 66 | 103 | 28(+) | 17(+) | 9 |
| 20 | L -1 | L | Ethiopia | 50 | 63 | 76 | 108 | 13(+) | 26(+) | 19 |
| 44 | Almansor | L | Portugal | 55 | 75 | 72 | 80 | 20(+) | 17(+) | -12 |
| 4 | L -45 | L | Syria | 55 | 100 | 102 | 117 | 45(+) | 47(+) | -30 |
| 12 | L -18 | L | Egypt | 72 | 83 | NF | NF | 11(+) | -- | -- |
| 21 | L -7 | L | Ethiopia | 50 | 78 | 96 | NF | 28(+) | 46(+) | -- |
| 33 | Mahon Demiaz | L | Algeria | 61 | 102 | 98 | NF | 41(+) | 37(+) | -- |
| 36 | L -10 | L | Algeria | 63 | 102 | 106 | NF | 39(+) | 43(+) | -- |
| 41 | Lodi | L | Portugal | 51 | NF | 68 | NF | > 50(+) | 17(+) | -- |
| 5 | Bezostaya | L | Turkey | 56 | NF | 76 | NF | > 50(+) | 20(+) | -- |

I =improved cultivar, L = local cultivar.
+ = sensitive, - = insensitive.
NF = did not flower.

### 4.2.2. Water Use Efficiency of Wheat under Controlled and Field Conditions in Mediterranean Environoments

Water availability is a major factor limiting crop production in Mediterranean environments. The objective of this study was to assess variability in grain yield and WUE among genotypes of two *Triticum* species. Four genotypes each of durum and bread wheat were grown in a greenhouse under four moisture regimes (35, 55,75, and 95% of field capacity), and in the field in two locations Tel Hadya (TH) and Breda (Br) in northern Syria with different amounts of available water.

In the greenhouse experiment (Table 4.2.2) and field experiments (Table 4.2.3), mean grain and biological yields and harvest index decreased with increasing water stress. In general, grain yield of T. aestivum genotypes was more than T. durum genotypes though the biological yield were similar suggesting higher partitioning (Harvest index) in T. aestivum.

Greenhouse experiment shows that total water consumption per plant was reduced due to decreased water supply in the three water stress treatments (Table 4.2.3). There were large significant differences in the total amount of water used among genotypes in the well-watered treatment,while the differences were small and non-significant in the severely stressed treatment.Consumptive water use by Kabir 1 was the greatest while Yamama had the lowest in each moisture regime. The interaction between genotypes and moisture regimes was significant for the total water used. Severe moisture stress caused a significant decrease in WUE based on grain (WUEg) and biological yield (WUEb), especially in the driest treatment (35% Fc) (Table 4.2.3). The genotypes differed significantly for WUEg and WUEb,but the genotypes x moisture regime interaction was significant only for WUEb. Cham 6 and Dorghal had highest WUEg, while Kabir 1 and Gallareta had the lowest WUEg.

Field experiment shows that there were no significant differences among the genotypes for grain yield, biological yield and harvest index in the irrigated experiment at Tel Hadya (THI,Table 4.2.4).

**Table 4.2.2. Total grain yield/plant (GY g), biological yield (BY g) and harvest index of two Triticum species (G) under four moisture regimes (M) under greenhouse conditions in 1992**

| Genotypes | FC (%) | | | | FC(%) | | | | FC(%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 95 | 75 | 55 | 35 | 95 | 75 | 55 | 35 | 95 | 75 | 55 | 35 |
| | Grain yield (g plant$^{-1}$) | | | | Biological yield (g plant$^{-1}$) | | | | HI (%) | | | |
| *Triticum turgidum* ssp. *durum* | | | | | | | | | | | | |
| Omrabi 5 | 2.9 | 2.5 | 1.8 | 0.8 | 6.9 | 5.6 | 4.6 | 2.4 | 42.4 | 43.9 | 39.1 | 31.6 |
| Kabir 1 | 2.6 | 2.2 | 1.6 | 0.8 | 9.5 | 7.4 | 5.6 | 2.8 | 27.3 | 29.8 | 27.8 | 28.8 |
| Stork "S" | 3.0 | 2.1 | 1.9 | 0.7 | 7.5 | 4.9 | 3.8 | 1.7 | 42.5 | 42.7 | 48.6 | 42.9 |
| Gallareta | 2.5 | 2.2 | 1.3 | 0.6 | 7.2 | 5.9 | 3.9 | 1.9 | 35.5 | 36.9 | 33.3 | 40.1 |
| Mean | 2.8 | 2.2 | 1.6 | 0.8 | 7.8 | 6.0 | 4.5 | 2.2 | 36.9 | 38.3 | 37.2 | 35.8 |
| *Triticum aestivum* ssp *aestivum* | | | | | | | | | | | | |
| Cham 6 | 3.6 | 2.6 | 2.2 | 1.2 | 8.1 | 5.9 | 5.0 | 2.7 | 44.1 | 43.8 | 43.8 | 42.7 |
| Dorghal | 3.2 | 2.9 | 2.4 | 1.2 | 7.7 | 6.5 | 5.3 | 2.5 | 42.0 | 45.3 | 45.8 | 45.9 |
| Yamama | 2.8 | 2.4 | 1.9 | 0.8 | 6.7 | 6.0 | 4.1 | 1.8 | 41.9 | 40.6 | 46.8 | 50.9 |
| Debeira | 3.4 | 3.0 | 2.3 | 1.0 | 8.2 | 7.0 | 5.0 | 2.3 | 40.9 | 42.6 | 44.9 | 44.2 |
| Mean | 3.2 | 2.7 | 2.2 | 1.1 | 7.7 | 6.4 | 4.8 | 2.3 | 42.2 | 43.1 | 45.3 | 45.9 |
| CV% | 16.4 | | | | 8.8 | | | | | | | |
| SE for M | 0.06** | | | | 0.08** | | | | | | | |
| SE for G | 0.08** | | | | 0.11** | | | | | | | |
| SE for M x G | 0.17$^{ns}$ | | | | 0.22$^{ns}$ | | | | | | | |

** = significant at $p$ = 0.01
ns = not significant

**Table 4.2.3. Consumptive water use (litres/plant) of the two Triticum *species (G) under four moisture regimes (MR) under greenhouse conditions in 1992***

| Genotypes | FC (%) 95 | 75 | 55 | 35 | FC(%) 95 | 75 | 55 | 35 | FC(%) 95 | 75 | 55 | 35 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WCU (l plant$^{-1}$) | | | | $WUE_g$ (g l plant$^{-1}$) | | | | $WUE_b$ (g l plant$^{-1}$) | | | |
| *Triticum turgidum* ssp. *durum* | | | | | | | | | | | | |
| Omrabi 5 | 2.93 | 2.60 | 2.20 | 1.63 | 1.0 | 1.0 | 0.8 | 0.6 | 2.3 | 2.2 | 2.1 | 1.5 |
| Kabir 1 | 3.30 | 2.86 | 2.40 | 1.66 | 0.8 | 0.8 | 0.7 | 0.5 | 2.9 | 2.6 | 2.4 | 1.7 |
| Stork "S" | 2.83 | 2.36 | 2.03 | 1.43 | 1.1 | 0.9 | 0.9 | 0.5 | 2.7 | 2.1 | 1.9 | 1.2 |
| Gallareta | 3.00 | 2.56 | 2.13 | 1.63 | 1.0 | 0.9 | 0.6 | 0.5 | 2.4 | 2.3 | 1.8 | 1.2 |
| Mean | 3.01 | 2.59 | 2.19 | 1.58 | 0.9 | 0.9 | 0.8 | 0.5 | 2.6 | 2.3 | 2.0 | 1.4 |
| *Triticum aestivum* ssp. *aestivum* | | | | | | | | | | | | |
| Cham 6 | 2.80 | 2.40 | 2.13 | 1.50 | 1.3 | 1.1 | 1.0 | 0.9 | 2.9 | 2.5 | 2.3 | 1.8 |
| Dorghal | 2.96 | 2.70 | 2.26 | 1.66 | 1.1 | 1.1 | 1.1 | 0.8 | 2.6 | 2.4 | 2.3 | 1.5 |
| Yamama | 2.63 | 2.43 | 2.06 | 1.40 | 1.1 | 1.0 | 0.9 | 0.7 | 2.5 | 2.5 | 2.0 | 1.3 |
| Debeira | 3.03 | 2.73 | 2.26 | 1.53 | 1.1 | 1.1 | 1.0 | 0.7 | 2.7 | 2.6 | 2.2 | 1.5 |
| Mean | 2.85 | 2.56 | 2.17 | 1.52 | 1.1 | 1.1 | 1.0 | 0.7 | 2.7 | 2.5 | 2.2 | 1.5 |

| | |
|---|---|
| CV % | 3.5 |
| SE for MR | 0.01** |
| SE for G | 0.02** |
| SE for MR x G | 0.04** |

** = significant at $p = 0.01$
ns = not significant

This implies that there were no differences among the genotypes for grain yield potential under our experimental conditions. However, there were significant differences among genotypes for grain and biological yield under rainfed conditions(THR,BRI Table 4.2.4). These differences could be attributed to differential adaptation of genotypes to drier environments. Omrabi5 and Cham 6 had highest grain yield in the driest location (BR, Table 4.2.4), while Gullareta and Debeira produced the lowest biological yield under Tel Hadya rainfed condition. Harvest index was greatest under THI, intermediate in THR and least BR. Total seasonal water use was not significantly different among the genotypes in either experiment. Therefore, genotypes differed in their WUEg and biological yield (WUEb) under rain-fed locations. Improved WUEg may be associated with faster canopy development, earlier flowering, improved canopy structure and higher harvest index. In conclusion this study suggests that there are genotypic variations for improved WUEg among wheat cultivars in the water-limited Mediterranean environment. Further research is required to elucidate the possible role of early canopy cover and growth, leaf morphology and orientation, and harvest index as selection criteria for improved WUE. **- M.G. Mosaad, V. Mahalakshmi, I. Naji, J.M. Peacock, H. Ishag, M. Nachit and G. Ortiz-Ferrara.**

### 4.2.3. Micronutrient Studies

#### 4.2.3.1. Screening for Boron Toxicity Tolerance

Out of the 140 entries from the 1992-93 Regional Bread Wheat Crossing Block screened last season, 13 lines with low B-toxicity symptoms and shoot-B concentrations were grown in pots up to maturity in a plastic house. There were two treatments: control (0.4 ppm hot water extractable B) and +B (50 mg B/kg soil, giving a hot water extract of 18 ppm B).

The performance of the most B-toxicity tolerant lines is presented in Table 4.2.5. All lines had a reduction in grain yield under the +B treatment, except the highly tolerant check, Greek G61450. The best line, GRU 90-201736, which is an accession collected from Morocco, had a 9 % yield decrease.

**Table 4.2.4. Mean grain and biological yield of two Triticum species in three locations (Tel Hadya Irrigated, THI, Tel Hadya Rainfed, THR; and Breda Rainfed, BR) under field conditions in 1992/93**

| Genotype | THI | THR | BR | THI | THR | BR | THI | THR | BR |
|---|---|---|---|---|---|---|---|---|---|
| | Grain yield ($g\ m^{-2}$) | | | Biological yield ($g\ m^{-2}$) | | | Harvest index (%) | | |
| *Triticum turgidum* ssp. *durum* | | | | | | | | | |
| Omrabi 5 | 599 | 354 | 134 | 1731 | 1160 | 483 | 35.6 | 30.3 | 28.0 |
| Kabir 1 | 675 | 288 | 101 | 1865 | 1143 | 445 | 36.1 | 26.0 | 23.0 |
| Stork | 548 | 367 | 99 | 1561 | 1101 | 376 | 35.1 | 33.0 | 25.7 |
| Gallareta | 680 | 303 | 97 | 1595 | 861 | 371 | 42.9 | 35.1 | 26.1 |
| Mean | 626 | 328 | 107 | 1688 | 1066 | 419 | 37.4 | 31.1 | 25.4 |
| *Triticum aestivum* ssp. *aestivum* | | | | | | | | | |
| Cham 6 | 587 | 367 | 130 | 1710 | 1015 | 458 | 35.1 | 36.7 | 28.8 |
| Dorghal | 605 | 377 | 106 | 1591 | 1104 | 425 | 37.9 | 34.0 | 25.1 |
| Yamama | 562 | 370 | 100 | 1800 | 1150 | 471 | 31.0 | 32.7 | 21.1 |
| Debeira | 620 | 313 | 118 | 1684 | 994 | 453 | 36.8 | 31.5 | 26.3 |
| Mean | 594 | 357 | 114 | 1696 | 1066 | 452 | 35.2 | 33.7 | 23.2 |
| SE | $54.3^{ns}$ | 20.7* | 8.2* | $73.8^{ns}$ | 66.6* | 21.4* | | | |
| CV % | 17.8 | 12.1 | 14.7 | 8.7 | 12.5 | 9.9 | | | |

THI = Tel Hadya irrigated, THR = Tel Hadya rain-fed, BR = Breda
** = significant at $p = 0.01$
ns = not significant

Relative to grain yield, the reduction in straw yield was smaller. Again, Greek G61450 was the best, with a 17 % increase. Excessive soil B delayed heading. One of the sister lines of the cross Shi#4414/Crow'S' showed only half a day delay. Greek G16450 had the lowest B-toxicity symptom score. The level of B-toxicity tolerance of the 8 lines in Table 4.2.5 is comparable to the tolerant check, Halberd, but is lower than Greek G16450. - **S.K. Yau, G. Ortiz-Ferrara, M.C. Saxena**

**Table 4.2.5. Performance of the most B-toxicity tolerant bread wheat lines (in terms of least reduction in grain yield when grown in soil to which 50 mg B/kg soil [+B] was added as compared to the control [-B]).**

| Name/cross | B toxicity symptom score[1] at +B | Difference in days to heading (+B to -B) | % difference over -B plants | |
|---|---|---|---|---|
| | | | Straw yield | Grain yield |
| GRU 90-201736 | 1.0 | 7.5 | +10.0 | - 9.2 |
| Shi#4414/Crow'S' | 1.2 | 0.5 | -16.9 | -15.5 |
| NS.12.5.3/Atfn | 2.5 | 2 | -10.2 | -17.4 |
| Shi#4414/Crow'S' | 1.5 | 1.5 | -16.4 | -29.0 |
| Shi#4414/Crow'S' | 2.2 | 8 | -21.6 | -29.7 |
| Shi#4414/Crow'S' | 1.0 | 6 | -10.9 | -35.4 |
| C182.24/C168.3/3/ Cno*2/7C//Cc/Tob | 2.5 | 5.5 | +12.7 | -35.5 |
| Kavz'S' | 1.7 | 9 | +15.6 | -36.0 |
| Tolerant check | | | | |
| Halberd | 1.0 | 6.5 | -14.4 | -36.4 |
| Highly tolerant check | | | | |
| Greek G61450 | 0.7 | 4.5 | +17.0 | + 2.4 |
| Susceptible check | | | | |
| Zidane | 3.0 | 7.5 | -36.3 | -39.9 |
| Mean of 16 lines: | 1.6 | 6.3 | 6.3 | 31.3 |
| LSD (P=0.05): | 0.9 | 4.1 | 29.0 | 33.0 |

[1] 0-9 scale: 0 = no symptom, 9 = severe symptom. Scores taken at heading.

### 4.2.3.2. Zinc Deficiency

A preliminary experiment showed that unlike, Stork (durum wheat) and Harmal (barley), Mexipak bread wheat was responsive to Zn application when grown in a low Zn soil. - **S.K. Yau, J. Ryan (FRMP)**

## 4.3. International Nurseries

Regional bread wheat nurseries assembled by the joint CIMMYT/ICARDA bread wheat project at ICARDA are given in Table 4.3.1. There were 7 nurseries and 3 germplasm pools.

The Regional Crossing Block was assembled this year, while the Germplasm Pool for Stem Rust Resistance was withdrawn as scheduled, after having been available for two consecutive years. There was no seed shortage this year, except for the 'Segregating Populations' and 'Crossing Block'. A total of 277 regular nursery sets, which was similar to the number in 1993, were distributed. **- S.K. Yau and G. Ortiz-Ferrara, M.C. Saxena**

**Table 4.3.1. Regional bread wheat nurseries for 1994-95. Regular Nurseries**

| Nursery | Abbre-viation | No. of entries | No. of sets distributed |
|---|---|---|---|
| **Regular Nurseries** | | | |
| Crossing Block | WCB | 140 | 30 |
| Segregating Populations | WSP | 123 | 26 |
| Observation Nurseries: | | | |
| - Semi-arid Areas | WON-SA | 189 | 32 |
| - Favorable Areas | WON-FA | 183 | 48 |
| Yield Trials: | | | |
| - Semi-arid Areas | WYT-SA | 24 | 40 |
| - Favorable Areas | WYT-FA | 24 | 50 |
| **Specific-trait Nurseries** | | | |
| Heat Tolerance Obs. Nur. | HTON | 40 | 51 |
| Sub-total | | | 277 |
| **Germplasm Pools for Sources of Disease Resistance** | | | |
| Yellow Rust | WYRGP | 8 | 45 |
| Leaf Rust | WLRGP | 12 | 45 |
| Septoria Tritici Blotch | WSTGP | 5 | 34 |
| Sub-total | | | 124 |
| Total | | | 401 |

# 5. FACULTATIVE AND WINTER WHEAT (FWW) IMPROVEMENT

## 5.1. Objective

Intensification of early generation screening of facultative and winter wheat (FWW) germplasm to common bunt and yellow rust was a primary objective for the CIMMYT/ICARDA FWW project activities conducted at Tel Hadya during the 1993-1994 cycle. These activities were conducted in close collaboration with the Pathology team at ICARDA.

## 5.2. Screening for Common Bunt

A total of 3, 815 entries, from 17 FWW nurseries, were screened for common bunt (*Tilletia tritici* and *T. leavis*). Use of hill plots, planted on a 25 cm grid, allowed this screening to occupy an area of 10 x 30 m. Hills were sown with 25 pathogen inoculated wheat kernels. The fungal races used were T-11 and L-9 (world-wide occurence) and three new races (T-31, L-18, L-19, submitted for publication by O.Mamluk). None of the tested common bunt isolates was virulent against Bt 5, 6, 7, 8, 9, 10, 11 and p. Nursery check varieties included the susceptible cultivars Seri and Gerek, and Atay 85 and Bezostaya as resistant cultivars. At harvest, spikes from the entire hill were cut, and examined for common bunt infection. Infected-spike scores ranged from 0 to 100 percent, indicating good levels of infection thereby allowing thorough preliminary screening of the germplasm.

Upon request from the Iranian National Wheat Improvement Program, a special nursery comprising 130 common bunt resistant and tester genotypes (BUNT95) was assembled for distribution for the 1995 season. This nursery has been distributed to agricultural research institutes in Cumra, Eskisehir, and Izmir in Turkey, Iran, Afghanistan and to ICARDA/Turkey project.

Introduced germplasm originating from wheat breeding programs in countries bordering the Black Sea region (e.g., Bulgaria, Romania, Ukraine) and Oregon-CIT was found to possess a higher proportion of resistant lines, than

germplasm introduced from other programs tested.

### 5.3. Screening for Yellow Rust

Over 5000 plots were scored for reaction to yellow rust (Puccinia striiformis) in the FWW 1994 yield trial nurseries at Tel Hadya. Spreader borders surrounding the yield trial nurseries blocks, sown to a mixture of susceptible genotypes, were inoculated with the indigenous inoculum yellow rust, including race virulent to Yr9 [134E146(150)]. Excellent field infection and genotype differentiation occurred.

In addition, the pathologist provided data on intensive reaction to yellow rust for the 3rd Facultative and Winter Wheat Observation Nursery (3FAWWON) and for Crossing Block Facultative Winter 1994 (CBFW94), grown in artificially inoculated yellow rust screening trials at Tel Hadya.

### 5.4. Combined Results

Tel Hadya disease data were used with disease data reported from Fundulea, and Romania, multi-location yield and phenotypically scored data from Turkey, Syria, Iran and Oregon State, and industrial quality data from ICARDA for final selection purposes. Nine genotypes (Table 5.1) were observed to be resistant to both common bunt and yellow rust, and were high yielding, equal or exceeding the local checks, across locations. Four of the lines originated from spring x winter wheat crosses, three of which involved simple crosses with Seri 82 (=Veery 5 "Sib"). Thus, an immediate objective of the FWW program has been accomplished combining high grain yield and broad adaptation (strengths of Seri 82) with resistance to common bunt, Yr9 virulent yellow rust, and winter hardiness (traits for which Seri 82 is deficient) in this FWW germplasm. **- Thomas S. Payne**

**Table 5.1. Facultative and winter wheat genotypes resistant to both common bunt and yellow rust, and high yielding, equal or exceeding the local checks, across locations (Cumra, Ankara, Eskisehir) during the 1994 crop cycle.**

| Cross, Cross number, Selection Pedigree | Origin [1] Grain color |
|---|---|
| CO724377/NAC//SERI | White |
| SWM866509-8H-0YC-2YC-0YC | MXORCIT |
| CO724377/NAC//SERI | White |
| SWM866509-8H-0YC-4YC-0YC | MXORCIT |
| UNKNOWN | Red |
| KAREE/TUGELA | Red |
| 86U4-8-9-2YC-0YC | RSA-CIT |
| KVZ/CUT75/3/YMH//61.1523/DRC | White |
| ICWH850032-1AP-2AP-1AP-0AP-1AP-0AP | SYR-ICWH |
| LOV6/SMS//TAST/SPRW | Red |
| TE3469-0T-5R-0R-2YC-0YC | TE-CIT |
| NEELY/SPN//SPN/3/SPN//63-189-66-7/BEZ | White |
| WWN860129-2H-0YC-3YC-0YC | OR-CIT |
| PTZ NISKA/UT1556-170 | Red |
| WRB860365-5H-0YC-1YC-0YC | OR-CIT |
| SN64//SKE/2*ANE/3/SX/4/BEZ/5/SERI | White |
| SWM866442-7H-0YC-5YC-0YC | MXORCIT |

[1] MX=CIMMYT/Mexico, Toluca; OR=Oregon State University
CIT=CIMMYT/ICARDA/Turkey
SYR-ICWH=ICARDA/Syria, High elevations wheat program
RSA=Republic of South Africa
TE=Transitional Zones ARI, Eskisehir, Turkey

# 6. WHEAT PATHOLOGY

## 6.1. General

### 6.1.1. Disease Development in WANA

Major disease development in WANA in the season 1993/94 was the development of yellow rust epiphytotics in Lebanon, Iran, and, to a lesser extent in Syria. Yield losses due to the disease in Lebanon were high, especially on the cultivars Mexipak and Seri 82; durum wheat cultivars were in general not affected. In Iran, this is the second consecutive season marked by a yellow rust epiphytotic. This season's epiphytotic, though in many regions of the country, did not

reach the level of last year's. The rise in temperature late in Spring might have halted the further development of the disease. In Syria, where over 70% of the wheat growing area is planted to durum wheats, the epiphytotic was not destructive. Common bunt showed a remarkable come back in some regions of Morocco. **- O.F. Mamluk**

### 6.1.2. Collaboration with NARSs

The general areas of our collaboration with NARSs are the exchange and testing of germplasm. We provide NARSs with sources of resistance to the main wheat diseases, and specific material, such as pathotypes differentials. With some national programs we have developed specific collaboration as shown below. **- O.F. Mamluk**

#### 6.1.2.1. University of Aleppo, Syria

The yellow rust project, in collaboration with the University of Aleppo, yielded excellent results in its first year of implementation. The yellow rust differential was planted in two sites, Al Ushar/Hama and Hassakeh. Fifteen diseased samples were collected from different sites of Syria. Also, 10 samples from Lebanon were collected for inclusion in the virulence analysis. Results of the virulence analysis conducted at Tel Hadya (June 1994 - February 1995) revealed the presence of nine previously unreported yellow rust races, six from Syria (38E150, 6E150, 6E134, 6E148, 6E0 and 20E148) and three from Lebanon (166E150, 38E134 and 6E0). Races 6E150, 6E0 and 166E150 were reported from Turkey, Tunisia and Pakistan, and Ethiopia respectively, whereas 38E150, 6E134, 6E148, 20E148 and 38E134 have not been reported from any country in WANA yet. **- O.F. Mamluk; M.S. Hakim (University of Aleppo)**

#### 6.1.2.2. Wheat Rusts Network in the Nile Valley

The Wheat Rusts Network in the Nile Valley countries is in its second year of implementation. Results from this Network

are presented in the Annual Report of the Nile Valley Program. Results obtained include information on the presence of spores and duration of the two rusts (leaf and stem rusts), their virulence pattern, and the effective resistance genes in each of the Nile Valley countries.
**- O.F. Mamluk; Y. El-Daoudi (ARC/Giza); M. S. Ahmed (ARC/New Halfa); Eshetu Bekele (IAR/Holleta); Mangistu Hulluka ( Alemaya ARC/ Debre Zeit).**

### 6.1.2.3. Leaf Rust Project for the Magrheb Countries

A leaf rust project for the Maghreb countries has been established with IAV Hassan II, Rabat. Principal collaborator is Dr. B. Ezzahiri. The project foresees the establishment of a national leaf rust center with regional responsibility. This collaborative work forms part of the Durum Wheat Network coordinated by ICARDA. The implementation of the project starts this coming season with the evaluation of wheat germplasm under natural epiphytotics in areas with functionable alternate host with sexual production of the pathogen. **- O.F. Mamluk; B.Ezzahiri (IAV Hassan II/Rabat).**

### 6.1.3. *Aegilops* spp. as Sources of Resistance to Wheat Diseases

In the attempt to identify sources of resistance to wheat diseases in the ICARDA's collection of *Aegilops* spp., the screening of these species continued this season for yellow rust and septoria tritici blotch. There were 393 accessions tested for yellow rust in the field. The screening will be terminated by the end of 1994/95 season.

Preliminary results on the yellow rust screening and retesting over the last years indicated that a number of widespread tetraploid species such as *Ae. geniculata*, *Ae. neglecta*, *Ae. triuncialis*, and to lesser extend *Ae. biuncialis*, have generally good resistance to yellow rust, whereas species containing the D-genome, such as *Ae. crassa*, *Ae. cylindrica*, *Ae. juvenalis*, *Ae. taushii*, and *Ae. ventricosa*, are generally susceptible to the disease.

Ninety-six accessions of 23 Aegilops spp. were evaluated at the seedling stage for their resistance to isolates of septoria tritici blotch, comparing the visual scoring and the sporulation level as characteristics the resistance/susceptibility of Aegilops spp. to the disease. With results obtained from this test, the evaluation of Aegilops spp. for resistance to septoria is terminated.

All obtained data on Aegilops spp. screening for wheat diseases since 1988/89 season are now on data-base at the GRU. The data-base includes data on the major diseases of wheat: three rusts, common bunt and septoria tritici blotch. **- O.F. Mamluk; M. van Slageren and J. Konopka (GRU); A. Yaljarouka; M. Abu Daher (Lebanese University)**

### 6.1.4. Crop Loss Assessment Trial

Crop loss assessment trials for yellow rust disease were conducted since 1988 at Tel Hadya. This season sixteen cultivars/lines: 10 durum wheat and 6 bread wheat, were assessed for their actual yield loss due to the disease. These cultivars are under verification from the joint DSAR/ICARDA Collaborative Research and Training Program. The trial was conducted as a split-plot experiment in a randomized complete block design with three replications. The treatments (protection with Fungicide I, triademenol; protection with Fungicide II, Zeneb; and no protection = Infected) were applied in main-plots and the 16 cultivars in the sub-plots. Cultivar performance was assessed for a number of traits. Data for durum wheat (Table 6.1) and for bread wheat (Table 6.2) are presented separately in section 6.2 and 6.3 respectively. **- O.F. Mamluk; M. Singh (CBSU).**

## 6.2. Durum Wheat Pathology

### 6.2.1. Summary of Disease Data on the Key Location Disease Nursery (DKL-93)

Useful information on the DKL-93 was received from Tel Hadya and Terbol (Lebanon) on yellow rust; from Tel Hadya and Debre Zeit (Ethiopia) for leaf rust; from Tel Hadya, Sakha (Egypt)

and D. Zeit for stem rust; from Tel Hadya, Gorgan (Iran), and Elvas (Portugal) on septoria tritici blotch; from Tel Hadya on barley yellow dwarf virus (BYDV), in collaborative with the Virology Laboratory, and common bunt; and from Gorgan on powdery mildew.

From this multilocation testing, 31 %, 8%, 13%, 15%, 7%, 2%, and 4% of the tested lines (252, checks excluded) were resistant to yellow rust (≤ 2 ACI), leaf rust (≤ 5 ACI), stem rust (≤ 5 ACI), septoria tritici (≤ 5 on 0-9 scale), BYDV (≤ 5 on 0-9 scale), common bunt (≤ 15% head infection) and powdery mildew (≤ 10% severity), respectively.

Two lines (DKL-93 # 5 and 142) were resistant to all the three rusts; 1 line (DKL-93 # 141) was resistant to leaf rust and stem rust; 5 lines (DKL-93 # 81, 101, 121, 244, and 249) were resistant to septoria blotch and powdery mildew; and 1 line (DKL-93 # 9) for yellow rust and common bunt. - **O.F. Mamluk; M. Naimi; A. Yaljarouka**

### 6.2.2. The Performance of Lines in Durum Wheat Nurseries to Wheat Diseases in 1993/94

We report here the general performance of the durum wheat nurseries evaluated in 'hot spot' towards the diseases yellow rust, leaf rust, stem rust, septoria tritici blotch, and common bunt in the 1993/94 season (Fig. 6.1).

Durum wheat nurseries evaluated were Key Location Disease Nursery (DKL), Preliminary Disease Nursery (DPD), Aleppo Crossing Block (DAC), Restricted Fragment Length Polymorphism nursery (DRFLP) and the special purpose disease nurseries: Yellow Rust Nursery (DYR), Yellow Rust Nursery-High Elevation (DYRH), Leaf Rust Nursery (DLR), Stem Rust Nursery (DSR), Septoria Nursery (DST), Repeat Testing Bunt Nursery (RTB), and Common Bunt-II Nursery (CB-II). Selection criteria were for yellow rust ≤2 CI/ACI, for leaf rust and stem rust ≤5 CI/ACI, for septoria blotch ≤3 score (on 0-9 scale), and for common bunt 10-15% head infection.

The highest percentage (91%) of yellow rust resistant lines was found in DAC, followed by DYR (82%), DYRH (59%), DKL (47) and DPD (28%). The highest percentage (87%) of leaf rust resistant lines was found in DLR, followed by DRFLP (40%), DAC (20%), DPD (5%) and DKL (4%). The highest

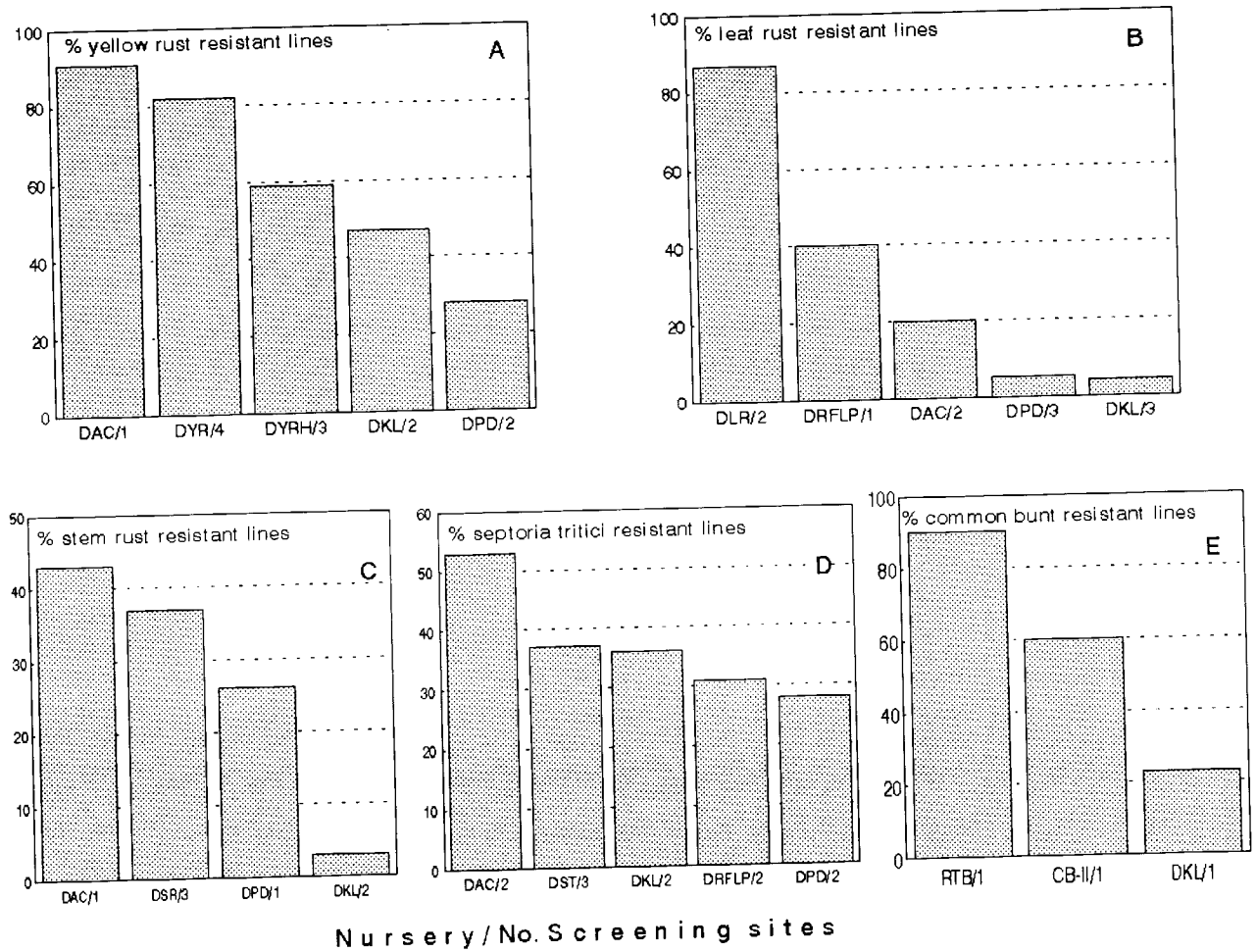



Fig. 6.1. The performance of lines in different durum wheat nurseries against yellow rust, leaf rust, stem rust, septoria tritici blotch and common bunt; 1993/94.

percentage (43%) stem rust resistant lines was found in DAC, followed by DSR (37%), DPD (26%) and DKL (3%). The highest percentage (53%) of septoria blotch resistant lines was found in DAC, followed by DST (37%), DKL (36%), DRFLP (31%) and DPD (28%). The highest percentage (90%) of common bunt resistant lines was found in RTB, followed by CB-II (60%) and DKL (23%). **- O.F. Mamluk, M. Naimi, A. Saleh, A. Yaljarouka.**

### 6.2.3. Crop Loss due to Infection by Yellow Rust

Table 6.1 represents the results obtained from the crop loss assessment trial. In general there was a slight decrease in disease score due to treatment with both fungicides. A remarkable yield increase of 29.9 and 20.5% due to application of the Fungicide II treatment was found on Haurani and Douma 13792, respectively. However, results indicate that even a slight increase in disease score from 0.2 to 0.4 ACI can cause a yield decline of 19.1% in the cultivar Douma 13792. **- O.F. Mamluk, M. Singh (CBSU), M. Naimi, A. Saleh**

## 6.3. Bread Wheat Pathology

### 6.3.1. Summary of Disease Data of the Key Location Disease Nursery (WKL-93)

Useful information on the WKL-93 were received from Tel Hadya, Terbol and Diyarbakir (Turkey) on yellow rust; from Tel Hadya and Ciano (Mexico) on leaf rust; from Tel Hadya and Sakha (Egypt) on stem rust; from Tel Hadya, Elvas (Portugal) and Debre Zeit (Ethiopia) on septoria tritici blotch; and from Tel Hadya on barley yellow dwarf virus (BYDV), in collaboration with the Virology Laboratory, and common bunt.

From this multilocation testing, 38%, 12%, 25%, 24%, 11% and 2% of the tested lines (216, checks excluded) were resistant to yellow rust (≤ 2 ACI), leaf rust (≤ 5 ACI), stem rust (≤ 2 ACI), septoria blotch (≤ 3 on 0-9 scale), BYDV (≤ 5 on 0-9 scale), and to common bunt (≤ 15% head infection), respectively.

**Table 6.1. Effect of yellow rust (*Puccinia striiformis*) on yield and yield components of durum wheat cultivars; Tel Hadya, Syria 1994; under artificial epiphytotics created by single time inoculation.**

| Cultivar | Treatment | Yellow rust Score | | ACI | Yield t/ha | %Yield increase | No.tillers per m | No.seed per spike | 1000KW (g.) |
|---|---|---|---|---|---|---|---|---|---|
| Haurani 27 | Infected | 13.9 | MR-M | 6.6 | 2.44 | | 67.3 | 27.4 | 46.4 |
| | Fungicide I | 8.3 | MR-MS | 4.0 | 2.61 | 7.0 | 66.3 | 43.0 | 39.1 |
| | Fungicide II | 12.2 | MR-MS | 6.7 | 3.17 | 29.9 | 81.3 | 30.0 | 42.2 |
| Douma 12690 | Infected | 4.6 | MR | 1.8 | 4.21 | | 62.7 | 48.1 | 43.8 |
| | Fungicide I | 6.1 | R-MR | 2.1 | 4.36 | 3.6 | 66.0 | 37.3 | 47.8 |
| | Fungicide II | 3.7 | R-MR | 1.4 | 4.22 | 0.2 | 56.7 | 39.8 | 48.4 |
| Marrout | Infected | 5.6 | R-MR | 2.1 | 4.31 | | 63.0 | 38.2 | 42.5 |
| | Fungicide I | 5.6 | R-MR | 2.1 | 4.10 | -4.9 | 61.3 | 40.4 | 50.2 |
| | Fungicide II | 4.3 | MR | 1.7 | 4.23 | -1.9 | 67.7 | 38.9 | 47.3 |
| Lahn | Infected | 1.9 | R-MR | 0.6 | 3.86 | | 50.3 | 42.3 | 51.1 |
| | Fungicide I | 1.0 | R | 0.2 | 3.53 | -8.6 | 50.7 | 48.0 | 50.6 |
| | Fungicide II | 1.0 | R | 0.2 | 3.82 | -1.0 | 57.0 | 33.5 | 54.2 |
| Douma 13792 | Infected | 1.4 | R-MR | 0.4 | 4.19 | | 59.3 | 44.1 | 48.2 |
| | Fungicide I | 1.0 | R | 0.2 | 4.36 | 4.1 | 58.3 | 46.2 | 47.0 |
| | Fungicide II | 1.0 | R | 0.2 | 4.96 | 20.5 | 66.0 | 47.1 | 49.0 |
| Cham 1 | Infected | 1.0 | R | 0.2 | 3.87 | | 69.7 | 41.6 | 40.6 |
| | Fungicide I | 1.0 | R | 0.2 | 3.83 | -1.3 | 67.3 | 34.7 | 44.0 |
| | Fungicide II | 1.0 | R | 0.2 | 3.94 | 1.8 | 75.3 | 39.7 | 41.6 |
| Om Rabi 3 | Infected | 7.2 | MR-M | 3.7 | 4.64 | | 73.0 | 39.4 | 46.4 |
| | Fungicide I | 5.7 | R-MR | 2.2 | 4.46 | -3.9 | 70.0 | 38.9 | 45.6 |
| | Fungicide II | 8.9 | MR-M | 4.1 | 4.30 | -7.3 | 73.7 | 40.3 | 45.1 |
| Awalbit 8 | Infected | 6.1 | R-MR | 2.0 | 4.17 | | 73.7 | 36.8 | 43.9 |
| | Fungicide I | 4.6 | R-MR | 1.7 | 4.21 | 1.0 | 60.0 | 39.7 | 44.8 |
| | Fungicide II | 3.2 | MR | 1.3 | 4.28 | 2.6 | 73.3 | 44.7 | 39.0 |
| Om Ruf 1 | Infected | 3.7 | R | 0.7 | 3.98 | | 66.7 | 34.8 | 45.9 |
| | Fungicide I | 4.7 | R-MR | 1.0 | 3.94 | -1.0 | 70.7 | 32.8 | 52.0 |
| | Fungicide II | 1.9 | R-MR | 0.6 | 3.94 | -1.0 | 72.3 | 32.4 | 51.9 |
| Genil 5 | Infected | 2.3 | R | 0.5 | 4.19 | | 78.0 | 35.3 | 45.6 |
| | Fungicide I | 1.0 | R | 0.2 | 4.04 | -3.6 | 64.7 | 33.1 | 45.6 |
| | Fungicide II | 1.0 | R | 0.2 | 4.20 | 0.4 | 63.0 | 36.5 | 47.1 |
| | SE 1 | | | | 0.27 | | 5.82 | 3.19 | 2.71 |
| | SE 2 | | | | 0.23 | | 5.75 | 3.28 | 2.76 |
| | CV% | | | | 10 | | 14 | 15 | 11 |

Fungicide I = triadimenol (Bayfidan EC 250), 0.5 l/ha, applied twice.
Fungicide II = zeneb (Zinat 70% WP), 0.9 kg/ha, applied six times. SE 1 to compare treatment at same or different levels of cultivars; SE 2 to compare cultivar at same levels of treatment.

Two lines (WKL-93 # 6, 47) were found resistant to all the three rusts, 1 line (WKL-93 # 67) for leaf rust and stem rust; 5 lines (WKL-93 # 5, 23, 34, 153, 156) for septoria blotch and BYDV; and 3 lines for yellow rust and common bunt (WKL-93 # 231, 235, 237). **- O.F. Mamluk, A. Yaljarouka, A. Saleh**

### 6.3.2. The Performance of Lines in Bread Wheat Nurseries to Wheat Diseases in 1993/94

We report here the general performance of the bread wheat nurseries evaluated in 'hot spot' towards the diseases yellow rust, leaf rust, stem rust, septoria tritici blotch, and common bunt in the 1993/94 season (Fig. 6.2).

Bread wheat nurseries evaluated were Key Location Disease Nursery (WKL), Preliminary Disease Nursery (WPD), Regional Yield Trials-LRA (RY-L), Regional Yield Trials-MRA (RY-M), Facultative Winter Wheat Observation Nursery (FWW), Observation Nursery FA (ON-F), and the special purpose disease nurseries: Yellow Rust Nursery (WYR), Yellow Rust Nursery HE (WYRH), Leaf Rust Nursery (WLR), Stem Rust Nursery (WSR), Septoria Nursery (WST), Repeat Testing Bunt Nursery (RTB), and Common Bunt-II Nursery (CB-II).

In general, best performing bread wheat germplasm towards the tested diseases was that in the special purpose disease nurseries. The highest percentage (32%) of yellow rust resistant lines was found in WYRH, followed by WPD (14%), WYR (9%), RY-L (6%), RY-M, ON-F, and WKL (5%); FWW had only 4% resistant lines.

The highest percentage (80%) of leaf rust resistant lines was found in WLR, followed by WPD (66%) and WKL (13%). The highest percentage (46%) of stem rust resistant lines was found in WSR, followed by WKL (25%) and WPD (13) [illegible]

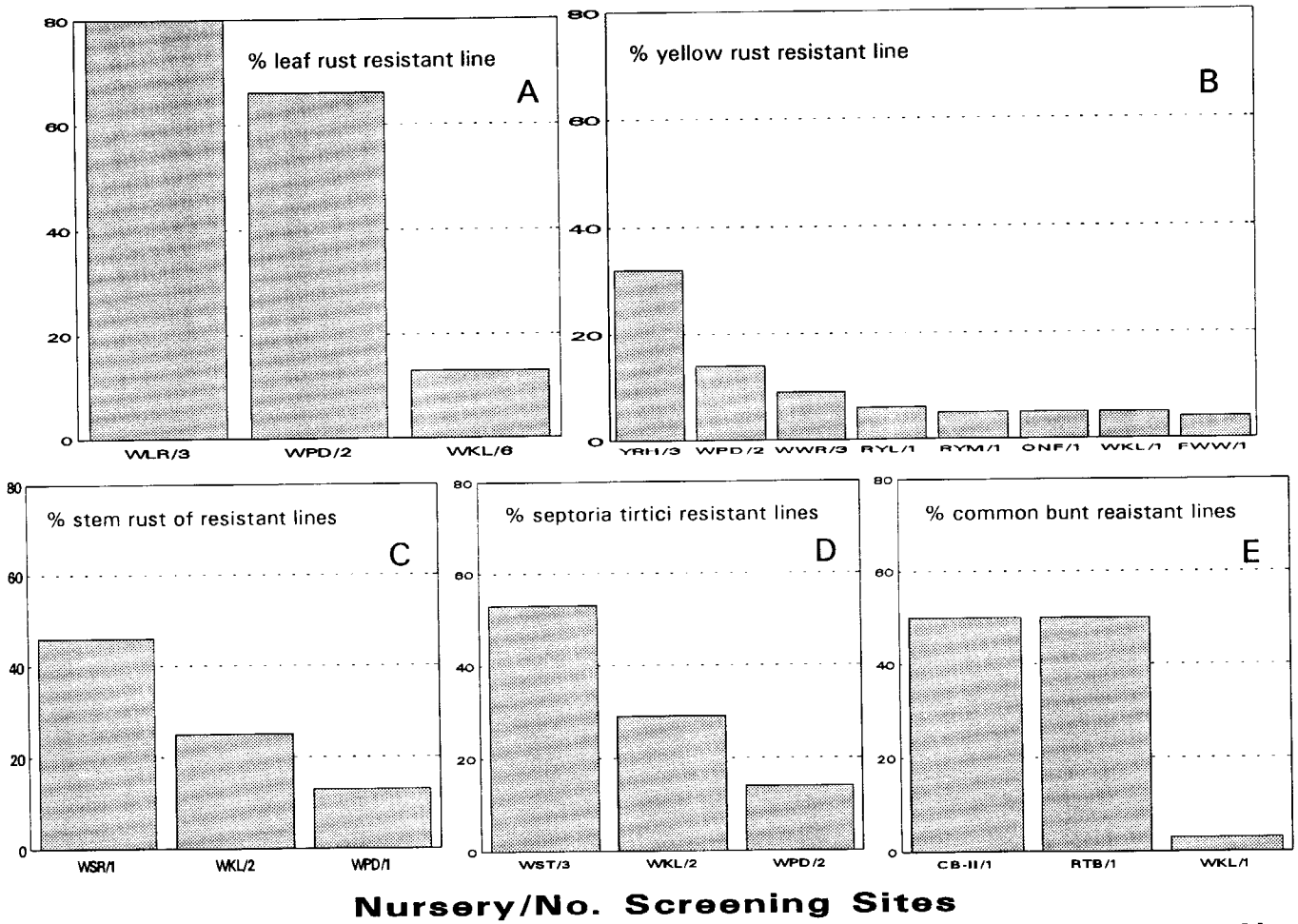



Fig. 6.2. The performance of lines in different bread wheat nurseries against yellow rust, leaf rust, stem rust, septoria tritici blotch and common bunt; 1993/94.

### 6.3.3. Crop Losses due to Infection by Yellow Rust

Table 6.2 shows the results of the crop loss assessment trial. Disease severity decreases, as shown by the scores and ACI values, in the treatment "Fungicide I" as compared to "Infected" treatment in all cultivars except in the resistant cultivar Douma 11670. Yield increases of 31.7%, 27.9% and 16.1% were found in the cultivars Mexipak, Kea and Chirezo, respectively with Fungicide I. This increase was significant ($P < 0.05$) for Mexipak and Kea. The decreases in the infection level from 73.9 down to 68.3 ACI in Mexipak and from 65.0 down to 45.7 ACI in Kea contributed to the above associated yield increases. **- O.F. Mamluk, M. Singh (CBSU), M. Naimi, A. Saleh**

### 6.3.4. Germplasm Pools for Sources of Resistance to Diseases

Germplasm pools for resistance to wheat diseases were dispatched in 127 sets to collaborators in WANA and beyond. These sets were of the Bread Wheat Germplasm Pool for Yellow Rust Resistance, WYRGP 93 (8 lines); Bread Wheat Germplasm Pool for Leaf Rust Resistance, WLRGP 93 (12 lines); and Bread Wheat Germplasm Pool for Septoria Tritici Resistance, WSTGP 93 (5 lines). **- O.F. Mamluk, M. Naimi**

## 6.4. Winter and Facultative Wheat

See section 5 for the collaborative work on disease resistance screeing.

# 7. CEREAL VIRUSES

Work on cereal viruses focused on evaluation of cereal breeding lines and wild relatives for barely yellow dwarf virus resistance. Research was also conducted to simplify screening methodology by monitoring virus invasion of phloem bundles in cereal tissue by the tissue-blot immunoassay (TBIA).

**Table 6.2. Effect of yellow rust (*Puccinia striiformis*) on yield and yield components of bread wheat cultivars; Tel Hadya, Syria 1994; under artificial epiphytotics created by single time inoculation.**

| Cultivar | Treatment | Yellow rust Score | / | ACI | Yield t/ha | %Yield increase | No.tillers per m | No.seed per spike | 1000KW (gr.) |
|---|---|---|---|---|---|---|---|---|---|
| Mexipak | Infected | 73.9 | S | 73.9 | 2.90 | | 70.7 | 39.6 | 37.5 |
| | Fungicide I | 68.3 | S | 68.3 | 3.82 | 31.7 | 72.7 | 38.8 | 34.3 |
| | Fungicide II | 73.3 | S | 73.3 | 2.69 | -7.2 | 64.7 | 38.4 | 32.3 |
| Kea | Infected | 65.0 | S | 65.0 | 3.12 | | 97.7 | 28.9 | 28.4 |
| | Fungicide I | 46.1 | MS-S | 45.7 | 3.99 | 27.9 | 96.3 | 26.4 | 34.7 |
| | Fungicide II | 60.0 | S | 60.0 | 3.31 | 6.1 | 96.7 | 29.9 | 29.8 |
| Chirezo | Infected | 75.6 | S | 75.6 | 3.10 | | 76.7 | 32.4 | 40.5 |
| | Fungicide I | 61.1 | S | 61.1 | 3.65 | 17.7 | 74.7 | 37.0 | 37.3 |
| | Fungicide II | 73.3 | S | 73.3 | 3.26 | 5.2 | 68.7 | 39.3 | 34.9 |
| Douma 12140 | Infected | 11.7 | MR-MS | 8.9 | 4.07 | | 79.0 | 46.0 | 34.4 |
| | Fungicide I | 8.9 | MR-MS | 5.7 | 4.45 | 9.3 | 66.0 | 46.4 | 34.0 |
| | Fungicide II | 12.8 | MR-MS | 8.9 | 3.72 | -8.6 | 81.0 | 42.9 | 34.2 |
| Douma 11670 | Infected | 3.2 | R-MR | 0.9 | 4.76 | | 71.7 | 39.5 | 40.3 |
| | Fungicide I | 3.2 | R-MR | 0.9 | 4.25 | -10.7 | 76.0 | 37.6 | 41.7 |
| | Fungicide II | 3.7 | R-MR | 1.6 | 4.34 | -8.8 | 82.7 | 41.1 | 40.6 |
| Dorage | Infected | 10.6 | R-M | 8.0 | 4.40 | | 89.0 | 33.5 | 33.7 |
| | Fungicide I | 4.6 | MR | 1.8 | 3.88 | -11.8 | 87.0 | 33.7 | 35.8 |
| | Fungicide II | 12.2 | MR-M | 5.9 | 4.26 | -3.2 | 91.0 | 34.6 | 33.2 |
| | SE 1 | | | | 0.27 | | 5.82 | 3.19 | 2.71 |
| | SE 2 | | | | 0.23 | | 5.75 | 3.28 | 2.76 |
| | CV% | | | | 10 | | 14 | 15 | 11 |

Fungicide I = triadimenol (Bayfidan EC 250), 0.5 l/ha, applied twice.
Fungicide II = zeneb (Zinat 70% WP), 0.9 kg/ha, applied six times. SE 1 to compare treatment at same or different levels of cultivars; SE 2 to compare cultivar at same levels of treatment.

## 7.1. Screening Cereals for Barely Yellow Dwarf Virus (BYDV) Resistance

Over 200 barley, durum and bread wheat lines were evaluated for their resistance to BYDV after artificial inoculation with the virus. Results are in Table 7.1.

**Table 7.1. Evaluation of cereal germplasm for tolerance to BYDV resistance after artificial inoculation with the virus during the 1993/94 growing season.**

| Nursery | Number of lines tested | Lines found to be highly tolerant to infection |
|---|---|---|
| DKL - 93 | 30 | 36, 104, 124, 131, 155, 156, 169, 255, 271 |
| BKL - 93 | 41 | 57, 68, 75, 76, 78, 93, 104, 256 |
| WKL - 93 | 37 | 11, 23, 24, 35, 111, 125, 156, 183, 219 |
| SY | 68 | 1, 4, 5, 7, 8, 11, 12, 15, 18, 19, 20, 25, 26, 37, 42, 44, 47, 49, 51, 52, 58, 59, 64, 65, 67 |
| HF | 45 | 1, 2, 3, 4, 6, 10, 13, 19, 20, 21, 22, 27, 33, 34, 37, 38. |

DKL, BKL and WKL refer to ICARDA durum, barley and bread wheat key location nurseries, respectively. Numbers on the right hand column refer to ICARDA nursery serial number, e.g. 36 in the first nursery is DKL-93-36.

SY represent elite series of BYDV tolerant bread wheat lines collected from many countries and institutions and tested at Agriculture Canada/Laval University. These lines were the best performing lines after 15 years of testing.

HF lines derived from Laval University/Agriculture Canada/CIMMYT collaboration for gene pyramiding, and represent semidwarf wheat lines tolerant to many disease, especially BYDV.

Many lines were found to be resistant (barley) or tolerant (durum and bread wheat) to infection with the virus (Table 7.1). Evaluation was based on the severity of symptoms produced and grain yield. Some of the lines (HF nursery) had multiple disease resistance. When lines

originated from different interspecific crosses (crosses of wheat with Aegilops spp., Elytrigia repens, Triticum diccoides, T. monococum) were evaluated for their reaction to BYDV, some of them were found to be tolerant to BYDV infection (Table 7.2).

**Table 7.2. Evaluation of wheat interspecific crosses for their reaction to BYDV after artificial inoculation with the virus during the 1993/94 growing season.**

| Nursery | Number of lines tested | Lines found to be highly tolerant to infection |
|---|---|---|
| SAB | 263 | 4, 8, 9, 10, 13, 14, 20, 21, 26, 30, 34, 40, 56, 70, 71, 72, 73, 74, 78, 80, 82, 90, 91, 98, 135, 143, 158, 166, 199, 203, 210, 216, 225, 228, 229, 231, 232, 262 |
| Allop 94 | 200 | 22, 27, 31, 33, 39, 41, 42, 44, 45, 46, 48, 78, 101, 102, 106, 111 |
| AC/LU interspecific crosses | | |
| wheat/Aegilops spp. | 16 | 92 EE 23, 92 EF 38, 92 EG 36, 92 EG 56 |
| wheat/Elytrigia repens | 1 | 92 RC 6 |

SAB contains backcrosses of *Aegilops* spp. (*umbellulata, biuncialis, triuncialis, kotschyi, speltoides*) to various bread wheats. Aegilops accessions were evaluated for their tolerance to BYDV at ICARDA, Syria and backcrosses were conducted at Agriculture Canada/Laval University, Sainte Foy, Quebec, Canada.

Allop 94 contains alloplasmic lines derived from interspecific crosses of Aegilops spp. with Chinese Spring wheat or Jones Fife winter wheat.

AC/LU contains interspecific crosses made at Agriculture Canada/Laval University.

## 7.2. Evaluation of Cereals for their Sensitivity to BYDV Infection by the Tissue-blot Immunoassay.

The tissue-blot immunoassay (TBIA) is a recent simple, yet very sensitive, test for BYDV detection. Accordingly, a study was initiated to evaluate the usefulness of TBIA in assessing resistance of different cereals to BYDV infection. Assessment with TBIA was made one and three weeks after inoculation, and extent of virus invasion was compared with the disease index (D.I.) and yield loss caused by the virus. Results obtained showed that in barley (Table 7.3) there was a strong correlation between the extent of virus invasion one week after inoculation and yield loss. Barley lines with no or little virus invasion did not suffer significant yield losses. However, in durum and bread wheat, such correlation did not exist. Consequently, extent of virus invasion of phloem bundles as measured by TBIA is a useful criteria for identifying barley lines resistant to BYDV, but not so for durum or bread wheat because they have no or low level of BYDV resistance.

## 7.3. Evaluation of Wheat Wild Relatives for their Reaction to BYDV

When 156 *Aegilops* and *Triticum* accessions were evaluated for their reaction to BYDV by the TBIA method, 33 accessions were found resistant to infection, as virus invasion of the vascular bundles was limited (Table 7.4). These accessions will be re-evaluated next year and are potential sources for BYDV resistance in interspecific crosses. **- K.M. Makkouk and W. Ghulam**

**Table 7.3. Screening cereals for barley yellow dwarf virus resistance using symptoms disease index, yield loss and extent of phloem invasion with the virus as revealed by the tissue-blot immunoassay.**

| Entry | D.I. | No. of stained phloem bundles 1 week (after inoculation) | 3 weeks | % Yield loss |
|---|---|---|---|---|
| **BARLEY** | | | | |
| Morrison (susceptible) | 7 | 19 | 19 | 81.9 |
| Harmal (susceptible) | 7 | 19 | 29 | 51.9 |
| C-YD-BA-92-62 | 2 | 1 | 10 | 31.5 |
| Corris | 2 | 0 | 4 | 31.5 |
| BKL-93-68 | 2 | 0 | 10 | 29.6 |
| BKL-86-35 | 4 | 0 | 8 | 29.0 |
| BKL-93-75 | 3 | 2 | 6 | 19.9 |
| BKL-92-93 | 2 | 0 | 9 | 6.6 |
| BKL-92-65 | 4 | 0 | 12 | 3.1 |
| Atlas-68 | 2 | 2 | 10 | 1.3 |
| **DURUM WHEAT** | | | | |
| DKL-92-29 (susceptible) | 8 | 2 | 17 | 89.0 |
| 12th-IDSN-74 (susceptible) | 9 | 6 | 20 | 78.1 |
| DKL-89-8 (susceptible) | 8 | 6 | 19 | 70.7 |
| C-YD-DW-92-41 | 7 | 1 | 7 | 62.8 |
| Boohai | 5 | 1 | 12 | 69.5 |
| 12th-IDSN-227 | 4 | 1 | 6 | 23.7 |
| DKL-93-25 | 4 | 3 | 19 | 16.6 |
| DON-LRN-86-25 | 6 | 6 | 15 | 15.1 |
| DKL-93-264 | 7 | 1 | 20 | 5.5 |
| **BREAD WHEAT** | | | | |
| 12th-IBWSN-459 (susceptible) | 9 | 17 | 14 | 76.4 |
| WKL-92-247 (susceptible) | 7 | 4 | 21 | 67.7 |
| C-YD-BW-92-106 | 5 | 10 | 12 | 60.1 |
| RWYT-LRA-90-5 | 6 | 4 | 13 | 240.2 |
| WKL-92-130 | 5 | 4 | 8 | 24.9 |
| WCB-90-155 | 6 | 5 | 15 | 17.7 |
| IAS-20 | 4 | 10 | 13 | 16.0 |
| WKL-93-24 | 6 | 8 | 13 | 5.3 |

**Table 7.4. Reaction of *Aegilops* and *Triticum* species to infection with BYDV, when the plants were artificially inoculated with BYDV during the 1993/94 growing season.**

| Plant species | Total no. of accessions tested | Average no. of of stained phloem bundles (and range) | No. of accessions selected as resistant | Average no. of stained phloem bundles of the selected resistant accessions |
|---|---|---|---|---|
| *Aegilops neglecta* | 14 | 6.8 (3.3-9.7) | 4 | 4.3 |
| *Ae. biuncialis* | 12 | 5.5 (3.5-7) | 4 | 4.4 |
| *Ae. crassa* | 10 | 8.8 (3.7-14.7) | 2 | 4.9 |
| *Ae. cylindrica* | 10 | 8.2 (6-11.3) | 3 | 6.3 |
| *Ae. lorgissima* | 10 | 7.7 (4-15) | 2 | 4.2 |
| *Ae. ovata* | 9 | 8.8 (6.7-10.3) | 2 | 7.0 |
| *Ae. searsii* | 9 | 7.2 (4-11.3) | 1 | 4.0 |
| *Ae. tanschii* | 9 | 8.7 (6-13) | 2 | 6.2 |
| *Ae. ventricosa* | 6 | 7.6 (5.7-12) | 0 | - |
| *Ae. triuncialis* | 6 | 7.7 (4.3-10.3) | 1 | 4.3 |
| *Ae. caudata* | 1 | 4.0 | 1 | 4.0 |
| *Ae. speltoides* | 1 | 2.7 | 1 | 2.7 |
| *Triticum monococcum* | 8 | 6.8 (3.7-8.7) | 2 | 4.4 |
| *T. turgidum dicoccoides* | 38 | 8.1 (1-12) | 6 | 2.3 |
| *T. urartu* | 7 | 10.1 (7-14) | 1 | 7.0 |
| *T. timopheevii araraticum* | 6 | 9.1 (7-11) | 1 | 7.0 |
| Total | 156 | | 33 | |

# 8. CEREAL ENTOMOLOGY

## 8.1. Survey of Wheat and Barley Insects in Syria

A survey of wheat and barley insects, with emphasis on Russian wheat aphid (RWA), Diuraphis noxia, was conducted in southern and eastern Syria in mid April, 1994. Fields were sampled south of Homs, near the border with Lebanon, near Izraa' and Daraa', Jebel Druze near Suweida, Saleh, Shabha and along the Tadmor-Deir Ezzor road and along the Euphrates from Deir Ezzor to Aleppo. Russian wheat aphid was found in the high valleys adjacent to Lebanon, in the Hauran near Shabha, in irrigated fields east of Tadmor, between Tadmoor and Deir Ezzor and in the irrigated Euphrates valley near Deir Ezzor and Raqqa. This and the previous surveys showed that RWA is present throughout the rainfed wheat and barley growing regions and in the periphery of irrigated wheat fields in Syria. Although aphid numbers are low, during drought seasons RWA may rapidly increase to outbreak status as has been recently observed in Algeria and Morocco. The development and use of drought and RWA-resistant varieties may negate this threat.

Few other cereal pests were observed during this survey, an exception being high populations (nearly 1 insect/$m^2$) of cereal leaf beetle, Oulema melanopus in wheat near Bosra and Saleh. In all cereal fields, Rhopalosiphum maidis was the most common aphid species observed, especially on barley, with Schizaphis graminum and Rhopalosiphum padi also found on wheat in the Hauran Valley and in Euphrates River Valley.

Subsequent observations have shown that sun pest, Eurygaster integriceps is present along Syria's northern border with Turkey, although not in densities as high as in past years. **- R. Miller, I. Ghannoun, S. Weigand**

## 8.2. Crop Rotation Effects on Ground Pearl (*Porphyrophora tritici*) in Barley

Extensive and severe infestations of *Porphyrophora tritici* occur in marginal areas of northern Syria receiving 200 to 250 mm annual rainfall. Infestations vary greatly from location to location and from to plant within an infested field. Densities of 5 to 12 insects/plant may be sufficient to kill the plant, depending on its vigour. Several factors such as cereal monoculture, stubble left in the field, stressed plants in marginal environments, etc., may promote *P. tritici* infestations. Therefore, the effect of different rotation schemes on *P. tritici* infestations was studied in Breda in three separate long-term barley rotation trials. In rotation trial 1 barley variety Tadmor was alternated with clean fallow, in rotation trial 2 barley variety Arabi Abiad was alternated with fallow and forage legumes, and in rotation trial 3 barley variety Arabi Aswad was alternated with vetch. In mid April, 5 plants per plot were collected and checked for the number of *P. tritici*.

Significant differences were observed in the number of *P. tritici* per plant between rotation treatments within a rotation trial (Table 8.1). Plots continuously planted to barley had the highest infestations in all 3 trials. Barley plots following a legume or clean fallow were less heavily infested and did not differ significantly from each other in trial 2 or when data from all 3 trials were pooled. The barley-legume rotation had significantly lower *P. tritici* infestation than the continuous barley in trial 3. Differences in insect densities between continuously planted barley and the barley-fallow rotation in trial 1 were not significant.

There were significant differences in the mean number of *P. tritici* per plant in plots with different application rates of N and P2O5 (Table 8.1) but there were no clear rate dependent trends. Likewise, different tillage schemes, superimposed in trial 3 also did not have a clear effect on *P. tritici* populations.

These results show that barley grown in monoculture, especially in marginal environments, is more susceptible to *P. tritici* than barley grown in rotation with legumes or clean fallow. Thus, *P. tritici* infestations may best be

managed or prevented from causing economic loss by using a forage legume or clean fallow. Chemical insecticides, although effective, would not be economical in marginal areas. **- R. Miller, H. Harris, M. Jones, F. Mouzayek (ARC Aleppo), S. Weigand**

**Table 8.1. No. of first and second instar specimens of ground pearl/plant as affected by crop sequence, and application of nitrogen and phophorous to barley in 1993/94 in different long term barley rotation tirals at Breda, Syria.**

| Treatment | Crop Rotation | | | |
|---|---|---|---|---|
| Data | 1 | 2 | 3 | Pooled |
| Rotational effects: | | | | |
| Barley Barely | 4.3a | 7.9a | 8.0a | 6.4a |
| Barley Fallow | 3.2a | 5.0b | - | 3.9b |
| Barley Forage Legume | - | 5.5b | 2.6b | 4.4b |
| Nitrogen effect: | | | | |
| 0 kg N/ha | 4.8a | 5.2b | 6.0a | 5.4b |
| 20 " | - | 7.7a | 6.6a | 7.0a |
| 40 " | - | 5.8a | - | 5.5b |
| 60 " | 2.9a | - | 5.4a | 2.9d |
| 120 " | 4.3a | - | - | 4.3c |
| Phoshorous effect: | | | | |
| 0 kg $P_2O_5$/ha | 3.0b | 4.8a | 6.1a | 4.7b |
| 45 kg $P_2O_5$/ha | 4.4a | - | - | 4.4b |
| 60 kg $P_2O_5$/ha | - | 6.6a | 5.9a | 6.2a |
| 90 kg $P_2O_5$/ha | 5.0a | - | - | 5.0 |

Means followed by the same letter are not significantly different at $P \leq 0.05$.

## 8.3. Russian Wheat Aphid Screening Trials

Screening for resistance to Russian wheat aphid (RWA) was continued in the field under artificial infestation. The screening included 200 lines of barley, 577 lines of Aegilops, 96 previously selected promising lines and the set of 90 lines selected in the wheat stem sawfly (WSS) screening. Plants were rated 3 times using the 1 to 6 scale combining plant damage and aphid density. Most resistant lines were found in the Aegilops germplasm. In the set of WSS promising lines, 2 barley and 2 durum wheat lines were promising (Table 8.2). In the RWA-rescreening, all the best

lines were derived from crosses between the durum wheat line Stork and T. dicoccoides. The screening will be continued, concentrating on landraces and Aegilops which might be used in crossing.

**Table 8.2. Promising wheat, barley and Aegilops lines showing resistance to Russian wheat aphid in hill plot screening trials, Tel Hadya, 1993/94.**

| Line ID | Mean score for RWA |
|---|---|
| **Barley** | |
| Deir Alla 106/Strain 205//Rihane-03 | 2.0 |
| Rihane-05//As 46/Aths*2 | 2.17 |
| Robur/Hor 728//F3 Bulk Hip/3/Harma-02//M480/Gva | 2.17 |
| WSS promising | |
| Harmal-02/3/Arr/Esp//Alger/Ceres,362-1-1 | 2.67 |
| As 46//Deir Alla 106/Strain 205 | 2.83 |
| **Aegilops** | |
| 400 002 biuncalis | 1.67 |
| 400 003 biuncalis | 1.67 |
| 400 009 biuncalis | 1.83 |
| 401 602 triuncalis | 1.83 |
| 401 507 biuncalis | 1.83 |
| 401 631 ovata | 1.83 |
| 401 659 ovata | 1.83 |
| 400 005 biuncalis | 1.83 |
| 400 004 biuncalis | 1.83 |
| 401 599 ovata | 1.83 |
| **RWA rescreening** | |
| Stork x T. dicoccoides 455-2 | 2.50 |
| Stork x T. dicoccoides 451-5 | 2.50 |
| Stork x T. dicoccoides 465-7 | 2.67 |
| Stork x T. dicoccoides - | 2.83 |
| Stork x T. dicoccoides 458-1 | 2.83 |
| Stork x T. dicoccoides 461-7 | 2.83 |
| Stork x T. dicoccoides 466-4 | 2.83 |
| **Durum wheat** | |
| Rusomar-3/IC 19939 (Mar)//Stojocri-1 | 1.17 |
| Rusomar-3/IC 19941 (Mar)//)mtel-1 | 1.67 |

## 8.4. Wheat Stem Sawfly Screening Trials

Trial was planned for both Saraqueb and Tel Hadya; Saraqueb is 20 km south of Tel Hadya and is a "hot spot" for wheat stem sawfly (WSS). Table 8.3 shows results of WSS screening under natural infestation in farmer's field at Saraqueb. Several lines have shown consistently in last three years in

Saraqueb. Natural infestation at Tel Hadya was insufficient and results are not reported.

### 8.5. Wheat Stem Sawfly Yield Trial

Small scale yield trial was again conducted at Tel Hadya and Saraqueb to examine yield loss due to wheat stem sawfly in both barley and wheat. Results are shown from the trial in Saraqueb. As in the previous year WSS infestations were insufficient for differentiation at Tel Hadya and the results are not reported. Except for the durum line 16143, susceptible checks had higher sawfly infestations than did other lines (Table 8.4). Yield results were inconsistent. In barley, the susceptible check outyielded all test lines inspite of the higher infestation. In durum wheat, 2 lines, Ru/Mrb15 and D-2/Bit, outyielded the susceptible check. Yield of the other lines was similar to the susceptible check. In bread wheat, all WSS-resistant lines outyielded the susceptible check, with line Kayson//Pvn'S'/Sprw'S' showing the highest yield and line Shi#4414/Crow'S' having no infestation. The line Shi#4414/Crow'S' has shown good resistance and yield also in previous years. - **R. Miller, I. Ghannoun, S. Weigand**

**Table 8.3. Best performing barley, durum, and bread wheat varieties in WSS screening trial at Saraqueb, 1993/94. Also shown are results from past years screenings.**

| Crop/Genotype | Pedigree | Source | No. | Percent infestation in the year | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1987 | '88 | '89 | '90 | '91 | '92 | '93 | '94 |
| **Barley** | | | | | | | | | | | |
| H.SPONT.41-1/TADMOR | ICB87-1833-61AP-0AP | F6HS92 | 3 | - | - | - | - | - | - | 0 | 4.17 |
| As46/Rihane-05 | ICB85-0380-3AP-2AP-0TR-4AP-0TR-0AP | BPT92N | 7073 | - | - | - | - | - | 1.67 | 1.67 | 3.75 |
| Avt/1763-2L//Kenya/Cam | ICB84-1082-3AP-2AP-0AP-0AP | BAT92N | 216 | - | - | - | - | - | 0.83 | 2.5 | 8.33 |
| As46//Deir Alla 106/Strain 205 | ICB85-0383-1AP-4AP-0TR-1AP-0TR-0AP | BPT92N | 1049 | - | - | - | - | - | 1.67 | 2.5 | 2.08 |
| H.SPONT.41-1/TADMOR | ICB87-1833-125AP-0AP | F6HS92 | 5 | - | - | - | - | - | - | 2.5 | 2.5 |
| H.SPONT.41-1/TADMOR | ICB87-1833-61AP-0AP | F6HS92 | 3 | - | - | - | - | - | - | 2.5 | 5.42 |
| H.SPONT.41-1/TADMOR | ICB87-1833-150AP-0AP | F6HS92 | 9 | - | - | - | - | - | - | 2.5 | 2.92 |
| Deir Alla 106/4/Deir Alla 106//Api/ EB89-8-2-15-4/3/Robur/ CI11577//F3 BulkHip | ICB85-0316-1AP-1AP-0AP | BAT92N | 213 | - | - | - | - | - | 1.67 | 3.33 | - |
| Arabi Abiad | | Check | - | - | - | - | - | - | - | - | 3.33 |
| H.SPONT.41-1/TADMOR | ICB87-1833-139AP-0AP | F6HS92 | 6 | - | - | - | - | - | - | 3.34 | 2.08 |
| Ager//Api/CM67/3/Cel/WI2269//Ore | ICB81-1275-0SH-1AP-0AP-0AP | BAT88 | 405 | - | 7.5 | 5.03 | 0.83 | 16.67 | 5 | 5.83 | 3.75 |
| FB73-075- | | BAB85 | 14 | 0.83 | 2.08 | 2.93 | 5 | 13.33 | 8.33 | 10 | 3.75 |
| **Durum Wheat** | | | | | | | | | | | |
| D-2/Sham 1 | ICD79-0282-10AP-3AP-2AP-1AP-0SH | DAB87 | 140 | - | 8.33 | 5 | 0 | 10.83 | 0.42 | 0 | 2.92 |
| Awalbit-6 | ICD84-0322-ABL-5AP-TR-AP-15AP-0TR | DAT92 | 1304 | - | - | - | - | - | 0.42 | 0.84 | 4.58 |
| Awl2/Bit | ICD84-0322-ABL-7AP-TR-AP-21AP -TR-2AP-0TR | DAT92 | 617 | - | - | - | - | - | 0.83 | 0.84 | 5.42 |
| Mrbl1//Snipe/Magh | ICD85-0538-ABL-TR-9AP-0TR | DAT92 | 812 | - | - | - | - | - | 0.83 | 0.84 | 10.83 |
| Marrout | CD 52612-7AP-4AP-0AP | DAT92 | 1309 | - | - | - | - | - | 0.83 | 0.84 | 5.28 |
| Heider//Mt/Ho | ICD86-0414-ABL-0TR-2AP-0TR-10AP-0TR | DAT91 | 801 | - | - | - | - | 10.83 | 0 | 1.67 | 2.92 |
| IC 19939 (MOR) | | DGR92 | 46 | - | - | - | - | - | - | 1.67 | 2.5 |
| GdoVZ | ICD86-0149-ABL-3AP-0TR-6AP-0TR | DAT92 | 409 | - | - | - | - | - | 0 | 1.67 | 2.5 |
| Heider//Mt/Ho | ICD86-0414-ABL-0TR-4AP-0TR-9AP-0TR | DAT92 | 1218 | - | - | - | - | - | 0.42 | 2.5 | 4.17 |
| Haurani | | Check | 1 | - | - | - | - | - | - | 5.0 | 2.5 |
| Gezira 17/Scaup | ICD-HA81-1917-3AP-1AP-1AP-0AP | DCB87 | 37 | 0.83 | 5 | 3.35 | 0.42 | 11.67 | 3.75 | 7.5 | 3.33 |

continued....

**Bread Wheat**

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BOL "S"/Pvn "s" | CM 58696-5AP-2AP-1AP-1AP-0AP | WOM | 87 | 42 | 2.9 | 110 | 7.50 | 3.75 | 35.83 | 2.84 | 1.25 |
| Snb'S'//Flk'S'/Hork | ICW87-0050-300AP-0L-4AP-0L-0AP | WAM92 | 322 | - | - | - | - | - | 0.75 | 1.67 | 5.0 |
| Fta/W71//Imuris | CMH80A-276-1B-2Y-1B-2Y-2B-0Y | WCB87 | 71 | 0.83 | 5.42 | 1.70 | 2.08 | 26.67 | 0.50 | 1.67 | 3.75 |
| Vee'S'//Ald'S'/Huac'S' | ICW86-0605-08AP-300L-3AP-0L-0BR-0L-0AP | WAM92 | 314 | - | - | - | - | - | 0.75 | 1.67 | 3.33 |
| Pato/On//Maya74/4/Bb/3/Pato//Inia/Napo /5/Ald'S'/Pima77/3/CMH24A.630/Bu | | | | | | | | | | | |
| | ICW84-0205-08AP-300L-4AP-300L-0AP | WAL90 | 204 | - | - | - | 0.42 | 13.33 | 0.75 | 1.67 | 4.58 |
| Ures.81/Genaro.81 | ICW85-0063-300L-300AP-300L-4AP -0L-2AP-0L | WAL92 | 421 | - | - | - | - | - | 0.50 | 1.67 | 3.75 |
| Tsi/Vee'S'//Lovrin24/Coc75 Kvz/Cgn/5/Maya74'S'/On//II60.147 /3/Bb/Gll/4/Chat'S' | ICW89-0775-0L-0Br-2AP | WS592 | 703 | - | - | - | - | - | 2.5 | 0 | |
| | ICW86-1101-300AP-0L-11AP-0L-0AP | WAL92 | 610 | - | - | - | - | - | 0.50 | 2.5 | 4.17 |
| Pvn'S'/Sprw'S'//W3918A/Jup | ICW87-1052-0L-1AP-0L-0AP | WAL92 | 216 | - | - | - | - | - | 0.50 | 2.5 | 6.25 |
| Tsi/Vee'S'/5/RBS/Anza/3/Kvz /Hyz//Ymh/Tob/4/Bow'S' | ICW89-0773-0L-0Br-2AP | WS592 | 70 | - | - | - | - | - | - | 2.5 | 0 |
| Tob'S'/8156//Y50E/Kal(3)/4 /Mrs//Kal/BB/3/AZ | ICW82383-023AP-300AP-1AP-300L-4AP-300L-0 | WAL91 | 21 | - | - | - | - | 22.5 | 0.25 | 5 | 2.5 |
| Golan | Local Check | | - | - | - | - | - | - | - | - | 2.25 |

**Table 8.4. Results of small scale yield trials for wheat stem sawfly resistant wheat and barley conducted at Saraqueb, Syria, 1993/94.**

| Name/Genotype | Pedgree | Source | SN | %Inf | Yield(g)$m^2$ | 1000KW |
|---|---|---|---|---|---|---|
| **Barley** | | | | | | |
| FB73-075 | - | BAB85 | 14 | 1.66 | 294.3 | 38.7 |
| Ager//Api/CM67/3/Cel/WI2269//Ore | ICB81-1275-0SH-1AP-0AP-0AP | BAT88 | 405 | 1.66 | 353.7 | 36.5 |
| H.SPONT.41-1/TADMOR | ICB87-1833-145AP-0AP | F6HS92 | 8 | 1.66 | 249.2 | 35.2 |
| H.SPONT.41-1/TADMOR | ICB87-1833-61AP-0AP | F6HS92 | 3 | 1.66 | 251.7 | 29.3 |
| H.SPONT.41-1/TADMOR | ICB87-1833-150AP-0AP | F6HS92 | 9 | 1.66 | 357.3 | 37.8 |
| H.SPONT.41-1/TADMOR | ICB87-1833-165AP-0AP | F6HS92 | 11 | 1.66 | 329 | 32.3 |
| Arabi Abiad | | Check | 1 | 3.33 | 449.5 | 33.8 |
| **Durum Wheat** | | | | | | |
| Awl2/Bit | ICD84-0322-ABL-7AP-TR-AP-21AP-0TR | DAT92 | 110 | 1.66 | 552.2 | 46.2 |
| Bit/Creso | CD 34346-2TR-2AP-1AP-0AP | DCB87 | 20 | 1.66 | 543.2 | 45.5 |
| 16143 | | SOLSTE | 72 | 3.33 | 533.7 | 44.3 |
| Ru/Mrb15 | ICD84-1257-8AP-0TR | DAT91 | 121 | 1.66 | 677.3 | 46.3 |
| Rufom-4 | ICD84-1257-14AP-TR-13AP-0TR | DAT91 | 505 | 1.66 | 459.8 | 45.3 |
| D-2/Bit | CD 20796-4AP-6AP-2AP-0AP | DAT87 | 116 | 1.66 | 753.3 | 41 |
| Haurani | | Check | 1 | 3.33 | 556.3 | 45.8 |
| **Bread Wheat** | | | | | | |
| Tsi/Vee's' | CM 64335-3AP-3AP-1AP-0AP | WOL88 | 12 | 1.66 | 426.8 | 35.7 |
| Bol'S'/Pvn'S' | CM 58696-5AP-2AP-1AP-1AP-0AP | WOM87 | 42 | 1.66 | 471 | 39 |
| Kasyon//Pvn'S'/Sprw'S' | ICW86-0860-300L-300AP-0L-0AP | WAM91 | 311 | 1.66 | 521.2 | 35 |
| Fta/W71//Imuris | CMH80A-276-1B-2Y-1B-1Y-1B-0Y | WCB87 | 72 | 1.66 | 447.3 | 33.5 |
| 66.122.66.2/No66//Lov2F1/3/F1Kvz.Hys /4/7C//Tob/Cno'S'/3/kal/6/Mb*2//In | ICW84-0440-04AP-300L-7AP-300L-0AP | WAL90 | 217 | 1.66 | 411.3 | 48.2 |
| Shi#4414/Crow'S' | SWM11508-1AP-1AP-4AP-1AP-5AP-0AP | WAT88 | 613 | 0 | 442.7 | 43.2 |
| Golan | | Check | 1 | 3.33 | 396 | 33.5 |

# 9. BIOTECHNOLOGY

## 9.1. Double Haploid Production in Barley

The interest in Double Haploid (DH) line production from a breeders point of view is because of reduction in the time required for the development of populations and to start screening progenies of crosses in complete homozygous state. Regenerated haploid plants of barley hybrids after colchicine doubling represent a complete homozygous population. Furthermore, with the introduction of DNA-marker technology in plant breeding for gene tagging and genome mapping, DH lines represent the ideal plant material for this technology. Screening of populations with DNA-markers is more informative in complete homozygous populations such as DH populations as compared to F2 or backcross progenies.

Anther culture in wheat (Lashermes 1990-91) as well as crosses with *H. bulbosum* in wheat and barley (Inagaki 1988-90) were conducted in ICARDA to evaluate the potential of DH production. None of the DH production techniques has been established in ICARDA as an alternative to conventional development of homozygous populations. The low efficiency of the method and the genotype dependancy to successfully regenerate are the main reasons. In order to evaluate the potential of DH line production in barley the efficiency of the anther culture and bulbosum method were compared.

### 9.1.1. Anther Culture in Barley

F1 plants of the cross Tadmor x WI2291 were grown as donor plants in growth chambers with a daylength/temperature cycle of 16h, 14°C, 400 E $m^{-1}$, 8h, 12°C in the dark. Two different induction media were compared for their ability to induce embryogenesis: BK, a solid medium containing charcoal to absorb inhibitory metabolism products and FHG, a standard liquid media containing Ficoll (after Hunter) (Table 9.1). Calli induction in the dark occured sometimes as early as seven days after plating (Fig. 9.1). Green plant development was already observed in the induction medium in the dark. Only a few additional embryoids developed into green plants

after embryoids had been transferred to regeneration media. The frequency of green plants regenerated per 100 anthers was 0.6 for the solid and 0.92 for the liquid induction medium and the respective values for albino plants were 0.26 and 0.50 (Table 9.2) (Fig.9.2). We found that 10.3% of embryoids developed into green plants on the solid media and 15.5% on the liquid media, which is comparable to frequencies reported by others. However, the frequency of calli and embryoid induction and, therefore, the overall green plant production was low. The total number of regenerated green plants from this experiment was 48.

It appears in general, that the material from Syrian spring barley varieties, especially material developed out of landraces, responds far less to androgenesis than that from European or North-American varieties (A. Gland, A. Comeau, unpublished). However, the donor plants produced in growth chambers in pots in our experiment showed symptoms of water stress. A humidity of 80%, as recommended for the best development of donor plants, is technically difficult to achieve. To produce better quality donor plants we suggest to reduce water stress conditions by using a system of hydroponic culture or to culture donor plants in a semi liquid agar system.

**Table 9.1. Composition of induction and regeneration media used for barley $F_1$ anther culture.**

| Component | Induction media | | Regeneration medium |
|---|---|---|---|
| | FHG | BK | |
| Macroelements | + | + | + |
| Microelements | + | + | + |
| Aminoacids | - | + | - |
| Vitamines | + | + | + |
| Fe EDTA | 27,85 mg | 27,85 mg | 27,85 mg |
| Glutamine | 730 mg/l | 975 mg/l | - |
| Ficoll | 00 g/l | 200 g/l | - |
| Maltose | 62 g/l | 62 g/l | 36 g/l |
| Inositol | 100 mg/l | 200 mg/l | 100 mg/l |
| Charcoal | - | 30 mg/l | - |
| pH | 5.8 | 5.8 | 5.5 |

+ = available in the medium
- = not available in the medium

In order to compare the capabilities of DH line production at ICARDA with that of others, we contracted a private company specialized in DH line production (Agrogene, Paris) to develop DH lines from the same plant material. With the same number of donor plants (42) Agrogene produced 71 DH lines using the more advanced microspore culture technique, as compared with 48 produced in ICARDA.

To use the anther-culture system for a routine mass production of DH lines the production of donor plants in growth chambers is too expensive.

Fig. 9.1. Induction of androgenesis in F1 hybrids of the barley cross Tadmor x WI2291.

**Table 9.2. Androgenesis in the barley cross Tadmor x WI2291**

| Number of anthers | Embryoids per callus | Plants/100 anthers | | Green plants regenrated as % of embryoids | Medium |
|---|---|---|---|---|---|
| | | albinos | green | | |
| 1890 | 116 | 0.26 | 0.63 | 10.3 | BK |
| 3810 | 225 | 0.50 | 0.92 | 15.5 | FHG |
| 5700 | 341 | 0.42 | 0.82 | 13.7 | Total |

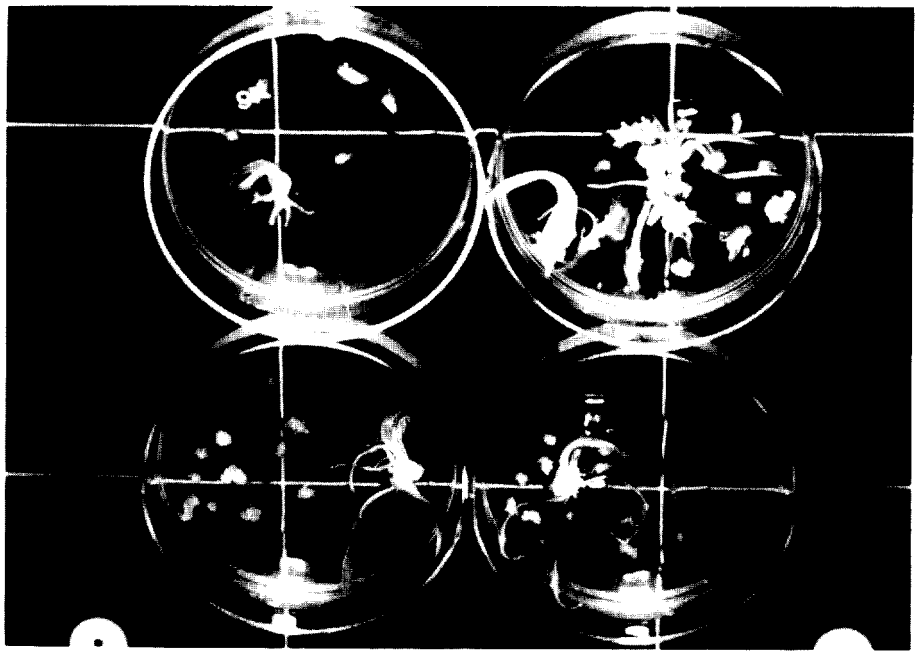


Fig. 9.2. Regeneration of haploid barley plants of the cross Tadmor x WI2291.

Glass- or plastichouse- and field-grown plants might be an alternative. To test the potential of field-grown donor plants for anther culture, spikes from 50 field grown genotypes were collected in March 1994 from F1-spring barley crosses. Altogether 5000 anthers were plated on a solid (BK) and a liquid (FHG) medium. A total of 500 embryoids were produced but only 20 green plants could be regenerated. During the time of spike collection the temperatures varied between 15-22°C during the day and 5-8°C during the night. Even though growing conditions of the donor plants in the field were better as compared to growth-chamber conditions, the temperature variation in the field could not be controlled. Higher temperatures during donor plant development (22°C versus 14°C) reduce the in vitro response potential greatly.

### 9.1.2. Crosses with *H. bulbosum*

Crosses between *H. bulbosum* as the male and *H. vulgare* as the female parent lead to preferential chromosome elimination of *H. bulbosum* chromosomes in the first 8 days after fertilization thus leaving haploid *H. vulgare* plants. This method has been demonstrated to be efficient for barley haploid production. Field grown barley genotypes of both spring and winter type were emasculated and crossed with a pollen mixture of different clones from a *bulbosum* collection at Tel Hadya. From about 200 developing caryopses, 108 green plants could be rescued on a regeneration media (Table 9.3, Fig. 9.3). On average 2 green plants per pollinated spike could be developed. The rescued plants are the result of a one day crossing experiment. However, cytological analysis of the rescued plants revealed that the plants were triploid hybrids (21 chromosomes) thus indicating that tetraploid bulbosum clones were the pollen donor. Only in crosses of diploid *H. bulbosum* with diploid barley the chromosome elimination and the production of haploid plants occurs. Literature reports show that in crosses with diploid *H. bulbosum* a range of 15-30 green plants per spike can be expected. - **S. Tawkaz, B. van Dorrestein, A. Comeau, P. Lacaze and M. Baum**

**Table 9.3. Plant regeneration of *H. bulbosum* crosses with spring and winter barley**

| Type | Genotypes | Green plants rescued |
|---|---|---|
| Spring barley | 423 | 32 |
| | 1050 | 18 |
| | 1043 | 15 |
| Winter barley | 287 | 25 |
| | 294 | 8 |
| | 296 | 10 |

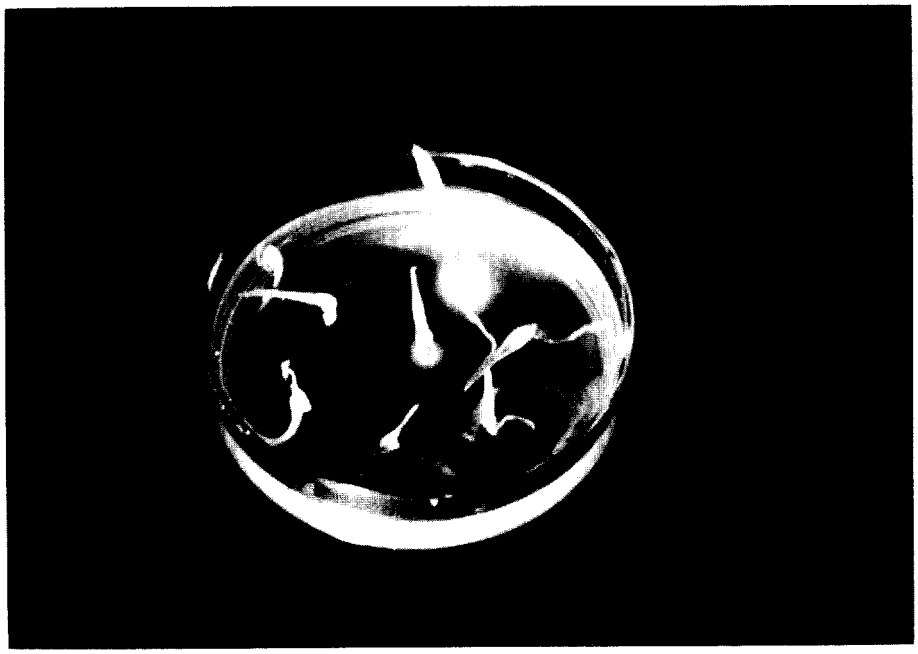


Fig. 9.3. Embryo rescue of hybrids between *H. vulgare x H. bulbosum*

## 9.2. Double Haploid Production in Wheat

In a collaborative project between bread wheat breeding, pathology and biotechnology the development of DH lines of bread wheat combining high yield, good adaptation and yellow rust resistance was initiated. Fifteen wheat F1 crosses were used for this experiment. The semi-liquid agar system to grow good quality donor plants (Fig. 9.4) was used to determine the effect of donor plant quality on *in vitro* response. - **M. Baum, O. Mamluk and M. Ortiz-Ferrara**

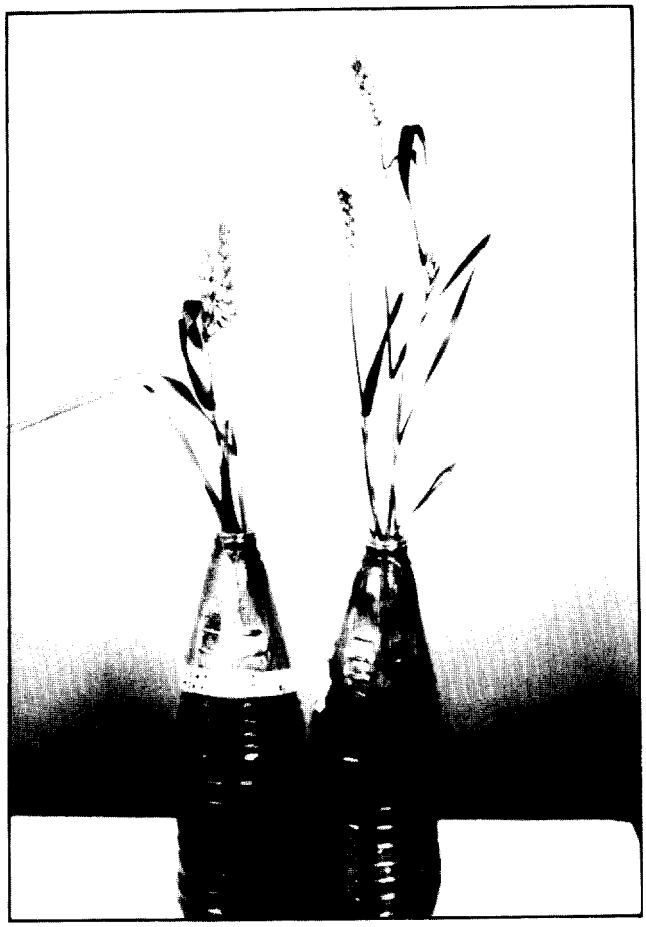


Fig. 9.4. Culture of wheat donor plants in a semi liquid agar system in bottles

## 9.3. Wide Crossing

Crosses of durum wheat with *Aegilops* and subsequent backcrosses are difficult to perform in the field. The wild *Aegilops* usually shed only little amounts of pollen very early in the morning. Therefore, we developed a detached-spike culture technique to make crosses in the laboratory under controlled environmental conditions.

### 9.3.1. Development of a Protocol for Detached Spike Culture

Detached spiked-stems (35-45 cm tall excluding the length of awns) were incubated in 50 ml class vials and grown with THMM nutrient solution {containing microelements, macroelements, 2,4-D, and 75mg/l of piperacin). The development of the leaf color, the consumption of the nutrient solution with variable amount of sucrose and the 1000 kernel weight were recorded. Response functions revealed that the optimal concentration of sucrose was 6-7% for filling the grain (Fig. 9.5) as expressed in 1000-grain weight.

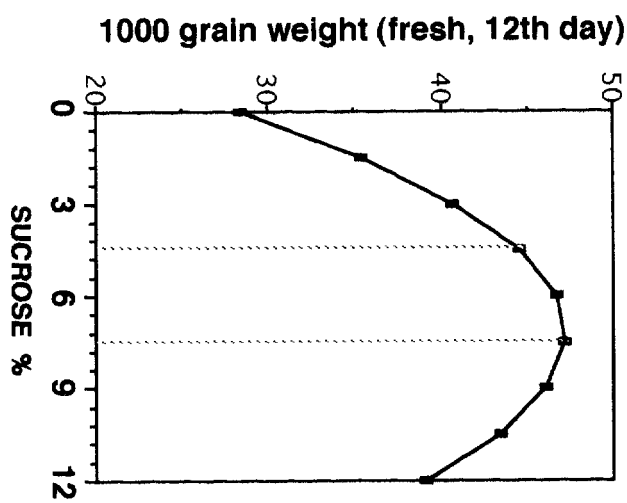



Fig. 9.5. Relationship between sucrose contents of the nutrient solution and 1000-grain weight of the detached spiked stems

However, a 4% or 5% sucrose solution gives the best maintenance of green color of the stem (Fig. 9.6). It requires an average consumption of 4-5 ml liquid per stem per day when the stems are young (Fig. 9.7). Consumption of liquid decreased linearly with the age (Fig. 9.8). The recommended detached-tiller method uses a 6% sucrose solution for the first three days, a 4% or 5% sucrose solution on the $4^{th}$ day. Presence of 2,4-D is needed for the first few days after pollination, thereafter it should be ommitted. Sulforous acid (0,075%) is to control bacterial and fungal infection.

Detached spikes were used for wide crosses of *Aegilops* with *T. durum*. Spikes of pollen donors were collected from the field and kept at 10°C. Detached tillers kept in sucrose solution were emasculated for pollination in the laboratory. Anther dehiscense of *Aegilops sp.* was induced under white light lamps and pollen collected on microscope slides. Previously emasculated flowers were pollinated with fine paint brushes. Pollinated flowers on detached spikes were kept in a growth chamber in sucrose solution at 20°C. Hybrid embryos were excised 12-14 days after pollination and incubated on a solid regeneration medium. The wide crosses successfully rescued and regenerated are shown in Table 9.4.

**Table 9.4. Wide crosses between *T. durum* and *Aegilops* sp.**

| *T.durum* parent | | *Aegilops* parent | Genomes | | No. of rescued hybrids |
|---|---|---|---|---|---|
| Omrabi-5 | x | *Ae. kotschii* | {US} | (2 accessions) | 4 |
| Omruf-2 | x | *Ae. kotschii* | {US} | (1 accession) | 1 |
| Omgan | x | Ae. ovata | {UM} | (2 accessions) | 1 |
| Heider | x | *Ae ovata* | {UM} | {2 accessions} | 4 |
| Heider | x | *Ae. neglecta* | {UMUn} | {1 accession} | 1 |
| Heider | x | *Ae. speltoides* | {S} | (1 accession) | 1 |
| STJ-6 | x | *Ae. speltoides* | {S} | (1 accession) | 4 |

Wherever the genomes of the wild species have a close homology with the *T. durum* genomes, offspring can be expected through selfing (eg. *T. durum* (AABB) x *Ae. speltoides* SS). In other cases, hybrids were subjected to colchicine treatment to produce amphidiploids.

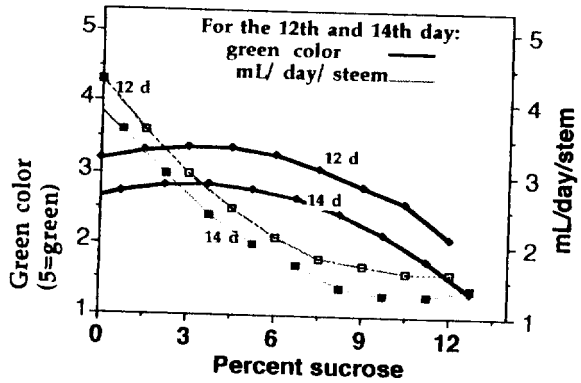



Fig. 9.6. Development of green color of detached spiked stems in relation to percentage of sucrose in the nutrient solution and consumption of nutrient solution.

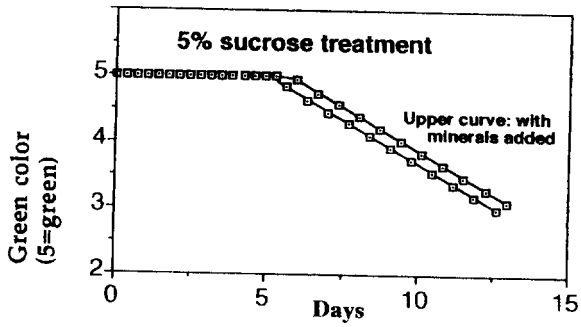



Fig. 9.7. Development of green color of detached spiked stems in a 5% sucrose solution.

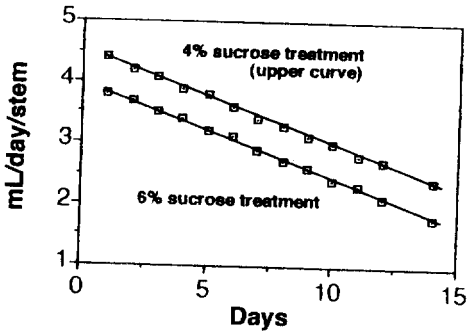



Fig. 9.8. Consumption of a nutrient solution containing 4 or 6% sucrose by young detached spiked stems.

### 9.3.2. Development of a Colchicine Treatment Machine

A colchicine treatment machine was built (design after A. Comeau) to standardize colchicine treatment for wide crossing and double haploid production. In a household refrigeration unit a perspex box was integrated in which either nutrient solution or the colchicine solution can be circulated through the roots of plants which are fixed on perspex rods. In preperation for colchicine treatment, plants were incubated in a nutrient solution at 20°C for two weeks to allow new root growth. One week before the colchicine treatment the temperature was reduced to 3°C. On the day of the treatment the nutrient solution was replaced by a 0.1% colchicine solution. The treatment occured for 4 h at 20°C. Subsequent the colchicine was replaced again by the nutrient solution and plants kept for 3-4 days at 4°C. Following this, the temperature was increased 2°C per day until a temperature of 20°C was reached. Plants were kept for another week in the unit in nutrient solution before they were transplanted in pots or field.

### 9.3.3. Immature Embryo and Spike Culture

The production of hybrids between *T. durum* and *Aegilops* is laborious and, depending on the cross combination, difficult to achieve. It is, therefore, of value to maintain succesfully established hybrids. Immature embryos and immature spikes can be used to induce calli for subsequent regeneration of plants from them. The regenerated plants represent vegetativly propagated plants of the same genotype. Depending on the length of the calli phase, somaclonal variation can be induced which produces chromosomal rearrangments between the genomes and chromosmes involved. Immature spikes of *T. durum* x *Aegilops* hybrids were incubated on a MS based mediuma with 2,4-D to induce calli (Fig.9.9). After successful induction, calli were tranferred on a MS based medium to induce shooting. In cases where root formation did not occur, shoots were transferred on regeneration medium containing 1mg/l IAA and BAP.

Fig. 9.9. Immature spike culture of hybrids between *T. durum* and *Aegilops* ssp.

When hybrids produce seeds, immature embryo culture can be used to maintain and to multiply the hybrids. Compared to the immature spike culture the immature embryo culture is easier to perform. Immature embryos from barley crosses (Tadmor x WI2291) were incubated on calli induction medium (MS + 2,4-D) and calli were regenerated on a regeneration medium (MS +IAA and BAP) (Fig. 9.10). Up to 10 plants could be regenerated from one immature embryo (Fig. 9.11). **- S. Tawkaz, F.'Jaiti, B. van Dorrestein, A. Comeau, M. Nachit and M. Baum**

## 9.4. The Barley Marker Project

A collaborative research project has been developed with the University of Weihenstephan, Munich to establish the non-radioactive protocols for the use of already mapped RFLP marker and to test DNA-molecular markers for their use in marker-assisted selection in cereals. The project aims to link agronomic differences between the parent Tadmor and WI2291 to genetic markers.

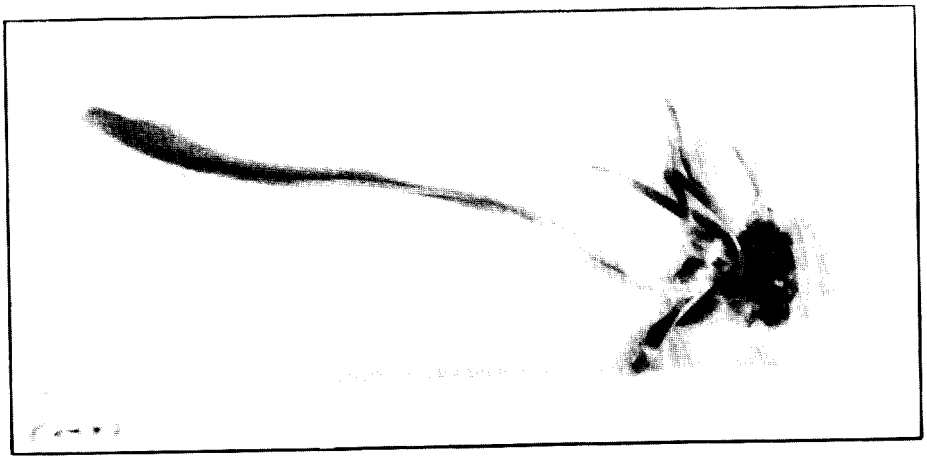


Fig. 9.10. Regenerated shoot from immature embryo culture from barley cross (Tadmor x Wi2291).

Fig. 9.11. Plant regeneration from calli induced by immature embryo culture.

### 9.4.1. Single- and Low Copy RFLPs Analysis between Tadmor and WI2291

A non-radioactive RFLP-protocol had to be adopted to perform RFLP-analysis with already mapped single- and low copy RFLP-marker. The method used is based on the system originally developed by Boehringer using digoxigenin-11-UTP labelled clones, which are hybridized to restricted total genomic DNA and visualized with an immunological detection system.

We carried out a comparison between colorimetric signal development and chemiluminescent signal development. Total genomic DNA of the parents Tadmor and WI2291 restricted with five restriction enzymes - EcoRI (EI), EcoRV (EV), BamH1 (B), HindIII (H) and Dra I (D) - was hybridized with the same RFLP-probe MWG003 (Fig.9.12). The signal development with chemiluminescence (Fig.9.12, left) revealed stronger signals of the major bands as compared with the colorimetric method (Fig.9.12 right). For all five enzymes used, RFLPs were detected between the parents. The banding pattern for the four enzymes (EcoRI, EcoRV, BamH1 and HindIII) were exactly the same. Only the hybridization pattern in the DraI digest differed between the two methods. The hybridization bands at about 2.5 and 5.2 kb in parent 1 and at about 6.7 kb in parent 2 obtained in colorimetric signal development did not develop in the chemiluminescence. The colorimetric signal development is, therefore, more sensitive than chemiluminescence. Although more bands and consequently more RFLPs can be detected with the colorimetric signal development, the colorimetric signal development has some drawbacks. As the signal is developed on the membrane itself, it is subsequently more difficult to destain the membrane and remove the probe for reuse of the membrane in other hybridizations. Therefore, this approach is more expensive, if the costs for DNA extraction, digest and blotting are taken into account.

Total genomic DNA of the parents Tadmor and WI2291 was digested with 5 restriction enzymes (EcoRI, EcoRV, BamH1, HindIII and DraI) and hybridized to single - or low copy RFLP probes.

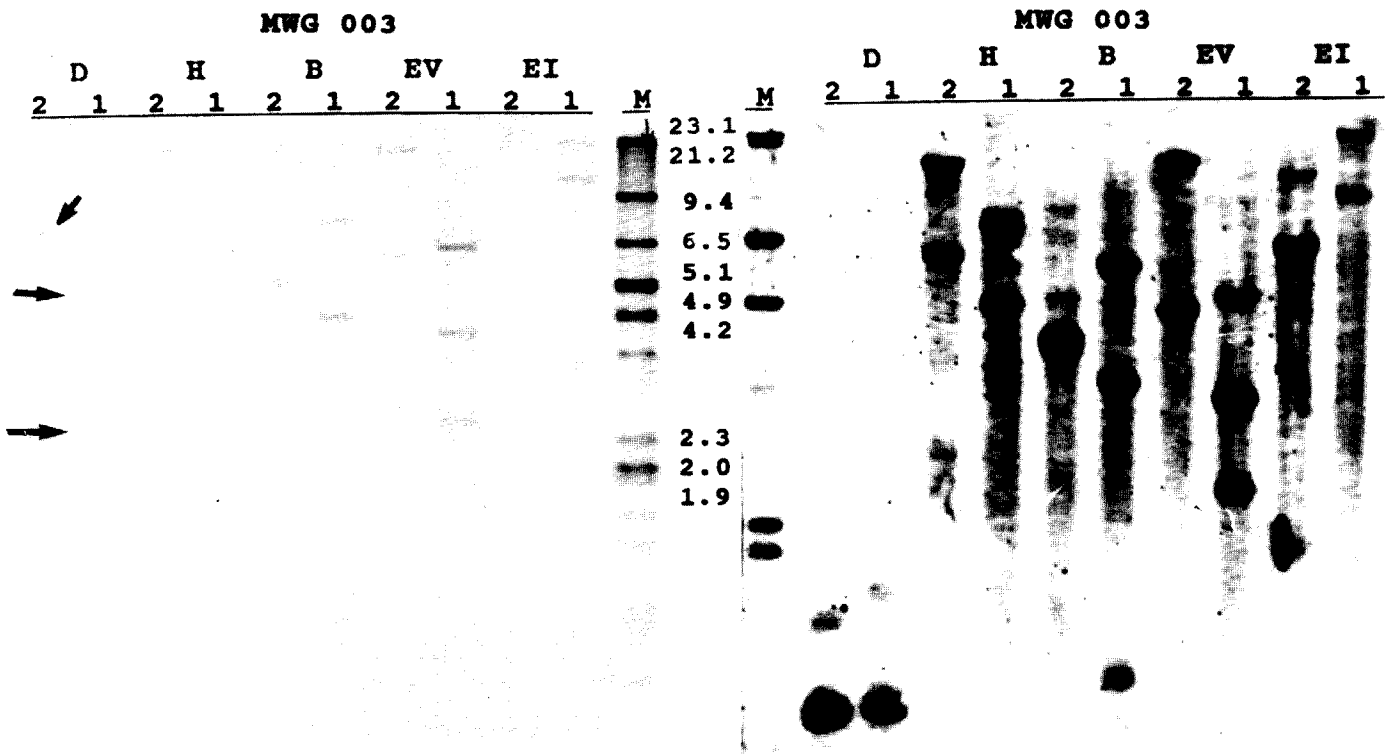



Fig. 9.12. Comparison of the colorimetric (left) and chemiluminescent (right) signal development after hybridizations with RFLP-marker MWG003. The hybridization bands at about 2.5 and 5.2 kb in Tadmor (1) and at about 6.7 kb in WI2291 (2) detected after colorimetric signal development are missing in the signal development with chemiluminescence.

Of the 51 markers tested, 40 markers revealed RFLPs with at least one of the tested enzymes between the parents (Table 9.5). The most frequent RFLPs were observed when the restriction enzymes BamH1 and EcoRV (53%) were used (Table 9.5). The lowest polymorphism was found in hybridizations on EcoRI digests. Digests with EcoRI were often incomplete. When only polymorphic and non polymorphic bands were compared, EcoRI would still have been one of the best enzymes for revealing RFLPs. If the three enzymes EcoRI, HindIII and BamHI would have been used for the parental screening, only 5 probes polymorphic for EcoRV would have been missed from the 40 (Table 9.6). Map construction is time consuming and expensive. The evaluation of RFLPs for the 5 different enzymes has shown that the use of the three cheaper enzymes (EcoRI, HindIII, BamH1) could be acceptable for a map construction and would reduce costs significantly.

Even though only a small number of clones have been tested so far, RFLPs could be detected in all linkage groups (Table 9.7). Very useful is the polymorphism in linkage groups 4H and 6H. Chromosme 4H showed only a low level of RFLPs in the map developed in the German Barley Gene Mapping Project and chromosome 6H in the map developed in the project in Cornell University, USA.

To date 30 clones of the MWG library, 19 clones of the CDO library and two clones of the TAG library have been tested for RFLPs. In most cases the clones of the MWG and CDO libraries were giving 1-3 hybridization bands, which indicates the presence of single- or low copy DNA sequences (Fig.9.13). However, some clones (see Fig.9.14) reveal a more complex pattern of more than 5 hybridization bands, suggesting a medium or high copy number of these DNA sequences in the genome e.g. pTAG169 (Fig.9.14, left) and CDO 388 (Fig.9.14, right) giving up to 5 or more bands after hybridization with all 5 restriction enzymes. These clones can still be used for segregation analyses but would be ideal for fingerprinting in barley to differentiate lines of different origin.

We have started with the RFLP-analysis of the Tadmor x WI2291 F. recombinant inbred lines (developed by SSD) with the probes being polymorphic between the parents. The segregation analysis obtained in this subsample of the F. population is promising. For the clones MWG878, and MWG82,

**Table 9.5. Screening of barley parents Tadmor and WI2291 for RFLP**

| No. | Probe | Restrection enzymes | | | | Mapped on chromosomes in | | |
|---|---|---|---|---|---|---|---|---|
| | | E1 | EV | B | H | D | Barley | Wheat |
| 1 | MWG518 | 0 | + | - | + | + | 1H | - |
| 2 | cMWG706 | 0 | + | + | + | - | 1H | - |
| 3 | MWG506 | + | + | + | + | - | 1H | - |
| 4 | MWG913 | 0 | + | + | - | 0 | 1H | - |
| 5 | MWG800 | 0 | + | + | - | + | 1H | - |
| 6 | MWG938 | 0 | + | + | + | + | 1H | - |
| 7 | CDO400 | + | - | - | - | - | 1HL | |
| 8 | CDO473 | - | + | - | - | - | 1HL,4HL | - |
| 9 | CDO388 | - | + | + | - | - | - | 5L |
| 10 | CDO213 | - | 0 | - | - | 0 | - | 5L |
| 11 | CDO412 | 0 | - | - | - | - | - | 5L |
| 12 | CDO548 | 0 | + | + | + | - | - | 5L |
| 13 | MWG082 | 0 | + | + | + | + | 2H | - |
| 14 | MWG520 | 0 | + | - | - | 0 | 2H | - |
| 15 | cMWG720 | 0 | - | 0 | - | 0 | 2H | - |
| 16 | CD0405 | + | 0 | - | - | 0 | - | 2S |
| 17 | MWG582 | 0 | - | - | + | - | 3H | - |
| 18 | MWG584 | 0 | + | + | - | + | 3H | - |
| 19 | MWG041 | + | + | + | + | + | 3H | - |
| 20 | MWG630 | + | + | - | - | - | 3H | - |
| 21 | CDO482 | + | + | - | + | + | - | 3L |
| 22 | CDO480 | 0 | + | + | - | + | - | 3S |
| 23 | CDO395 | + | - | + | - | - | - | 3S |
| 24 | MWG616 | - | - | - | - | - | 4H | - |
| 25 | MWG611 | + | + | + | + | - | 4H | - |
| 26 | MWG058 | 0 | + | + | + | + | 4H | - |
| 27 | MWG634 | + | + | + | + | + | 4H | - |
| 28 | CDO541 | 0 | - | + | - | - | - | 4L |
| 29 | MWG604 | + | + | + | + | + | 5H | - |
| 30 | cMWG653 | - | - | + | - | - | 6H | - |
| 31 | MWG514 | - | - | - | - | - | 6H | - |
| 32 | cMWG652 | 0 | 0 | + | + | + | 6H | - |
| 33 | cMWG669 | 0 | 0 | - | - | 0 | 6H | - |
| 34 | CDO497 | 0 | + | - | - | + | - | 6L |
| 35 | MWG539 | 0 | - | - | - | + | 7H | - |
| 36 | MWG077 | 0 | + | - | - | + | 7HL | - |
| 37 | MWG003 | 0 | + | + | + | + | 7H | - |
| 38 | cMWG703 | - | + | - | - | - | 7H | - |
| 39 | CDO472 | + | - | - | - | - | - | 7S |
| 40 | CDO676 | - | - | - | - | - | 7HS,6HL | |
| 41 | CDO580 | - | - | + | + | + | - | 1S |
| 42 | CDO572 | + | - | + | + | + | - | 1L |
| 43 | CDO393 | - | - | - | - | - | - | 1L |
| 44 | pTAG118 | 0 | - | - | - | - | - | 3 |
| 45 | pTAG163 | + | + | + | + | + | - | 1 |
| 46 | CDO484 | - | - | - | - | - | 2HL,4HL, 5HL,7HL | - |
| 47 | CDO534 | 0 | - | + | - | - | - | 1S |
| 48 | MWG532 | + | + | + | + | + | - | - |
| 49 | MWG878 | + | + | + | + | + | - | - |
| 50 | MWG932 | - | - | - | - | - | - | - |
| 51 | MWG950 | + | - | + | + | + | - | - |

+ = polymorhic between the parents,
- = non-polymorphic between the parents,
0 = not tested (either not tested or test was not possible of incomplete digestion or blot not readable)

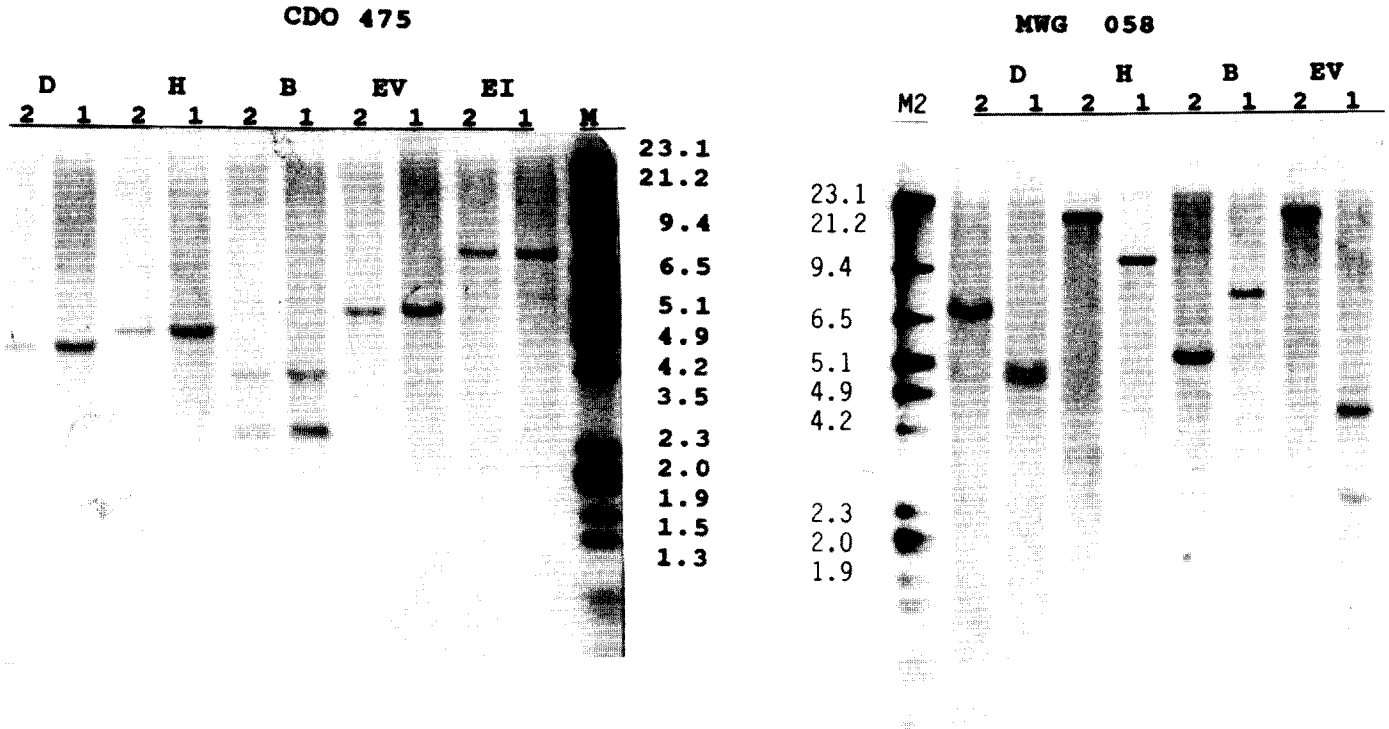



Fig. 9.13. Colorimetric signal development after hybridization with RFLP-marker CDO475 (left) and MWG058 (right). No RFLPs were detected between the parents Tadmor (1) and WI2291 (2) after hybridization with CDO475 in 5 restriction enzyme digests (EcoRI, EcoRV, BamHI, HindIII, DraI), whereas RFLPS in four restriction enzyme digests were detected after hybridization with MWG058.

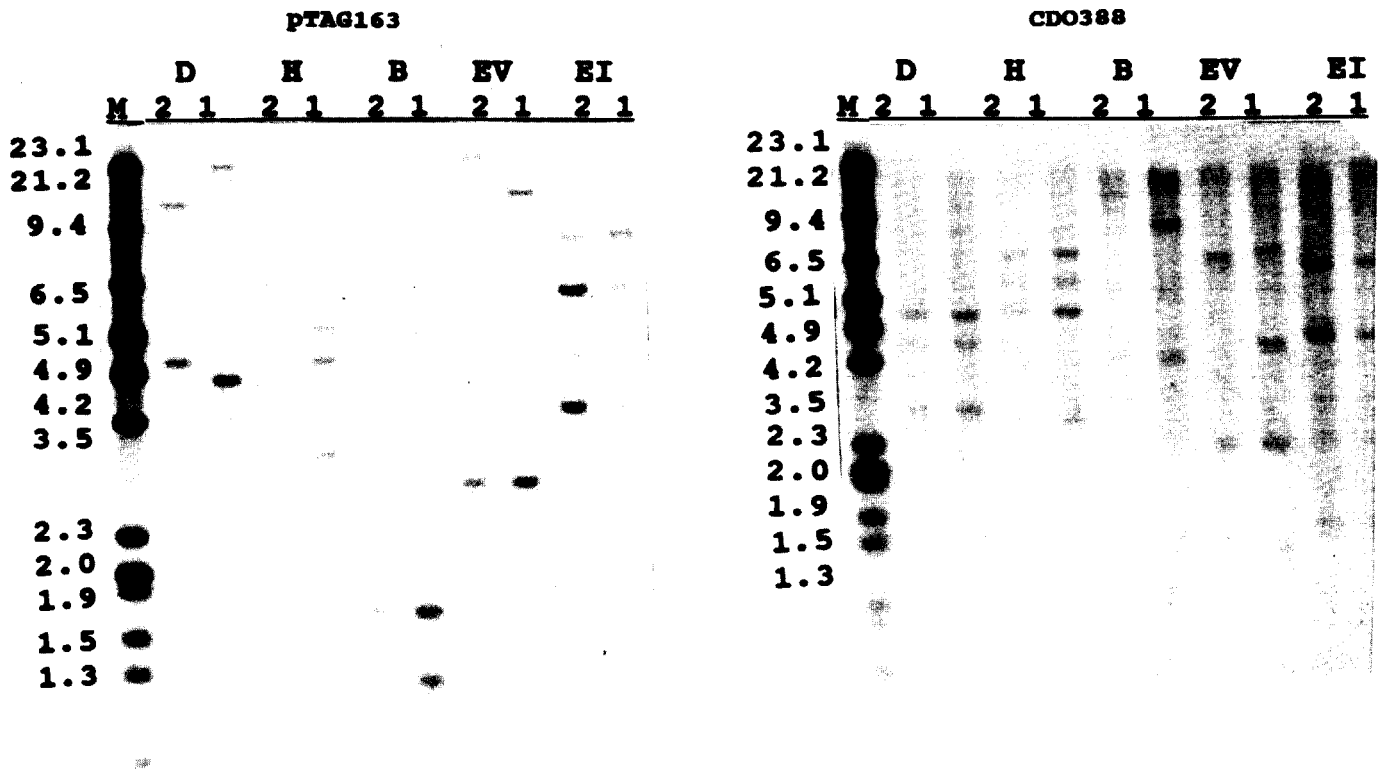



Fig. 9.14. Colorimetric signal development after hybridization with pTAG163 (left) and CDO388 right picture. RFLPs between the parents Tadmor 1) and WI2291 2) were detected in all 5 restriction enzyme digests for pTAG163. Both markers reveal several bands after hybridization.

we got a segregation of 6:6 (presence-absence of the RFLP band), and for MWG938, MWG634 and MWG532 a 5:7 segregation (Fig.9.15). This result indicates a random segregation of RFLP alleles and may also indicate a normal Mendelian segregation of Tadmor and WI2291 alleles.

**Table 9.6.** Evaluation of RFLPs between Tadmor x W12291

| Restriction enzyme | Ploymorphic No. | % | Non polymorphic | Not tested |
|---|---|---|---|---|
| E1 (EcorR1) | 16 | 31 | 12 | 23 |
| EV (EcoRV) | 27 | 53 | 20 | 4 |
| B (BamHI) | 27 | 53 | 23 | 1 |
| H (HindIII) | 21 | 41 | 30 | - |
| D (DraI) | 25 | 49 | 22 | 4 |

**Table 9.7.** Availability of RFLPs in the seven linkage groups

| | | | Restriction Enzyme | | | | |
|---|---|---|---|---|---|---|---|
| Group | Marker tested | | EI | EV | B1 | HIII | Dra1 |
| 1H | 12 | pol | 4 | 9 | 7 | 5 | 3 |
| 2H | 4 | pol | 1 | 3 | 2 | 2 | 3 |
| 3H | 7 | pol | 4 | 5 | 4 | 3 | 5 |
| 4H | 4 | pol | 1 | 4 | 4 | 2 | 3 |
| 5H | 1 | pol | 1 | 1 | 1 | 1 | 1 |
| 6H | 2 | pol | 0 | 1 | 2 | 1 | 1 |
| 7H | 4 | pol | 0 | 3 | 2 | 1 | 3 |
| not mapped | 8 | pol | 4 | 2 | 5 | 5 | 3 |

Screening of the barley lines Tadmor and WI2291 for RFLPs was also carried out in Munich with $P^{32}$-labelled probes (Table 9.8). In these experiments 87 clones have been tested and 55 were polymorphic (63%). The probes were selected based on the already existing map. It is planned to use about 100 polymorphic clones to cover the whole genome with distances between the markers not bigger than 10 cM. This would give a good chance to correlate agronomic traits with the presence or absence of chromosomal regions originating from one of the parents in the recombinant inbred lines. - **H. Sayed, V. Mohler, A. Jahoor, G. Fischbeck, S. Ceccarelli. S. Grando and M. Baum**

**Table 9.8. Tadmor/WI2291-Screening with $P^{32}$-labeled probes in Munich**

| 1H | 2H | 3H | 4H | 5H | 6H | 7H |
|---|---|---|---|---|---|---|
| MWG983 | cMWG682 | MWG584 | MWG2033 | MWG502 | ABG466 | MWG530 |
| MWG837 | MWG878 | MWG952 | MWG635a | MWG920 | cMWG652a | MWG564 |
| MWG896 | MWG858 | ABG453 | MWG2036 | cMWG770 | MWG916 | MWG89 |
| MWG800 | cMWG763 | MWG571a | MWG611 | MWG569 | ABG458 | MWG836 |
| MWG943 | MWG520a | MWG973 | MWG32 | ABC302 | MWG951 | MWG20772 |
| cMWG649b | MWG950 | ABG389 | MWG58 | ABC168 | MWG934 | MWG2031 |
| cMWG706a | MWG503 | MWG902 | MWG57 | MWG583 | MWG897 | cMWG696 |
| cMWG733 | MWG949 | MWG972 | MWG880 | MWG604 | MWG2053 | MWG940 |
| MWG954 | | | MWG838 | MWG2180 | MWG914 | cMWG633 |
| MWG2028 | | | MWG540 | JIP66 | MWG550 | MWG539 |
| MWG912 | | | | | MWG533 | |
| MWG824 | | | | | MWG900 | |
| MWG938 | | | | | MWG2020 | |
| GA949 | | | | | cMWG650 | |
| WHS856 | | | | | MWG602 | |
| WHS723 | | | | | MWG813a | |

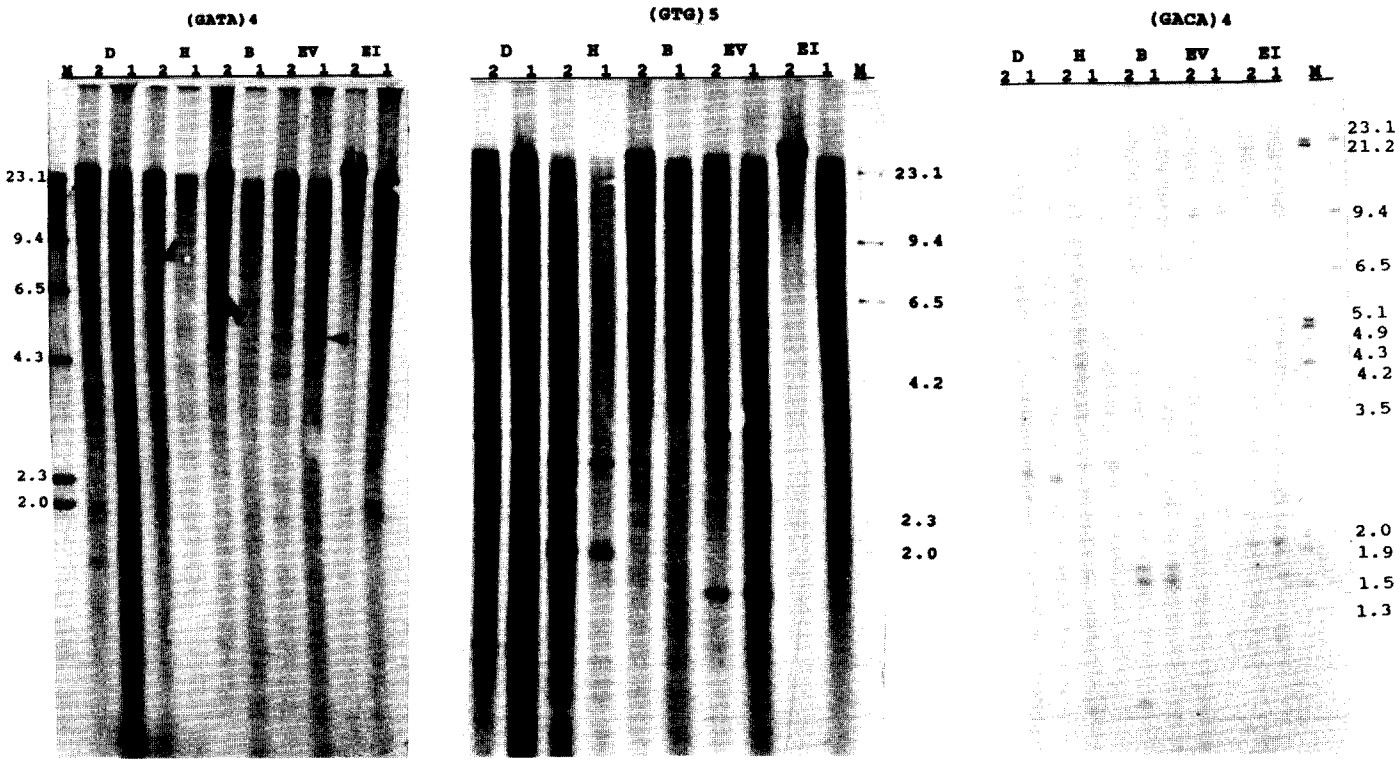



Fig. 9.15. Colorimetric signal development after hybridization with oligonucleotide probe (GATA)4 (left), (GTG)5 (middle) and (GACA)4 (right). No RFLPs were detected between the parents Tadmor (1) and WI2291 (2) after hybridization with (GACA)4 and (GTG)5 in 5 restriction enzyme digests (EcoRI, EcoRV, BamHI, HindIII, DraI), whereas (GATA)4 revealed some polymorphisms between the parents (indicated by arrows).

### 9.4.2. Markers for the MLg locus

The barley lines Tadmor and WI2291 as well as a differential set of lines with known resistance genes to powdery mlildew were infected with different powdery mildew isolates (Table 9.9.). The comparison of the reaction of WI2291 with the reaction of the differential set revealed the presence of the Mlg resistance locus in WI2291. The Mlg locus is located on barley chromosome 4, the RFLP-marker MWG 032 is located in the vincinity of about 2 cM. To develop even more closely linked markers clone MWG 032 was sequenced and two specific PCR primers were synthesized based on the sequence data of MWG 032:

239-1: 5'-CATTCTCCACCGTCTCTGTT-3'

239-2: 5'-TGTCAACACACAGCATCATG-3'

With this primer pair, an amplification product was generated with the genomic DNA of the parents Tadmor and WI2291. Unfortunately, no variation in the length of the product was found. Therefore, the amplified products in each parent were cloned and sequenced to detect mutations (basepair changes ) between them.

In the area of the RFLP-marker no variation could be found between the DNA sequence of both parents. Subsequent inverted PCR was used to amplify DNA sequences in the flanking region of the RFLP-marker. The direction of the two primers was therefore inverted:

239-Inv1: 5'-TTGTCTCTGCACCTCTTAC-3'

239-Inv2: 5'-GTACTACGACACAACTGT-3'

With this strategy a 180 bp fragment could be amplified with primer 239-Inv1 in Tadmor and was sequenced. With a new primer it will be tried to amplify this region also in WI2291 in order to analyze the DNA sequence. Differences in the sequences in Tadmor and WI2291 can then be used to design PCR primers specific for the MLg locus. - **V. Mohler, A. Jahoor, M. Baum and G. Fischbeck**

**Table 9.9. Comparison of powdery mildew resistance spectra of barley varieties (with known genes) with those of Tadmor, and WI2291 after infection with powdery mildew isolates (0=resistant, IV=susceptible 0.1-4.0=leaf coverage.**

| Cultivar | Gene | Isolate | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | WE-3 | GI-1 | TR-2 | RU-3 | VO-2 | AL-1 | VA-3 | PS-IS-2 | AR-4 | AR-1 | 129-13 | Apex-4 |
| Gitte | *Mla1* | 10.1 | IV 0.5 | 0 | 0 | 0 | IV 0.3 | 0 | III-IV 0.2 | 0 | 0 | 0 | 0 |
| Voldagsen | *Mla6* | 0 | 0 | IV 0.4 | 0 | IV 0.6 | 0 | 0 | III-IV 0.2 | IV 0.5 | 0 | IV 0.5 | IV 0.5 |
| Ortolan | *Mla7/Mlk* | III-IV 0.5 | II 0.1 | IV 0.4 | IV 0.6 | II 0.3 | II 0.1 | II 0.3 | 0 | I 0.1 | I 0.1 | IV 0.6 | I 0.1 |
| Welam | *Mla9* | IV 0.7 | 0 | 0 | IV 0.7 | 0 | 0 | 0 | III-IV 0.1 | 0 | 0 | 0 | 0 |
| Sultan | *Mla12* | I 0.2 | IV 0.5 | 0 | IV 0.6 | II 0.4 | IV 0.3 | III 0.3 | III-IV 0.5 | IV 0.5 | IV 0.5 | I 0.1 | IV 0.5 |
| Rupal | *Mla13* | I 0.05 | 0 | 0 | IV 0.7 | I 0.05 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Villa | *Mlg* | IV 0.7 | IV 0.5 | IV 0.5 | IV 0.5 | 0 | 0 | 0 | III-IV 0.1 | IV 0.5 | IV 0.4 | IV 0.5 | IV 0.5 |
| Bollo | *Mlh* | IV 0.8 | IV 0.6 | IV 0.5 | IV 0.8 | IV 0.8 | 0 | IV 0.8 | III-IV 0.5 | IV 0.7 | IV 0.1 | IV 0.7 | IV 0.6 |
| Yada | *Mlla* | III 0.5 | IV 0.3 | III 0.4 | III 0.5 | IV 0.7 | II 0.1 | IV 0.6 | III-IV 0.5 | II 0.1 | III 0.2 | III 0.5 | III 0.5 |
| H.T. 253 | *Mla (neu)* | I 0.1 | 0 | 0 | II-III 0.4 | I 0.1 | 0 | 0 | 0 | II 0.1 | 0 | 0 | |
| Hln | *mlo* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | IV 0.01 | 0 | 0 |
| Po-2 | *Mla3* | I 0.1 | I 0.05 | 0 | I 0.2 | II 0.1 | I 0.05 | I 0.1 | II 0.1 | I 0.1 | 0 | IV 0.5 | I 0.05 |
| Tadmor | - | IV 0.6 | IV 0.6 | IV 0.5 | IV 0.6 | IV 0.6 | IV 0.5 | IV 0.2 | IV 0.6 | IV 0.6 | IV 0.6 | IV 0.6 | IV 0.6 |
| WI2291 | *Mlg* | IV 0.4 | IV 0.5 | IV 0.2 | IV 0.6 | 0 | 0 | 0 | IV 0.5 | IV 0.5 | IV 0.6 | IV 0.5 | IV 0.5 |

### 9.4.3. DNA-fingerprinting with Oligonucleotides

Synthetic microsatelite probes, (GATA)4, (GACA)4, (GTG)5, were tested for their use in mapping in barley. Many hybridization bands occured in genomic digests after hybridization with (GATA)4. Some polymorphisms between the parents could be detected after the hybridization with (GATA)5 in EcoRV and BamH1 digests (Fig. 9.15), but the resolution in the agarose gel system used was not good enough to apply these probes for segregation analysis on populations. The evaluated probes were not useful for mapping prposes in our barley population. - **H. Sayed and M. Baum**

## 9.5. Genetic Distance Between Different Varieties of Barley

Six varieties of barley, used in the barley improvement program as parents of the 3 following crosses: Cross no. 3, P1= WI2269/Line 251-11-2, P2= Leb71/CBB37//Leb71/ CBB29; Cross no. 7, P1= Arta, P2= Harmal-02//Esp/1808-4L; Cross no. 9, P1=Zanbaka, P2= Pitayo/ Cam//Avt/ RM1508/3/Pon/4/Mona/Ben//Cam were DNA fingerprinted by several probe/enzyme combinations $(GATA)_4$, $(GACA)_4$, $(GGAT)_4$, $(GTG)_5$ and *Bam*HI, *Dra*I, *Eco*RI, *Eco*RV, *Hind*III, *Hinf*I and *Taq*I in order to detect the varietal variation at the DNA level to estimate the genetic distance between them.

The results show similar DNA patterns for plants from the same variety, indicating the purity of the varieties. In contrast polymorphisms were detected between the different varieties. The probe/enzyme combination (GATA)./*Taq*I detects the highest polymorphism (Fig. 9.16).

The estimation of genetic distance was the biggest between the parents of cross no. 9 (Index of similarity (IS) = 0.83). The smaller was estimated for cross no. 3 (IS = 0.874). The smallest genetic distance was estimated for cross no. 7 (IS = 0.904). - **F. Weigand, W. Choumane and S. Ceccarelli.**

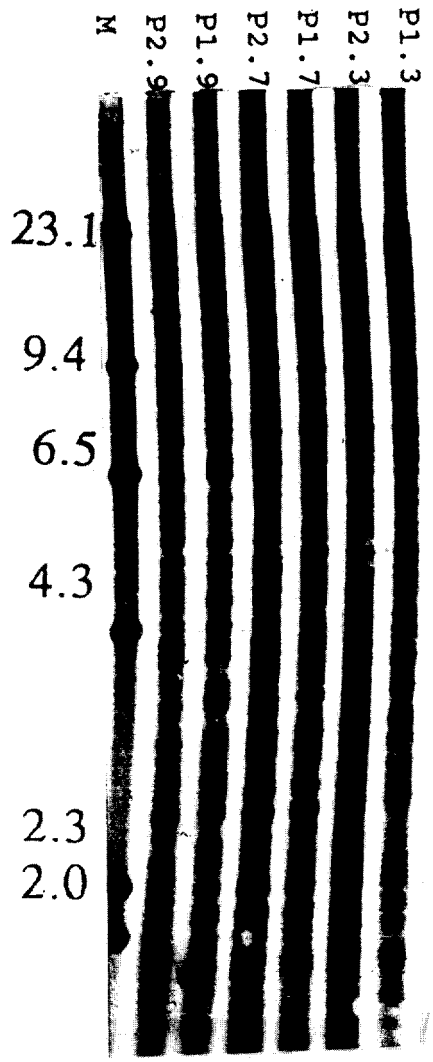



Figure 9.16. Different varieties of barley were DNA fingerprinted using the probe/enzyme combination $(GATA)_4$/*Taq*I. P1.9 and P2.9 show the parents of cross no. 9. P1.7 and P2.7 show the parents of cross no. 7. P1.3 and P2.3 show the parents of cross no. 3. Molecular weight marker is shown in kilobases.

## 9.6. Use of PCR-markers for Durum Quality

The two major storage protein groups in the wheat endosperm are the gliadins and glutenins. The glutenins are multimeric aggregats of subunits of high-molecular-weight (HMW = 'A' subunit) and low-molecular-weight (LMW = 'B' and 'C' subunits) interlinked by disulfide bridges. These proteins have important effects on the physical properties of wheat dough and their presence is associated with technological properties of flour for pasta making. As mentioned in the section on durum wheat improvement LMW-1 and LMW-2 glutenin subunits are responsible for differences in gluten viscoelasticity in durum wheat cultivars. The presence of the LMW-2 glutenin subunit in durum genotypes confers a superior pasta making quality. Originally, these properties of LMW-2 glutenins were attributed to the presence of gliadins, especially the component γ-45. As the gliadins are monomeric proteins, they do not have an important function for the formation of gluten. The γ-42 and γ-45 gliadins are allelic variants encoded by genes at the Gli-B1 locus on chromosome 1BS which are very tightly linked to genes at the GLU-B3 locus coding for LMW-1 and LMW-2 glutenin.

The objective of this study was to determine if the PCR amplification of LMW-1 and LMW-2 glutenins, as compared to γ-gliadins, HMW-glutenins and other quality parameters can be used as an informative and economic selection criteria. The primers used for the amplification of LMW-glutenins, γ-gliadine and HMW-glutenins have been synthesized on the basis of published sequences.

**LMW-glutenin primer sequence**
5'- ATG AAG ACC TTC CTC GTC TT- 3'
5'- AAC GCC GAA TGG CAC ACT A-3'

**γ-gliadin primer sequence**
5'-ATG AAG ACC TTA CTC ATC CT-3'
5'- ACA TAC ACG TTG CAC ATG G-3'

**HMW-glutenin primer sequence**
5'- TCT CAA GAT CCT ATG TTA AT- 3'
5'- TGC CCA TAT TGT CTT GCG AC-3'

### 9.6.1 LMW-glutenin Amplification

PCR amplification of low-molecular-glutenin sequences showed the presence of three bands, ranging between 900 and 1200 base pairs (bp) (Fig. 9.17a). The two smaller fragments were uniform in all genotypes. The size of the third long fragment differed between genotypes. The amplification product in genotypes possessing the LMW-2- subunits (Omrabi 5, Haurani, Mrb 9/ Haucan and Bicre 3/ Cham 1/ Gta/Stk) was about 50 bp longer than that obtained in genotypes possessing LMW-1- subunits (Cham 1 (Waha) and Chahba 88/ Mrb 11).

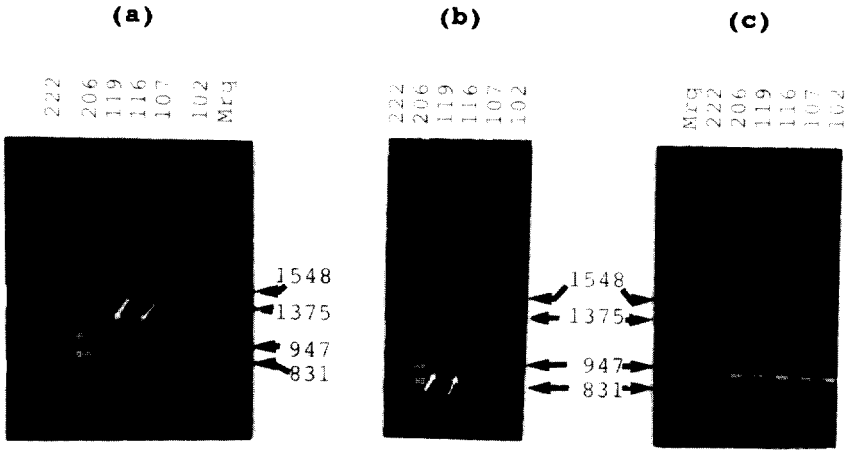



Fig. 9.17. PCR-amplification of genomic DNA of six durum genotypes with primers of (a) LMW-glutenin (b) gliadin and (c) HMW-glutenin. From right to left: Mr = marker III, Omrabi 5 (102), Haurani (107), Waha (116), Chahba 88/Mrb11 (119), Mrb 9/Haucan (206) and Bicre/Cham1/Gta/Stk (222).

### 9.6.2. Gamma Gliadin Amplification

With the gamma gliadin primers five major bands could be amplified ranging between 750 and 1000 bp (Fig.9.17b). No variation between all analysed genotypes was found for two smaller bands (830 and 800 bp) and one band of bigger size (970 bp). The two bands with medium size (950 and 900 bp) showed polymorphism between durum wheat genotypes. Cultivars showing the band at about 900 bp correspond to genotypes possesing γ-gliadin 42, whereas those with the band at about 950 bp belong to genotypes possesing γ-gliadin 45.

amplification correspond exactly with the electrophoretic pattern of the gamma gliadin protein fraction in SDS-page analysis. Waha and Chahba 88/ Mrb 11 belong to the group of genotype γ-42 lines, whereas Omrabi 5, Haurani, Mrb 9/Haucan and Bicre 3/Cham 1/Gta/Stk belong to the group of genotype γ-45.

### 9.6.3. HMW-glutenin Amplification

The primers used for amplification of HMW-glutenins (Fig.9.17c), revealed only one band at about 900 bp which was monomorphic for all analysed genotypes. Different primers for amplification of HMW-glutenin sequences have to be tried to reveal polymorphic patterns.

### 9.6.4. Comparison between Quality Parameters and Screening with PCR Primers

The durum wheat breeding program at ICARDA routinely analyses quality parameters such as NSDS, SDSI, SDSN, PROT %, TKW (g) and VIT % for the selection of parental lines for the following year. These analyses are complemented by SDS-page protein and farinogram analyses. A total of 456 genotypes of the advanced durum yield trials (1994) had been analysed. The best lines for each of the parameters tested were compared with the result of the PCR amplification of LMW-glutenins and/or γ-gliadins (Table 9.10.). No correlation exists between presence of LMW2 and TKW, SDSN, and protein content, a possible correlation exists between presence of LMW-2 and SDSI. These parameters alone cannot predict the presence of LMW-2 glutenin subunits. About 10% of the advanced durum yield lines posseses the LMW-1 glutenin subunits. If those lines can be identified extensive testing for these lines could be ommitted.

The farinogram of five genotypes (Table 9.11.) were analysed. The genotype with LMW-1 subunit glutenin had a weak quality and genotypes with LMW-2 subunit glutenin had weak or medium quality. The quality of durum wheat flour dough depends on environmental conditions and genotype. The genotypes used in this experiment were affected by bad weather conditions. The results obtained in this experiment

show that it is difficult to differentiate between good and weak quality genotypes based only on farinogram analyses. Depending on environmental conditions it would be difficult to detect genetic polymorphism. The use of PCR amplification for the identification of LMW-1, LMW-2 glutenin and γ-gliadins permits to select the lines with the potential for good technological quality even for genotypes grown under bad environmental conditions.

**Table.9.10. Quality parameters of the advanced durum yield trials (1994)**

| Sample | SDS | SDSM | Prot | %TKW | LMW glutenin/ γ-gliadin (950-900) |
|---|---|---|---|---|---|
| Best of SDS (ml): | | | | | |
| 822 | 38 | 4.7 | 12.3 | 37.2 | 2 |
| 1012 | 36 | 5.3 | 15.9 | 44.8 | 1 |
| 1313 | 37 | 5.9 | 15.9 | 37.7 | 950 |
| Best of SDSM:(index) | | | | | |
| 202 | 36 | 5.7 | 16.0 | 38.3 | 2 |
| 220 | 36 | 5.7 | 16.2 | 39.9 | 2 |
| 1313 | 37 | 5.9 | 15.9 | 37.7 | 950 |
| Best of protein: | | | | | |
| 204 | 35 | 5.7 | 16.2 | 39.9 | 2 |
| 1316 | 33 | 5.5 | 16.5 | 32.9 | 1 |
| 201 | 36 | 5.7 | 16.0 | 38.3 | 2 |

**Table 9.11. Farinogram of five genotypes, Omrabi 5 (102), Haurani (107), Waha (116), Mrb 9/Haucan(206) and Bicre/Cham1/Gta/Stk (222). Parameters were: absorbance (Abs), development time (DV.T, min), stability (St.T, min) and resistance rapport at 15 minutes and the 500 unit line (VR)**

| Sample | Abs | DV.T | St.T | VR | LMW glutenin type | Quality |
|---|---|---|---|---|---|---|
| 102 | 77 | 2.0 | 1.9 | 130 | 2 | Weak |
| 107 | 77 | 4.0 | 3.0 | 110 | 2 | Medium |
| 116 | 75 | 2.5 | 1.7 | 155 | 1 | Weak |
| 206 | 75.5 | 1.8 | 1.4 | 160 | 2 | Weak |
| 222 | 78 | 2.3 | 1.5 | 140 | 2 | Weak |

**- M. Labhilili, M. Nachit, M. Nachit, R. D'Ovidio, E. Porceddu, and M. Baum**

# 10. NORTH AFRICA REGIONAL PROGRAM

## 10.1. Introduction

Throughout the year the germplasm program support to the Maghreb NARS aimed at responding to the specific needS of each country and at pooling the region's resources for cooperative research activities. The available technical manpower in Morocco and Tunisia was encouraged to service the region as a whole and efforts were made to strengthen inter-institutional ties there. Activities in Algeria and Libya involved the planning and implementation of the seasonal workplans, and on the job training of junior research workers.

The activities implemented during the 1993/94 season were the following:

1. Technical support to cooperative regional improvement research within barley and wheat breeding and related diseases networks.
2. Support to on-farm research and technology transfer activities within the regional projects.
3. Building the cereal research capacity through on the job training and thesis work guidance.
4. Arranging the exchange of regional and international nurseries.
5. Development of workplans for the new regional projects.
6. Arranging regional coordination meetings and travelling workshops.
7. Expanding inter-regional variety trials and supporting NARS in taking lead in regional networks.

## 10.2. Seasonal Conditions and Production of Cereals

The 1993/94 season was generally favorable to field crop

production in Morocco, even though the rains stopped early affecting adversely the grain filling of late cultivars. In Algeria, Libya and Tunisia the season was very dry. Maghreb countries grow cereals on around ten million hectares every year. The cereal area in Morocco in 1993/94 increased from the long-term average of 4.8 million hectares to 5.6 million hectares, while the cereal area decreased in Algeria and Tunisia due to drought, late season frost and severe Hessian fly, sawfly, BYDV and Russian Wheat Aphid damage caused further reduction in the production of cereal in these two countries. Tunisia's total small grains production for example, was around 3 million quintals, compared to 18 million quintals as a long term average production. Production reached an all-time record high in Morocco (92.4 million quintals), which is 49% above the 1988/92 five year production average (61.9 million quintals). Total output in Tunisia, Algeria and Libya reflected the widespread crop failure across these countries, where only irrigated areas gave combine harvestable crops.

## 10.3. Salient Country Research Highlights

### 10.3.1. Algeria

Drought affected the whole country this season. Severe spring frost damage was relayed by damage from hot winds May and June. Consequently, a large number of nurseries and trials failed at several research sites. Yields were low even in the favorable coastal areas (Table 10.1).

**Table 10.1. Average yields ((q/ha) of wheat and barley over locations and trials in Algeria, 1993/94.**

| Crop | Number of trials | Yield range in Dry areas | Yield range in Favorable areas |
|---|---|---|---|
| Durum wheat | 3 | 2.28-6.57 | 14.29-23.89 |
| Bread wheat | 3 | 5.58-7.40 | 20.71- 1.38 |
| Barley | 6 | 3.23-8.76 | 26.70-46.88 |

The main highlight of the season is that many cultivars, earlier selected and released, continued to perform well even under the condition of extreme moisture and temperature stresses experienced this season:

Durum: Cando/Ru/3Rabi, Chen"S"/Poc, and Waha
Bread Wheat: HD 1220, As 81189/AA, and TRT"S"/Jun"S"
Barley: Rihane, Motan, and ACSAD 176

Although the number of lines selected from various nurseries was small, several screening nurseries provided valuable germplasm (Table 10.2).

The Special Barley Maghreb Nursery, developed to serve North Africa NARS, gave 112 promising lines, representing 30% of the total selected barley germplasm.

**Table 10.2. Number of lines selected in different cereal nurseries grown in Algeria in 1993/94.**

| Nurseries | Selection | Nurseries | Selection |
|---|---|---|---|
| POL.D | 10 | POL-BT | 12 |
| DON.MRA | 31 | WON.MRA/FAWW ON | 44 |
| MAT for Alg | 11 | POM | 30 |
| Pep. Magh | 15 | MATDEDZA | 35 |
| DON.HAA | 22 | POL-O | 6 |
| DCTON | 10 | Nacked Barley | 22 |
| DHTON | 20 | SMAG | 112 |
| AYTRL | 17 | All CIMMYT nurs. | 109 |

Characterization of durum parental material was carried out. Phenological and morphophysiological data showed that the available durum germplasm could be grouped in the following three classes:

Group 1: Land races with low yield (Oued Zenati types)
Group 2: Widely adapted cultivars such as Waha and Karim
Group 3: High yielders such as Chen"S"/Altar 84; Zb/Fg.

Results of Maghreb cooperative yield trials showed that in the dry environments, Om Rabi durum, Arz breadwheat and Aglou (Er/Apam) barley, were the highest yielders while under favorable conditions, Chen"S"/Altar and Sarif durum, Jouda and Saiss bread wheat and INRA 1759 barley were the best performers.

Although the climatic conditions did not favor disease development, a disease survey carried out in the eastern region showed that leaf rust and septoria were prevalent on durum, while net blotch and barley leaf stripe diseases were widespread on barley.

Agronomic studies conducted included response to supplemental irrigation, date of seeding and seeding rate. Supplemental irrigation studies on durum wheat showed that application of 45 mm of water at stem elongation stage resulted in 126% yield increase in Mohamed Ben Bachir, 44% in Waha and 47.5% in Zidane. Optimum date of sowing differed from location to location. The optimum seeding rate was 200 seeds/$m^2$ for barley and 400 seeds/$m^2$ for durum.

### 10.3.2. Morocco

The weather conditions were very favorable to plant growth until mid-March. Starting April, hot winds impaired grain filling, and also stopped diseases and pest development. Nevertheless, average yields of cereals exceeded 1.6 t/ha.

Some 21 national sceintists participated in collaborative research on cereals with ICARDA. The major achievements are summarized below:

Evaluation of North African and World Collection of durum germplasm resulted in identifying useful germplasm for crossing, carrying genes for tallness, stem solidness, awn colour, improved grain quality, resistance/tolerance to Hessian fly, and tolerance to root-rot complex.

Good sources of resistance for Russian Wheat Aphid were identified in barley and bread wheat. New sources of resistance to Hessian fly in bread wheat (H26 and ADC14) were identified. All genes effective against Hessian fly in North Africa have now

been incorporated in good agronomic type bread wheats. Durum lines carrying H5 gene have been developed.

The superiority of germplasm developed through collaborative projects with ICARDA has proven the effectiveness of decentralized breeding strategy. Three varieties of breadwheat (INRA 1755, 1756 and 1757) and three of durum wheat: (INRA 1749, 1750 and 1751) have been registered. The royalties to INRA have reached 6% of sale price of seed. Three varieties of durum wheat, three of bread wheat and two of barley will be presented to the catalog this season.

Use of anther culture and crosses with maize were used to improve haploid production in durum wheats; N6 medium appeared better than MS and R9 media for embryorescue in case of inter-specific crosses. The genes inhibiting regeneration from anthers in durum wheat are located on the chromosomes 1B and 5B.

In the studies on characterization of salt tolerance of cereal released varieties, local types proved superior to introduced material, although there were some noticeable exceptions. Studies on characterization of heat tolerance showed that durum lines selected from DHTON indeed possessed good tolerance to heat stress.

### 10.3.3. Libya

Currently cereals are grown on nearly 500,000 hectares annually. Barley represents over 80% of this area. Although mostly grown under rainfed conditions in the eastern Jabal Akhdar region, cereals are also grown under pivot irrigation in strategic production projects. The seasonal precipitation in 1993/94, although poorly distributed, was above long-term average. Cereals research in Libya during 1993/94 was strongly supported by scientists from other North African countries in collaboration with ICARDA.

#### 10.3.3.1. Barley

Best yielding lines during the season were Aglou (Er/Apam), ACSAD 176, Annaceur (Rihane), El Gattara, and Arig 8 under rainfed conditions (Table 10.3). They were also planted in large fields in the southern region under pivot irrigation. The performance of some selected barley lines in Special Trial for North Africa is shown in Table 10.4.

**Table 10.3. Average yield (t/ha) of the best varieties in the Barley Maghreb Cooperative Yield Trial, over two seasons (1992/93, and 1993/94), at Khoms Station.**

| Variety | Yield (T/ha) |
|---|---|
| Aglou | 4.1 |
| Annaceur | 3.7 |
| El Gattara | 3.6 |
| Arig 8 | 3.6 |

**Table 10.4. The performance of best barley lines in the special trial for North Africa, conducted at Musrata and Douma Stations, 1993/94.**

| Entry | % Check |
|---|---|
| Musrata Station | |
| Badia/5/Cr.115/Pro//BC | 187 |
| As 46/Aths*2//Saras | 143 |
| Api/CM67//Ager/3/Kantara | 143 |
| As 46/Rihane 05, Sel 1 | 139 |
| As 46/Rihane 05, Sel 2 | 124 |
| Derna Station | |
| As 46/Rihane 05, Sel 1 | 110 |

### 10.3.3.2. Wheat

Although wheat acreage is decreasing, research work aiming at identifying good lines for all regions continued. The highest yielders were:

Bread wheat: Bohouth 204 and Bohouth 206
Durum wheat: Cham 3, Omrabi 5, Bohouth 103, Zahra 5, Vitron, Sahl and Waha.

All above mentioned cereal varieties are under large multiplication and/or commercial production.

### 10.3.4. Tunisia

Drought was widespread in the country. It was coupled with high temperatures at critical grain filling stage. No major diseases developed this season.

#### 10.3.4.1. Durum wheat

Grain shrivelling was commonly noticed. The yields rarely exceeded 1.0 t/ha. Razzak and Khiar 92 gave good performance. They were, respectively, 20 and 30% superior to the most widely grown variety in North Africa Karim. This year's drought allowed the program to advance its genetic gains for drought and heat tolerance. Lines that show most promise are: LIKAN/INIA, CHEN/ALTAR, ALTAR/AOS, CORM"S"/RUFO"S", LAGOST-2, and DWL-5023.

The highest yielder in the dry areas was Omrabi 3 (18.8 q/ha) which even outyielded the most popular new varieties Razzak (16.9 q/ha) and Khiar 92 (15.4 q/ha). Due to its tallness and high biomass yield, Omrabi 3 is likely to become the most popular variety throughout the semi-arid areas of Tunisia. In addition to Omrabi 3, several ICARDA derived crosses are showing good adaptation to drought and other associated stresses common in Central and South Tunisia. These are: Mrb/Chen; Lahn/Mrb Sh; Lahn/GP/Stk and Chen/Altar, confirming the superiority of Mrb and Lahn as parents for getting drought tolerance.

**10.3.2.4. Barley**

INRAT is pursuing a barley improvement program to cater to the needs of both moderate-rainfall and dry areas. Research for the development of high yielding cultivars suffered from the drought but the following lines were higher yielding than Rihane, the present best cultivar: Manel 92; Arizona 5908/Aths//Lign e 640; Arizona 5908/Aths//Asse/3/F20S-74; and Roho/UC566.

For very dry areas, the following breeding lines were very promising:

Gloria"S"/ Copal"S"..., Gloria"S"/Come"S", and Rihane/Lignee 527.

**10.3.4.3. Bread Wheat**

The widely grown variety and standard check Salambo was the best in the large production plots in farmers' fields. In research plots several lines outyielded the check cultivar Tanit 80 but only one line (BT2731) confirmed last year's promise and occasionally outyielded Salambo as well. BT2731 has large and more attractive seed than Salambo.

**10.4. Regional Collaborative Activities:**

**10.4.1. Cereal Travelling Workshop:**

Two barley scientists, two durum scientists and two bread wheat scientists each from Morocco, Tunisia, Algeria, Libya and Egypt as well as one scientist from Sudan and four ICARDA researchers, participated in the Cereal Travelling Workshop in Morocco early May, 1994.

Researchers carried out selection at Jemaa-Shaim, Sidi Laydi, Merchouch, Douyet and Annaceur stations on jointly developed germplasm, Maghreb trials and nurseries as well as on the Morocco national program nurseries. Discussions were held during the last day to look at ways of accelerating: research advances against drought, progress in barley shuttle breeding between Aleppo and all Maghreb programs, and support to Libyan colleagues in their selection work under extreme heat and drought stresses.

### 10.4.2. Barley Development for North Africa

#### 10.4.2.1. Decentralized Breeding

This collaborative activity has been described in detail in Section 2.1. This fourth year of testing special barley nurseries for North Africa has been most profitable as extremes of drought and typical barley growing conditions prevailed in different areas of North Africa. The scheme developed is well understood by NARS collaborators and implemented in all the Maghreb countries. The regional approach is well incorporated in the overall scheme since there is a sharing of the locally selected germplasm through the regional nursery system. The results are reflected in the positive shift in the genetic material developed through this collaborative effort. Areas of consolidation needed for this activity include the following:

a) Extra nursery sets for south eastern Libya
b) Early return of data is necessary to design crossing block and nurseries of the following season.
c) Necessity to layout the trials as Lattices
d) Allow the possibility to include desired checks (flexibility of scheme).
e) Need for a special nursery to be screened by Dr. Lhaloui in Morocco for barley gall midge resistance.
f) ICARDA scientist should analyze the data and

provide collaborators with the summary of results as early as possible.

#### 10.4.2.2. Development of Barley for High Elevation Areas

This region requires tolerance to cold and terminal drought and heat stress. Crosses were made using Annaceur, Atlas 68, Lignee 527, and local lines Arig 8, Rabat 8, Rabat 101 and Rabat 077 and segregating populations evalutated at Annaceur Research Station in the Atlas Mountain region of Morocco. Several populations have shown good performance, but Annaceur "Rehane" continues to be the most promising line there.

#### 10.4.2.3. Salt-tolerance Studies in Barley

Comparison of slat tolerance of local and introduced cultivars of barley was done in Morocco. The local genotypes-Merzaga, Aglou, Annaceur and Tiddas outyielded European varieties and tolerated higher level of salinity. Among European introductions Albacete (a Spanish cultivar) was most tolerant. The tolerance to salt was associated with proline accumulation.

### 10.4.3. Entomology Research in Wheat and Barley

The entomology research collaboration within the Maghreb was reviewed, and the following recommendations were made in the light of staff reductions at ICARDA:

a) Morocco will take the lead on Hessian fly research with Dr. M. El Bouhssini as the principal scientist.
b) Entomology work should be extended to cover other insect pests (i.e. barley: barley gall midge and RWA; and for bread and durum wheat: Hessian fly, cereal leaf beatle and RWA).

c) Sources of resistance should be made available to all cereal breeders in the region.

### 10.4.4. Characterization of Durum Collection

The 1993/94 season was the second year of ICARDA/Maghreb NARS cooperation targeted at identification of sources of resistance to prevalent pathogens in durum wheat. Another 1000 accessions from the world collection were screened for Tan spot in Morocco and sources of resistance were identified. Another 3000 North African durum accessions and over 1000 accessions from world collection were evaluated for resistance to Hessian fly and root rots. Several accessions were tolerant to root rots, and only one accession was found resistant to Hessian fly. This is the first time such a resistance is found in durum.

### 10.4.5. ICARDA/MAGHREB/IFAD Project on Technology Transfer

This project involves the semi-arid regions of Sidi Bel Abbes in Algeria; Kef in Tunisia; Settat in Morocco; and Derna in libya. The project aimed at verifying in farmers field technologies produced at experimental stations but which have not reached the farmers. The project which is in its fourth year has produced important results. It has allowed production of profitable and ecologically safe recommendations for crop production in the Maghreb; ensured involvement of research, teaching and extension institutions; has strengthened the capacities of national programs in the on-farm problem solving research; and has allowed each national program to develop an approach for technology transfer and evaluate its effectiveness. Detailed results are published in biannual progress reports while highlights are available in the proceedings of the Annual Regional Coordination Meetings. Some of the important results with respect to the cereals are reported here.

Production demonstrations were undertaken using most widely grown cultivars as well as the newly developed cultivars.

Some of these production plots were used to test the desirability of supplemental irrigation which proved economically justifiable. A supplementary irrigation at tillering was more beneficial than one at heading on grain filling. The following agronomic practices proved superior to the practices traditionally adopted by farmers:

a) Earlier maturing, newer genotypes were superior to older ones in both high-and low-fertility environments as demonstrated for the second year, in large on-farm verification trials in Morocco.

b) Weed control and fertilizer application allowed small farmers to get a harvestable crop in this dry season in Tunisia.

## 11. TRAINING AND VISITS

In 1994, GP in collaboration with NARS in WANA conducted group courses at headquarters and in the region and provided training and consultancy to individual trainees and students from various countries.

### 11.1. Long-term Course in Cereal Improvement

Due to the continued requests from NARS, the long-term course on cereal improvement was again conducted from 1 March through 30 June 1994 for the benefit of 12 participants from 10 countries (Algeria, Egypt, Ethiopia, Iraq, Libya, Oman, Pakistan, Sudan, Syria and Yemen). Participants generally were young researchers working on wheat and barley in their respective national programs. The course covered breeding and breeding-related disciplines (pathology, entomology, grain quality, physiology, biotechnology and statistics). Focus was on practical training where each trainee was given a specific assignment throughout the season. Training was therefore individualized and based on the principle of learning by practicing. Participants presented final reports on their work and comments on the usefulness of the course and ways for further improvement. The trainees rated the course highly beneficial.

### 11.2. Insect Control in Legumes and Cereal Crops

This course was held at Tel Hadya during 18-28 April 1994. The topics included: description and diagnosis of major insect pests of legumes (*Helicoverpa* spp., leafminer and aphids in chickpea and *Sitona* in lentil) and cereal crops (wheat stem sawfly, sunibug, Hessian fly, aphids and *Zabrus* spp.). Classroom and practical sessions were given on insect biology, insect collection and preservation, crop damage and control measures.

Participants were researchers (mostly at the BS level) from 9 countries (Algeria, Egypt, Eritria, Ethiopia, Iran, Jordan, Libya, Syria and Tunisia). The course was judged as successful by the participants and the instructors. Although the course has been conducted five times in the past (1989, 1990, 1991, 1992, 1994) NARS's demands have not decreased. It may be offered in alternate years in the future.

### 11.3. Diagnosis of Plant Viruses

This course, jointly organized by FAO, GTZ and ICARDA was held at Tel Hadya, ICARDA during 28 August - 8 September 1994. Thirteen participants 5 females and 8 males from 10 countries (Egypt, Iraq, Jordan, Lebanon, Libya, Oman, Sudan, Syria, Tunisia and Yemen) attended. Instructors were from ICARDA, Germany and ICRISAT. The course covered the description, classification and transmission of plant viruses and focused on practical techniques for diagnosis and detection of viruses including the methods of ELISA, dot-blot ELISA, and TBIA (tissue-blot immunoassay) with a special emphasis on variants requiring no expensive facilities. All participants rated highly the course and expressed a keen interest in taking part in national surveys on viral diseases in their respective countries with backup from ICARDA and other agencies.

### 11.4. DNA Molecular Marker Techniques

Nine participants (including 2 females) from 8 countries (Table 11.1) participated in this course that was held at Tel Hadya during 18-29 September 1994. Instructors were two from Germany and four from ICARDA. The course covered DNA markers and their use in genetic studies (in legumes and cereal crops, and pathogens). Theory, scope and limitations of the techniques were presented and discussed and special emphasis was put on practical laboratory applications including DNA extraction and purification, gel electrophoresis, RFLP and PCR. Because the

scientific level of participants was relatively high, the course was an opportunity for fruitful discussions and exchange of ideas and opinions on the various techniques. This course continues to attract attention of NARS's scientists.

**Table 11.1. Participants of the ICARDA course on DNA molecular marker techniques for germplasm evaluation and crop improvement, 18-29 September 1994.**

| Name | Degree | Institution/country |
|---|---|---|
| Khaldoun Abdel Hamid | PhD | ITGC, Algeria |
| Adnan Yassin | MS | NCARTT, Jordan |
| Jamal El-Haddoury | MS | INRA, Morocco |
| Tereza Doroszewska | PhD | ISSPC, Poland |
| El-Gailani Adam Abdallah | MS | ARC, Sudan |
| Amira Zein | MS | Aleppo Univ., Syria |
| Abdel Baset Al-Mouslem | PhD | Aleppo Univ., Syria |
| Afif Ghneim | PhD | DASR, Syria |
| Hakan Ulukan | MS | Ankara Univ., Turkey |

## 11.5. Cereal Breeding and Disease Methodology

An in-country course on "Cereal Breeding and Disease Methodology" was conducted during 7-17 May 1994, at Karmanshah, Iran, in collaboration with the Agricultural Research, Education and Extension Organization of the Iranian Ministry of Agriculture. The topics covered breeding methods for wheat and barley with emphasis on stress-prone environments of Iran, special breeding techniques (tissue culture, interspecific hybridization, use of DNA markers), disease diagnosis and plant evaluation for disease response, and breeding for disease resistance. The topics were presented and discussed in the classroom, and field visits were arranged on two separate days to Sararood and Islamabad stations where participants had the opportunity to observe evaluation of germplasm of wheat and barley for their response to diseases, insects and abiotic stresses.

Several of the 28 participants were able to communicate

in the English language but translation was generally necessary for others. The evaluation of the course showed a positive impact on most participants who made suggestions for inclusion in the future courses of such topics as experimental design and data analysis.

### 11.7. IAEA-AEC Course

The Program hosted for 2 days (23-24 November 1994) the participants of a regional training course on "Mutation Techniques for Improvement of Stress Tolerance in Basic Food Crops" organized by the International Atomic Energy Agency (IAEA) and the Syrian Atomic Energy Commission (AEC). There were 15 participants from 9 countries (Bulgaria, Hungary, Jordan, Lithuania, Poland, Romania, Syria, Turkey and UAE). Presentations were made by ICARDA scientists on breeding wheat, barley, chickpea, and lentil for stress environments, and on the use of tissue culture and wide hybridization for cereal improvement. The participants visited the biotechnology lab facilities and observed demonstrations of some aspects of anther culture and the use of DNA-marker techniques.

### 11.7. Individual Training

Requests for individual non-degree training in various research areas continued to be high, particularly from Syria (Table 11.2). The duration of training varied between 2 weeks and 7 months. Those trainees who spent longer periods had the opportunity to conduct a piece of research with ICARDA scientists. Trainees from Lebanon conducted research as part of their requirements for a university degree. Also, three students from Aleppo University worked on their BS graduation projects in diseases and grain quality.

Graduate-degree training is being strengthened with 12 students (6 MS and 6 PhD candidates) from five countries supported by GP in 1994 (Table 11.3). Graduate degree-training

is valued by NARS and ICARDA scientists and is expected to get an even higher priority in the future.

**Table 11.2. Individual non-degree training* in cereal crops at Germplasm Program, ICARDA, 1994.**

| Country | No. of trainees | Total duration (person-month) | Topic |
|---|---|---|---|
| Syria | 13 | 22 | Durum breeding, wheat breeding, barley breeding, cereal diseases, cereal insects, grain quality, data analysis |
| Lebanon | 3 | 6.5 | Grain quality, cereal diseases |
| Sudan | 2 | 3 | Cereal breeding |
| Egypt | 1 | 1 | Barley breeding |
| Iran | 1 | 4 | Cereal diseases |
| Jordan | 1 | 1 | Biotechnology |
| Morocco | 1 | 1 | Biotechnology |
| Total | 19 | 37.5 | |

* Includes training of undergraduate students from Lebanon (three trainees) and Syria (2 trainees: 1 person-month).

## 11.8. Visits

Scientists from Ethiopia, Iran, Japan, Morocco and Syria visited GP for short periods (1-2 weeks) for consultancy or technical assistance in specific research areas. Others from Germany, Italy and USA also visited for short periods to discuss on-going joint projects. Visiting scientists from Egypt, Sudan and Syria spent longer periods (2-3 months) to conduct research at ICARDA in breeding , physiology or pathology.

Groups of students and teachers from Aleppo, Damascus and Tishreen Universities of Syria visited the Program to learn about ICARDA's work in cereal improvement.

GP scientists in return visited NARS in WANA and other countries to discuss collaborative work and evaluate cereal germplasm grown in these countries. - **H. Ketata and GP staff**

**Table 11.3. Graduate students working on cereal crops at GP, ICARDA, 1994.**

| Name | Degree | University | Topic | Date of completion |
|---|---|---|---|---|
| Mr. Ahmed Shawki El-Sebaee | MSc. | Suez Canal | Wheat breeding | 1995 |
| Mr. Mohsen Shehata | PhD. | Ain Shams | Bread Wheat breeding | 1995 |
| Mr. Claus Einfeldt | PhD. | Hohenheim | Barley breeding | 1995 |
| Mr. Uwe Scholz | MSc. | Bonn | Cereal cyst nematode | 1995 |
| Mr. Alfredo Impiglia | PhD. | Cordoba | Durum wheat breeding | 1995 |
| Mr. Taher Ahmed A. Aleem | MSc. | Jordan | Wheat physiology | 1996** |
| Mr. M. Ibrahim Ismail | MSc. | Jordann | Wheat physiology | 1996** |
| Mr. Amir M.H. Ibrahim | MSc. | AUB | Bread wheat breeding | 1994* |
| Mr. Suleiman Raad | PhD. | Damascus | Durum wheat quality | 1995 |
| Mr. Ramez Mahmoud | MSc. | Aleppo | Durum wheat quality | 1995 |
| Mr. Farid makdees | MSc. | Aleppo | Wheat physiology/breeding | 1995 |
| Mr. Ghassan Naassa | PhD. | Aleppo | Barley breeding | 1995 |

* Graduated. ** Started in 1994

# 12. PUBLICATIONS

## 12.1. Journal Articles

Ali, Z.I., Mahalakshmi, V., Singh, M., Ortiz-Ferrara, G., and Peacock, J.M. 1994. Variation in cardinal temperatures for germination among wheat (Triticum aestivum) genotypes. Ann. appl. Biol. 125: 367-375.

Ceccarelli, S. 1994. Specific adaptation and breeding for marginal conditions. Euphytica 77: 205-219.

Ceccarelli, S. and Grando, S., 1993. From conventional plant breeding to molecular biology. In D.R. Buxton *et al.*, (ed.) International crop science I. Crop Science Society of America, Madison, WI. pp 533-537.

Ceccarelli,, S., Erskine, W., Hamblin, J., and Grando, S. 1994. Genotypes by environmental interaction and international breeding programmes. Expl. Agric. 30: 177-187.

Chen, F.Q., Prehn, D., Hayes, P.M., Milrooney, D., Corey. A. and Vivar, H.E. 1994. Mapping genes for resistance to barley stripe rust Puccinia striiformis f. sp. hordie Theor. Appl. Genet. 88. 215-219.

Comeau, A., Makkouk, K.M., Ahmad, F., and St-Pierre, C.A. 1994. Bread wheat X Agrotricum crosses as a source of immunity and resistance to the PAV strain of barely yellow dwarf luteovirus. Agronomie 2:153-160.

Dakheel, A.J., Peacock, J.M., Naji, I., and Acevedo, E. (1994). Carbon isotope discrimination and water use efficiency in barley under field conditions. Aspects of Applied Biology 38: 173-184.

Dakheel, A.J., Makdis, F., Safi, S., Naji, I., and Peacock, J.M. 1994. Effects of glaucousness and awns on

transpiration efficiency in durum wheat isolines. Aspects of Applied Biology 38: 121-130.

Dakheel, A.J., Radosevich, S.R., and Barbour, M.G. 1994. Effects of temperature and moisture on growth, interference and photosynthesis of Bromus tectorum and Taeniatherum asperum. Weed Research 34: 11-22.

Jaby El-Haramein, F. and Adleh, B. 1994. Bread in Syria. Food Reviews International 10 (4): 419-436.

Lashermers, P., Blake, T. and Ceccarelli, S. 1994. Identification of polymorphism in reference barely genotypes based on the polymerase chain reaction. J. Gent. and Breed. 48: 207-210.

Lister, R.M., Aboul-Ata, A.E., El-Daoudi Y.H., Marshal, D., Makkouk, K., Satour, M.M., Ghanem E., and Burnett, P.A. 1994. Serotyping of barley yellow dwarf virus isolates from Egypt. Phytopathologia Mediterranea 33: 152-157.

Mahalakshmi, V., Grando, S., Naji, I., Ceccarelli, S., and Peacock, J.M. 1994. Improving water use efficiency of cultivated barley by introgression with *Hordeum vulgare* spp. *spontaneum*. What promise does it hold? Efficiency of Water Use in Crop Systems. Aspects of Applied Biology 38: 145-151.

Makkouk, K.M., Comeau, A. and Ghulam W. 1994. Resistance to barley yellow dwarf luteovirus in *Aegilops* species. Canadian Journal of Plant Science 74(3):631-634.

Makkouk, K.M. and Comeau, A. 1994. Evaluation of various methods for the detection of barley yellow dwarf luteovirus by the tissue-blot immunoassay and its use for BYDV detection in cereals inoculated at different growth stages. European Journal of Plant Pathology 100:71-80.

Makkouk, K.M., Comeau, A. and St-Pierre, C.A. 1994. Screening for barley yellow dwarf luteovirus resistance in barley on the basis of virus movement. Journal of

Phytopathology 141:165-172.

Mamluk, O.F. and Nachit, M.M. 1994. Sources of resistance to common bunt (Tilletia foetida and T. caries) in durum wheat. J. Phytopathology 142:122-130.

Mosaad, M.G., Ortiz-Ferrara, G., Mahalakshmi, V., and Hamblin, J. 1994. Leaf development and phenology of *Triticum aestivum* and *T. durum* under different moisture regimes. Plant and Soil 4180:1-5.

Mosaad, M.G., Ortiz-Ferrara, G., Mahalakshmi, V., and Fischer, R.A. 1995. Photoperiod and vernalization response in spring wheat. Crop Science 35 (1): 168-171.

Ortiz-Ferrara, G. 1994. Experiences, difficulties and prospects for stress resistance breeding of wheat in WANA. Melhoramento 33 (1): 105-118.

Reynnolds, M.P., Sayre, K.D., and Vivar, H.E. 1994. Intrcropping of wheat and barley with N-fixing legume species: A method for improving ground cover and productivity in low inputs systems. Journal of Agricultural Science 123: 175-183.

Simane, B., van Keulen, H., and Stol, W., and Struik, P.C. 1994. Application of crop growth model (SUCROS-87) to assess the effect of moisture stress on yield potential of durum wheat in Ethiopia. Agricultural Systems 44: 337-353.

Tahir, M. and Singh, M. 1994. Assessment of screening technique for heat tolerance in wheat. Crop Science 33: 740-744.

van Oosterom, E.J. and Ceccarelli, S. 1993. Indirect-selection for grain yield of barely in harsh Mediterranean environments. Crop Science 33: 1127-1131.

van Oosterom, E.J, Kleijn, D., Ceccarelli, S. and Nachit,

M.M. 1993. Genotype-environment interactions of barley in the Mediterranean region. Crop Science 33:669-674.

Veneklaas, E.J. & Peacock, J.M. 1994. Growth, biomass allocation and water use efficiency of two wheat cultivars in a Mediterranean environment; a pot experiment under fields conditions. Plant and Soil 162: 241-247.

Veneklaas E.J. and van Den Boogard, R. 1994. Leaf age-structure effects on plant water use and photosynthesis of two wheat cultivars. New Phytol. 128: 331-337.

Yau, S.K. 1994. Regression and AMMI analyses on genotype by environment interactions - an empirical comparison. Agron. J. 87:121-126.

Yau, S.K. and Hamblin, J. 1994. Relative yield as a measure of entry performance in variable environments. Crop Sci. 34(3): 813-817.

Yau, S.K. and Ortiz-Ferrara, G. 1994. Regression and cluster analyses of elite wheat lines grown in diverse rainfed environments. J. Genet. & Breed. 48: 183-190.

## 12.2. Conference Papers

Benlhabib, O., R. Hmoud, O. El Khlifi, Nachit, M.M., Baum, M. Sharma, H. 1994. Croisements intergénériques concernant le blé et analyse chromosomique des descendants de retrocroisements. In: Ressources Phytogénétiques et Développement Durable. IAVH2, 24-26 October, 1994, Rabat, Morocco.

El Bouhssini, S. Lhaloui, Hatchett, J., Amri, A., Jlibene, M., Nsarellah N., and Nachit, M.M., Mergoum, M., Benlhabib, O. 1994. Genetic control of cereal insects in the semi-arid and arid regions of Morocco. In: Acquis et perspectives de la recherche agronomique dans les zone arides et semi-arides du Maroc. May 24-27, 1994, Rabat, Morocco.

El-Daoudi, Y.H., Mamluk, O.F., Sherif, S.O., Mengistu Huluka and Ahmed M.S. 1994. Race dynamics and gene expression of wheat leaf and stem rust in the Nile Valley countries. A45/48 in: Abstracts, 5th Arab Congress of Plant Protection (B. Ezzahiri and M. Bouhache eds.). November 27-December 21994. Fez, Morocco.

El-Daoudi, Y.H., Mamluk, O.F., Eshetu Bekela, Ghanem H., Solh, M.B. and Shafik, I. 1994. Prevalence and sources of resistance to leaf and stem rusts of wheat in the Nile Valley countries and Yemen. A11/33 in: Abstracts, 5th Arab Congress of Plant Protection (B. Ezzahiri and M. Bouhache eds.). November 27-December 21994. Fez, Morocco.

El-Naimi, M. and Mamluk, O.F. 1994. Occurrence and virulence of wheat rusts in Syria. A13/34 in: Abstracts, 5th Arab Congress of Plant Protection (B. Ezzahiri and M. Bouhache eds.). November 27-December 21994. Fez, Morocco.

Makkouk, K.M., Lesemann, D.E., Saari, E.E., Altay, F., Suzen, B., Bolat, N., Braun, H.J., Payne, T.S. and Beniwal, S.P.S. 1994. Identity of and screening for resistance to a new soil-borne virus affecting wheat in Turkiye. Proceedings of the 9th Congress of the Mediterranean Phytopathological Union (MPU), Kusadasi, Aydin, Turkey, September 18-24, 1994, p. 271.

Makkouk, K.M., Comeau, A. and Ghulam, W. 1994. Screening cereals for barley yellow dwarf virus resistance, using Tissue-blot immunoassay. Fifth Arab Congress of Plant Protection, November 27 - December 2, 1994, Fes, Morocco.

Mamluk, O.F. 1993. Seed-borne diseases of wheat and barley. Pages 40-47 in: FAO Plant Production and Protection Paper 119. Proceedings of the Workshop on Quarantine for Seed in the Near East, held at ICARDA, Aleppo, Syrian Arab Republic, 2-9 November 1991 (S.B. Mathur and H.K. Manandhar eds.).

Mamluk, O.F. and van Slageren, M.W. 1993. Diversity for important wheat diseases in the WANA region in an Aegilops collection. Page 173 in: Abstarcts, 6th International Congress of Plant Pathology. July 28 - August 6, 1993, Montreal (Quebec) Canada.

Mamluk, O.F. and van Slageren, M.W. 1994. Sources of resistance to wheat diseases in Aegilops and Amblyopyrum spp. Pages 269-270 in: Proceedings, 9th Congress of the Mediterranean Phytopathological Union. September 18-24, 1994, Kusadasi-Aydin, Turkey.

Mamluk, O.F. 1994. Remarks on the proposed concept of a "North-South Center for Development Research (ZEF)". Pages 98-104 in:Dokumentation des Symposiums Wissenschaft im interkulturellen Dialog. Rheinische-Friedrich-Wilhelms-Universität Bonn. December 13-14, 1993. Bonn, Germany

Mergoum M., Nsarellah, O., and Nachit, M.M. 1994. Screening durum wheats for root rot (*Fusarium Culmorum and Colchiobolus Sativus*) in Morocco. In: Acquis et perspectives de la recherche agronomique dans les zone arides et semi-arides du Maroc. May 24-27, 1994, Rabat, Morocco.

Mergoum, M., Nsarellah, N., El Bouhssini M., Nachit, M.M. 1994. Evaluation des collections de bl s pour la r sistance aux pourritures racinaires et a la c cidomyie au Maroc. In: Ressources Phytogenetiques et D veloppement Durable. IAVH2, 24-26 October, 1994, Rabat, Morocco.

Nachit, M.M. and Maali, S.H. 1994. Use of *T. dicoccoides* to improve grain quality in *T. turgidum* L. var Durum. Ressources Phytogenetiques et Developpement Durable. IAVH2, 24-26 October, 1994, Rabat, Morocco.

Nsarellah, N. and Nachit M.M. 1994. Breeding durum wheat for the semi-arid Areas of Morocco. Acquis et perspectives de la recherche agronomique dans les zone arides et semi-arides du Maroc. May 24-27, 1994, Rabat,

Morocco.

Nsarellah N., Nachit M.M., and Mergoum M. 1994. Factors affecting durum wheat performance under early and mid season drought stress. Acquis et perspectives de la recherche agronomique dans les zone arides et semi-arides du Maroc. May 24-27, 1994, Rabat, Morocco.

Ouassou, A., Nachit, M.M. 1994. Evaluation of durum wheat collections for powdery mildew, stem rust, and Hessian fly. Ressources Phytogenetiques et Developpement Durable. IAVH2, 24-26 October, Rabat, Morocco.

Reynnolds, M.P., Sayre, K.D., and Vivar, H.E.1994. Intercropping small grains with legume species under reduced N fertility to improve ground cover, nitrogen use effciency and productivity. In 15th World Congress of Soil Science. Acapulco, Mexico. July 10-16, 5a, 702-703.

Sayed, H. and Baum, M. 1994. RFLP-analysis in barley using a non-radioactive protocol. Presented in: Workshop on Biotech Applications. Safawi, November 11-15, 1994, Jordan.

Tawkaz, S., Comeau, A., Baum, M. 1994. Development of anther culture protocols for the production of double haploids in Hordeum vulgare adapted to the dry areas. Presented in: Workshop on Biotech Applications. Safawi, November 11-15, 1994, Jordan.

Vivar, H.E. 1994. Mejoramieto de cebada contra enfermedades. In Memorias sobre el taller sobre resistencia duradera en Cultivos Alto-An.

Vivar, H.E.1994. Investigation de cebada en America: Un panaorama. Reunion Internacional de Cebada Maltera. Cochabamba, Bolivia. Noviembre 18-Diciembre 1.

Vivar, H.E.1994. Uso de una pradera mixta de alfalfa silvestre en ascociacion con cebada bajo condiones de temporal. Aguals Calientes. Mexico. Septiembre 8.

Yau, S.K. and Nachit, M.M.1994. Performance of 'Drira Outcross 7' triticale in West Asia, North Africa and Mediterranean Europe. Third International Triticale Symposium, June 13-17, 1994, Lisbon.

**12.3 Miscellaneous Publications**

Jaby El-Haramein, F., Ortiz-Ferrara, G., and Williams, P. C. 1992. Influence of bread wheat kernel color on flour and Arabic two-layered flat bread. RACHIS 11 (1/2): 72-76.

Makkouk, K.M. and Ghulam, W. 1992. Resistance of barley genotypes with the Yd2 gene to the movement of barely yellow dwarf virus. RACHIS 11(1/2):81-82.

Singh, M., and Tahir, M. 1992. The effect of outliers on interpretation of breeding data on heat tolerance in wheat. Rachis 11 (1/2): 6-50.

Tahir, M., Pashayani, H., Ottekin, A., Tosun, H., Akar, T., and Shevstov, V., 1993. Multilocation testing of winter barley in ICARDA region. Barley Newsletter Vol. 37: 113-116.

Tahir, M., and Valkoun, J. 1994. Genetic diversity in wheat- an international approach in its evaluation and utilization. Wheat Inform. Service 78: 1-12.

Yau, S.K., Hamblin, J., Ceccarelli, S., Tahir, M., Ryan, J. and Grando, S.1994. Screening for boron toxicity resistance. Barley Newsletter 37: 110-112.

Yau, S.K., Ryan, J., Nachit, M., Ortiz-Ferrara, G. and Hamblin, J.1994. Screening for boron toxicity resistance in durum and bread wheat. Annual Wheat Newsletter 40: 204-205.

## 13. CEREAL VARIETIES RELEASED BY NATIONAL PROGRAMS.

| Crop | Country | Year of release | Variety |
|---|---|---|---|
| **Barley** | Algeria | 1987 | Harmal |
| | | 1992 | Badia |
| | | 1993 | Rihane-03 |
| | Australia | 1989 | Yagan |
| | | 1991 | High |
| | | 1993 | Kaputar |
| | | 1993 | Namoi |
| | Bolivia | 1991 | Kantuta |
| | | 1993 | Kolla |
| | Brazil | 1989 | Acumai |
| | Canada | 1993 | Falcon |
| | | 1994 | Tukwa |
| | | 1994 | Seebe |
| | Chile | 1989 | Leo |
| | | 1989 | Centauro |
| | China | 1988 | Shenmai 1 |
| | | 1989 | V-24 |
| | Cyprus | 1980 | Kantara |
| | | 1989 | Mari/Aths* |
| | Ecuador | 1989 | Shyri |
| | | 1992 | Calicuchima-92 |
| | | 1992 | Atahualpa-92 |
| | Egypt | 1993 | Giza 125 |
| | Ethiopia | 1981 | BSH 15 |
| | | 1984 | BSH 42 |
| | | 1985 | Ardu |
| | Iran | 1986 | Aras |
| | | 1990 | Kavir |
| | | 1990 | Star |
| | Iraq | 1994 | Rihane-03 |
| | | 1994 | IPA 7 |
| | | 1994 | IPA 9 |
| | Jordan | 1984 | Rum (6-row) |
| | Kenya | 1993 | Ngao |
| | Lebanon | 1989 | Rihane-03 |
| | Libya | 1992 | Wadi Kuf |

| Crop | Country | Year of release | Variety |
|---|---|---|---|
| **Barley** | Libya | 1992 | Wadi Gattara |
| | Mexico | 1986 | Mona/Mzq/DL71 |
| | Morocco | 1984 | Asni |
| | | 1984 | Tamellat |
| | | 1984 | Tissa |
| | | 1988 | Tessaout |
| | | 1988 | Aglou |
| | | 1988 | Rihane |
| | | 1988 | Tiddas |
| | Nepal | 1987 | Bonus |
| | Pakistan | 1985 | Jau-83 |
| | | 1987 | Jau-87 |
| | | 1987 | Frontier 87 |
| | | 1993 | Jau-93 |
| | Peru | 1987 | Una 87 |
| | | 1987 | Nana 87 |
| | | 1989 | Bellavista |
| | Portugal | 1982 | Sereia |
| | | 1983 | CE 8302 |
| | | 1991 | Ancora |
| | Qatar | 1982 | Gulf |
| | | 1983 | Harma |
| | S. Arabia | 1985 | Gustoe |
| | Spain | 1987 | Resana |
| | Syria | 1987 | Furat 1113 |
| | | 1991 | Furat 2 |
| | | 1994 | Impr. A. Abiad |
| | Thailand | 1987 | Semang1 |
| | | 1987 | Semang2 |
| | Tunisia | 1985 | Taj |
| | | 1985 | Faiz |
| | | 1985 | Roho |
| | | 1987 | Rihane"S" |
| | | 1992 | Manel 92 |
| | Turkey | 1993 | Tarm 92 |
| | | 1993 | Yesevi 93 |
| | Vietnam | 1989 | Api/CM67//B1 |
| | Yemen AR | 1986 | Arafat |
| | | 1986 | Beecher |

| Crop | Country | Year of release | Variety |
|---|---|---|---|
| **Durum wheat** | Algeria | 1986 | Sahl |
| | | 1986 | Waha |
| | | 1992 | Korifla |
| | | 1992 | Omrabi 6 |
| | | 1984 | Timgad |
| | | 1993 | Heider |
| | | 1993 | Kabir 1 |
| | | 1993 | Omrabi 9 |
| | | 1993 | Belikh 2 |
| | Cyprus | 1982 | Mesoaria |
| | | 1984 | Karpasia |
| | Egypt | 1979 | Sohag I |
| | | 1988 | Sohag II |
| | | 1988 | Beni Suef |
| | | 1990 | Sohag III |
| | | 1990 | Beni Suef I |
| | Greece | 1982 | Selas |
| | | 1983 | Sapfo |
| | | 1984 | Skiti |
| | | 1985 | Samos |
| | | 1985 | Syros |
| | Iraq | 1994 | 'Waha Iraq' |
| | Jordan | 1988 | Korifla=Petra |
| | | 1988 | N-432=Amra |
| | | 1988 | Cham1=Maru |
| | | 1988 | Stork=ACSAD75 |
| | Lebanon | 1987 | Belikh 2 |
| | | 1989 | Sebou |
| | Libya | 1985 | Marjawi |
| | | 1985 | Ghuodwa |
| | | 1985 | Zorda |
| | | 1985 | Baraka |
| | | 1985 | Qara |
| | | 1985 | Fazan |
| | | 1992 | Khiar 92 |
| | | 1993 | Zahra 5 |
| | Morocco | 1984 | Marzak |
| | | 1989 | Sebou |
| | | 1989 | Omrabi |

| Crop | Country | Year of release | Variety |
|---|---|---|---|
| **Durum wheat** | Morocco | 1991 | Tensif |
| | | 1992 | Brachoua |
| | | 1992 | Omrabi 5 |
| | Pakistan | 1985 | Wadhanak |
| | Portugal | 1983 | Celta |
| | | 1983 | Timpanas |
| | | 1984 | Castico |
| | | 1985 | Heluio |
| | Saudi Arabia | 1987 | Cham 1 |
| | Spain | 1983 | Mexa |
| | | 1985 | Nuna |
| | | 1989 | Jabato |
| | | 1991 | Anton |
| | | 1991 | Roqueno |
| | Syria | 1984 | Cham 1 |
| | | 1987 | Cham 3 |
| | | 1987 | Bohouth 5 |
| | | 1994 | Cham 5 |
| | Tunisia | 1987 | Razzak |
| | | 1993 | Omrabi 3 |
| | | 1993 | Khiar |
| | Turkey | 1984 | Susf bird |
| | | 1985 | Balcili |
| | | 1988 | EGE 88 |
| | | 1990 | Cham 1 |
| | | 1991 | Kizilton |
| | | 1994 | Firat 93 |
| | | 1994 | Aydin 93 |
| **Bread wheat** | Algeria | 1982 | Setif 82 |
| | | 1982 | HD 1220 |
| | | 1989 | Zidane 89 |
| | | 1992 | Nesser = Cham 6 |
| | | 1992 | Cham 4=Sidi Okba |
| | | 1992 | Rhumel |
| | | 1992 | Alondra=21AD |
| | | 1992 | Soummam |
| | | 1992 | ACSAD 59=40DNA |
| | | 1994 | Mimouni |

| Crop | Country | Year of release | Variety |
|---|---|---|---|
| **Bread wheat** | Algeria | 1994 | Ain Abid |
| | China | 1994 | Mayoun 1 |
| | Egypt | 1982 | Giza 160 |
| | | 1988 | Giza 162 |
| | | 1988 | Giza 163 |
| | | 1988 | Giza 164 |
| | | 1988 | Sakha 92 |
| | | 1991 | Gammeiza 1 |
| | | 1991 | Giza 165 |
| | | 1993 | Sahel 1 |
| | | 1994 | Sids 1 |
| | Egypt | 1994 | Sids 2 |
| | | 1994 | Sids 3 |
| | | 1994 | Giza 166 |
| | | 1994 | Giza 167 |
| | Ethiopia | 1984 | Dashen |
| | | 1984 | Batu |
| | | 1984 | Gara |
| | Greece | 1983 | Louros |
| | | 1983 | Pinios |
| | | 1983 | Arachthos |
| | Iran | 1986 | Golestan |
| | | 1986 | Azadi |
| | | 1988 | Darab |
| | | 1988 | Sabalan |
| | | 1988 | Quds |
| | | 1990 | Falat |
| | Iraq | 1994 | Adnanya |
| | | 1994 | Hamra |
| | | 1994 | Abu Ghraib |
| | Jordan | 1988 | NASMA=Jubeiha |
| | | 1988 | L88=Rabba |
| | | 1988 | Nesser |
| | Lebanon | 1990 | Seri |
| | | 1991 | Nesser |
| | Libya | 1985 | Zellaf |
| | | 1985 | Sheba |
| | | 1985 | Germa |
| | Morocco | 1984 | Jouda |

| Crop | Country | Year of release | Variety |
|---|---|---|---|
| **Bread wheat** | Morocco | 1984 | Merchouche |
| | | 1986 | Saada |
| | | 1989 | Saba |
| | | 1989 | Kanz |
| | Oman | 1987 | Wadi Quriyat 151 |
| | | 1987 | Wadi Quriyat 160 |
| | Pakistan | 1986 | Sutlej 86 |
| | Portugal | 1986 | LIZ 1 |
| | | 1986 | LIZ 2 |
| | Qatar | 1988 | Doha 88 |
| | Sudan | 1985 | Debeira |
| | | 1987 | Wadi El Neel |
| | | 1991 | Neelain |
| | | 1993 | Sasarieb |
| | Syria | 1984 | Cham 2 |
| | | 1984 | Bohouth 2 |
| | | 1986 | Cham 4 |
| | | 1987 | Bohouth 4 |
| | | 1991 | Cham 6 |
| | | 1991 | Bohouth 6 |
| | Tanzania | 1983 | T-VIRI-Veery 'S' |
| | | 1983 | 69/BD |
| | Tunisia | 1987 | Byrsa |
| | | 1987 | Salambo |
| | | 1992 | Vaga 92 |
| | Turkey | 1986 | Dogankent-1 ( |
| | | 1988 | Kaklic 88 |
| | | 1988 | Kop |
| | | 1988 | Dogu 88 |
| | | 1989 | Es14 |
| | | 1990 | Yuregir |
| | | 1990 | Karasu 90 |
| | | 1990 | Katia 1 |
| | Yemen | 1983 | Marib 1 |
| | | 1983 | Ahgaf |
| | | 1988 | Mukhtar |
| | | 1988 | Aziz |
| | | 1988 | Dhumran |
| | | 1988 | SW/83/2 |

## 14. STAFF LIST

| | |
|---|---|
| Dr. S. Ceccarelli | Spring Barley Breeder |
| Dr. H. Ketata | Training Scientist/Breeder |
| Dr. O.F. Mamluk | Wheat Pathologist |
| Dr. K. Makkouk | Virologist |
| Dr. R.H. Miller[1)] | Cereals Entomologist |
| Dr. J.M. Peacock | Crop Physiologist |
| Dr. M. Tahir | Winter & Facultative Barley Breeder |
| Ir. J.A.G. van Leur[2)] | Barley Pathologist |
| Dr. F. Weigand | Molecular Biologist |
| Dr. G. Ortiz-Ferrara | Bread Wheat Breeder (CIMMYT) |
| Dr. M. Nachit | Durum Wheat Breeder (CIMMYT) |
| Dr. T.S. Payne[3)] | Winter Wheat Breeder (CIMMYT) |
| Dr. A. Morgunov[4)] | Winter Wheat Breeder (CIMMYT) |
| Dr. M.S. Mekni | Cereal Breeder, NARP (Morocco) |
| Dr. H. Vivar | Barley Breeder, LARP (Mexico) |
| Dr. Stefania Grando | Barley Breeder |
| Mr. I. Naji | Agronomist/Crop Physiologist |
| Dr. S.K. Yau | International Trials Scientist |
| Dr. M. Mayer[5)] | Post-Doctoral Fellow |
| Dr. L. Mustapha[6)] | Post-Doctoral Fellow |
| **Visiting Scientists:** | |
| Dr. M. Guirgis Mosaad[7)] | Bread Wheat Breeder |
| Dr. V. Mahalakshmi[8)] | Cereal Crop Physiologist |
| Dr. Victor Shevtsov[9)] | Winter Barley Breeder |
| Dr. Andre Comeau[10)] | Biotechnologist |
| **Consultant** | |
| Dr. Abdullah Dakheel | Cereal Crop Physiologist |
| Mr. A. Impiglia | Research Associate |
| Mr. M.A. Mousa | Research Associate |
| Mr. A.J. Sabouni | Training Assistant |
| Mr. A.P. Asbati | Research Assistant |
| Mr. F.J. El-Haramein | Research Assistant |
| Mr. A. Kourieh | Research Assistant |
| Mr. M. Michael | Research Assistant |
| Mr. M. Mushref | Research Assistant |
| Mr. M. Naimi | Research Assistant |
| Mr. H. Pashayani | Research Assistant |
| Mr. N. Rbeiz | Research Assistant (Terbol) |
| Mr. M. Jarrah | Research Assistant |

| | |
|---|---|
| Mr. G. Kashour | Research Assistant |
| Mr. Z. Alamdar | Senior Research Technician |
| Mr. M. Azrak | Senior Research Technician |
| Mr. A. Ayyan | Senior Research Technician |
| Mr. B. Shammo | Senior Research Technician |
| Mr. I. Ghannoum[11)] | Senior Research Technician |
| Mr. H. Sayed | Senior Research Technician |
| Mr. Z. Haj Younes | Research Technician |
| Mr. J. Aziz | Research Technician (Terbol) |
| Mr. S. Farrouh | Research Technician |
| Ms. N. Fadel | Research Technician |
| Mr. A. Yaljarouka | Research Technician |
| Mrs. W. Haj Juma'a | Research Technician |
| Mr. A. El-Saleh | Research Technician |
| Ms. S. Tawkaz[12)] | Research Technician |
| Mr. A.A. El-Jasem | Labour Foreman |
| Mr. A.S. Abdalla | Assistant Technician |
| Mr. O. El-Jasem | Farm Labourer |
| Mr. H. El-Khatib | Ass. Research Technician (Terbol) |
| Mr. M. Abu Nakad | Ass. Research Technician (Terbol) |
| Ms. R. Nalbandian | Program Secretary |
| Ms. S. Toutounji | Secretary |
| Ms. R. Rahwan | Secretary |

**Research Fellow:**

| | |
|---|---|
| Ms. A.M. Gallo | Durum Wheat (Viterbo) |

**Students:**

Mr. Farid Makdis
Mr. Ghassan Na'ase
Mr. Claus Einfeldt

---

1) Left in June 1994
2) Left in May 1994
3) Left in October 1994
4) Joined in October 1994
5) Left in March 1994
6) Joined in April 1994
7) Left in June 1994
8) Left in August 1994
9) Left in June 1994
10) Left in June 1994
11) Left in May 1994
12) Joined in March 1994