Wheat Breeding: Objectives, Methodology, and Progress
Proceedings of the Ukraine/CIMMYT Workshop

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Mironovka, Kiev Region, Ukraine
CIMMYT is an internationally funded, nonprofit, scientific research and training organization. Headquartered in Mexico, the Center is engaged in a worldwide research program for maize, wheat, and triticale, with emphasis on improving the productivity, profitability, and sustainability of maize and wheat systems in poor countries. With national program partners, CIMMYT works to increase food security, protect natural resources, and alleviate poverty in the developing world. It is one of 16 nonprofit international agricultural research and training centers supported by the Consultative Group on International Agricultural Research (CGIAR), which is sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), and the United Nations Development Programme (UNDP). The CGIAR consists of a combination of 40 donor countries, international and regional organizations, and private foundations.

CIMMYT receives core support through the CGIAR from a number of sources, including the international aid agencies of Australia, Austria, Belgium, Brazil, Canada, China, Denmark, Finland, France, Germany, India, Italy, Japan, Mexico, the Netherlands, Norway, the Philippines, Spain, Switzerland, the United Kingdom, and the USA, and from the European Union, Ford Foundation, Inter-American Development Bank, the OPEC Fund for International Development, UNDP, United Nations’ Environment Programme (UNEP), and the World Bank. CIMMYT also receives non-CGIAR extra-core support from the International Development Research Center (IDRC) of Canada, the Rockefeller Foundation, and many of the core donors listed above.

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The CGIAR, CIMMYT, and the CIMMYT Wheat Pathology Unit

H.J. Dubin

The Consultative Group on International Agricultural Research (CGIAR)

Primary financial support for CIMMYT's work comes from the CGIAR. This international consortium consists of 46 public and private, developed and developing country donors. It was formed in 1971 with the co-sponsorship of the United Nations' Food and Agriculture Organization (FAO), the World Bank, and the United Nations' Development Programme (UNDP). Recently the United Nations' Environment Programme (UNEP) joined the group of co-sponsors. Developing country membership has broadened to include Colombia, Ivory Coast, Egypt, Iran, and Kenya.

Through its financial backing of CIMMYT and 15 other international agricultural research centers (IARCs), the CGIAR promotes sustainable agriculture for food security in developing nations. The consortium is presently undergoing an important transformation toward more equitable North/South "ownership" of the system. It envisions a more equal partnership of all participants and a greater openness in establishing and carrying out a research agenda that reflects the needs and goals of the CGIAR's many partners in development.

CIMMYT

CIMMYT's mission is to help the poor by increasing the productivity of resources committed to maize and wheat in developing countries while protecting the environment. We do this through agricultural research together with national research systems.

It was explained that CIMMYT's predecessor in Mexico was the Office of Special Studies, sponsored by the Government of Mexico and the Rockefeller Foundation, which started in 1943. A great deal of progress in breeding wheat was achieved during the Rockefeller years and Dr. Norman Borlaug, Nobel Laureate and Wheat Program Director, built a worldwide breeding program on this. CIMMYT has staff in 16 countries and germplasm is distributed to over 100 countries. CIMMYT does not release cultivars; that is the role of national agricultural research programs of the cooperating countries. Under its mandate, CIMMYT holds its maize and wheat germplasm collections in trust for all humanity.

The impact of CIMMYT's wheat program was noted in various ways including the origin of spring bread wheat cultivars in less developed countries (LDCs) from 1965-90. During this period, cultivars containing CIMMYT germplasm ranged from 50 to 77% depending on the geographical region. The economic impact of CIMMYT was greatest in South Asia—about 15 million additional tons in 1990 due to breeding efforts in 1977-90. In economic terms, it meant about US$ 1.5 billion more in 1990 alone as a result of CIMMYT's research. Modern semidwarf cultivars now cover most irrigated environments in the LDCs. The greatest genetic gains have been obtained through resistance to diseases, especially the rusts, and higher yield potential.

1 CIMMYT Mexico.
The Wheat Program's structure and the role of outreach/regional programs have been described. It was noted that outreach staff did not have their own programs but rather worked within the national programs, giving technical support and training and, where feasible, financial support for equipment.

The Wheat Program Crop Protection Unit has as its major objective to aid in increasing wheat production and productivity through breeding support, research, training, and technical assistance in wheat pathology. Details of our organization and staff were discussed. The following are the diseases of concern at present: rusts; foliar blights and blotches; fusarium scab; smuts and bunts, and BYD.

Highlights of recent research at CIMMYT were given for specific diseases with emphasis on diseases of importance in Russia and Ukraine.

Adult plant (= slow rusting or rate limiting) resistance concepts were presented and discussed. It was emphasized that we believe this type of resistance, as a whole, will be longer lasting than the hypersensitive, major gene type. We are attempting to combine diverse sources of this type of resistance for leaf rust. Genetic studies indicate that many genes are involved in this kind of resistance in CIMMYT materials. Prominent are the Frontana and Pavon leaf rust resistance complexes. A study on Russian and Ukrainian spring bread wheats done at CIMMYT indicated that the Frontana complex type of resistance is commonly present in these wheats as are other sources of adult plant resistance, i.e., slow rusting resistance genes. Discussions were held on identifying slow rusting resistance and incorporating it into germplasm.

Further discussions were held on slow rusting resistance to yellow (stripe) rust. It was noted that, in CIMMYT germplasm, Anza-type durable slow rusting resistance is present as the Yr18 complex. In Pavon there are other sources of durable slow rusting resistance genes (probably 3-4). It appears that slow rusting resistance sensu Parlevliet is not present in the wheat:yellow rust system. The resistance is likely due to delayed primary hyphal growth.

Durable stem rust resistance worldwide appears to be due to a complex of genes linked to Sr2 derived from the cultivar Hope. No stem rust epidemics have occurred for many years in areas where this resistance has been in use.

Genetic studies on the basis of slow rusting and adult plant resistance for leaf and yellow rust are being conducted at CIMMYT. There are clear indications that a range of resistance genes are involved.

Information was presented on some of the best available spring bread wheat germplasm for resistance/tolerance to septoria tritici blotch (Tinamou, Catbird, Bobwhite, Milan); scab (Sumai 3, Wuhan 1,2,3, Suzhue 6, Frontana); powdery mildew (Kalyansona); BYD (Anza, Milan, Th. intermedium); eyespot (Rendezvous, Cappelle Desprez, Cerco), and common root rot (Marshall, Thatcher, Nordic, Norseman).

Discussions were held on how to increase cooperation and promote the exchange of germplasm and information.
Wheat Germplasm Improvement at CIMMYT Mexico

S. Rajaram 1 and A.I. Morgounov 2

Introduction

In 1994 the Wheat Program celebrated 50 years of wheat breeding at CIMMYT and its predecessor organization, the Office of Special Studies (founded in 1944 by the Government of Mexico and the Rockefeller Foundation). Within a span of 50 years, wheat breeding has evolved through three major strategic phases: 1) the bilateral phase (1944-1960) within Mexico; 2) the Green Revolution phase (1961-1976): internationalization of CIMMYT wheat breeding, and 3) the Post-Green Revolution phase (1977-present): globalization of CIMMYT wheat breeding.

Bilateral phase within Mexico (1944-1960)

During this 16-year period, stem rust resistance of a durable nature, derived from the variety Hope and based on the $Sr2$ complex was bred into adapted Mexican germplasm. Thus, the threat caused by this disease was virtually eliminated. Shuttle breeding, a revolutionary breeding methodology was implemented. This permitted selection of photoperiod insensitivity (based on the genes $Ppd1$ and $Ppd2$), which would allow adaptation of the gene pool far beyond Mexico. Dwarfing genes of Japanese origin ($Rht1$ and $Rht2$) were incorporated into the stem rust-resistant and photoperiod-insensitive varieties to reduce plant height. If either $Rht1$ or $Rht2$ are present, the reduction is 40 cm; if both genes are present the reduction is 55 cm. Consequently, lodging tolerance under optimum irrigation and high fertility conditions was achieved. The outcome of this experiment was revolutionary and resulted in the production of semidwarf advanced lines showing a yield advance of more than 50%. The essence of wider adaptation of the germplasm had been created.

Green Revolution phase (1961-1976)

CIMMYT’s breeding program was internationalized through the establishment of International Nurseries in the 60s. Diverse agroecological regions such as the Indo-Gangetic Plains of the Indian Subcontinent, the Nile Valley, the Mediterranean Basin, the Humid Pampa region of Argentina, and the high rainfall/irrigated coastal and pre-Cordillera areas of Chile were recognized as requiring focused efforts within CIMMYT’s overall mandate.

- The major breeding initiatives during this period were the following:
  - Exploitation of the spring x winter gene pool with additional assistance through a cooperative venture between CIMMYT and Oregon State University in the USA.
  - Septoria leaf blotch resistance in semidwarf wheats with additional assistance through a cooperative venture between CIMMYT, Tel Aviv University in Israel, and IPO, Wageningen, Holland.

1 CIMMYT Mexico
2 CIMMYT, P.K. 39 Emek 06511, Ankara, Turkey.
Slow rusting genes to leaf rust were identified, quantified, and bred with initial guidance from Dr. Caldwell at Purdue University, USA.

Industrial quality characters were emphasized.

Breeding for resistance to aluminum toxicity was initiated through a cooperative venture between CIMMYT and several Brazilian Agricultural Research institutes.

The concept of cooperating more directly with national programs through regional programs was established.

Breeding programs for durum wheat and triticale were officially initiated.

Germplasm dissemination through formalized International Nurseries for bread wheat, durum wheat, and triticale were established.

Post-Green Revolution phase (1977-present): Globalization of CIMMYT wheat breeding

CIMMYT’s breeding programs were globalized to serve all agroecological regions of developing world. Fourteen agroecological regions were identified later to be amalgamated into 12 mega-environments (MEs). Major initiatives and advances during this period include the following:

- A project on wheat for warmer nontraditional environments supported by the United Nations Development Program (UNDP) was initiated in 1982 to expand the adaptability and feasibility of growing wheat into these harsh environments, situated between 23° N and 23° S latitudes at altitudes below 1000 masl.

- In the early 1980s, CIMMYT began a systematic drought breeding program with extensive use of Huamantla and Yaqui Valley sites in Mexico as moisture stress environments combined with the testing of advanced lines under line source irrigation system.

- A winter wheat breeding program was initiated in 1985 in Turkey, as a joint venture between CIMMYT, the national program of Turkey, and ICARDA.

- A massive breeding program was started in 1985 to introgress Karnal bunt resistance into high yielding ME1 germplasm.

- Chinese germplasm of diverse origin (10 agroecological regions) began to be introgressed into CIMMYT base germplasm to further expand the genetic variability. Initiated in 1984, this effort is a continuing joint venture between the academies of Jiangsu (Nanging), Sichuan (Chengdu), and Heilongjiang (Harbin), CAAS (Beijing), Henan (Zhenghou) and CIMMYT. Head scab tolerance is emphasized in this cooperative program.

- Initiatives were taken to implement effective breeding/testing programs for tolerance to drought, heat, cold, sprouting, boron toxicity (Turkey), and cereal cyst nematode (Turkey); resistance to stripe rust...
and helminthosporium leaf blotch; and improved N and P utilization efficiency. All of these programs were carried out in the bread wheat program and some in the durum wheat and triticale as well.

- CIMMYT and ICARDA management agreed to facilitate a joint venture germplasm improvement undertaking in 1989 to serve the wheat germplasm needs of WANA (West Asia and North Africa).
- Since 1977, semidwarf wheat varieties have continued to replace original tall or landraces varieties at the rate of 2 million ha/year.
- Exploitation of the spring x winter gene pool, initiated in the second phase, has resulted in yield potential gains (Veery, Kauz, Attila) in the bread wheats.
- The durum wheat program has made higher yield potential gains through restructuring of the plant morphology (erect, thick stem and leaf).
- Triticales were given a semidwarf stature with a higher biomass and longer fertile spike. This resulted in higher yield.
- Stability of performance, yield potential, and disease resistance of these three species are similar; however, durum wheat and triticale are adapted to a reduced number of MEs.

**Shuttle breeding and international multilocalional testing**

These two core activities enhance stability of performance and avoid genetic vulnerability. Since 1944, segregating populations have been shuttled between two environmentally contrasting locations in Mexico: Cd. Obregon, Sonora, and Toluca, Mexico.

Obregon is situated at 27.5° N and 40 masl with plenty of sunshine hours. Wheat is grown under irrigated conditions and without major disease problems except some leaf rust and stem rust. At Obregon, planting is done in November/December when the day length is relatively short and the average temperature is rather low. Wheat matures in April/May when day length is getting longer and temperatures are warmer. The environmental conditions are considered optimum for wheat production and provide the opportunity for maximum expression of biomass and yield if the crop is managed well. On the station, the best genotypes have yielded up to 10 t/ha and 8-9 t/ha are not uncommon. In recent years, mean farmer yields in the area have reached 5 t/ha.

Toluca is situated in the high-rainfall highlands of Mexico at 18°N and 2640 masl; 1000 mm of annual rainfall mostly occur during the wheat growing season. This location is a natural disease hot spot for stripe rust, septoria leaf blotch, BYDV, fusarium head blight, bacteria (*Xanthomonas campestris*) and tan spot. At Toluca, planting is done in May/June when day length is becoming longer as temperatures increase. Harvesting is carried out in October when the day length is shortening and temperatures are cool. The location is relatively high yielding when diseases are genetically or chemically controlled. Experimental yields up to 7 t/ha have been registered.
The seven-cycle scheme outlined below shows how germplasm is shuttled between the two locations. Depending on the location where the cross is made, the cycle starts with the F1 in either Cd. Obregon or in Toluca. The example below uses the F1 in Cd. Obregon as the starting point:


F2: Toluca. 2000 plants/cross are space-planted. Selected individually under high multiple disease pressure and for agronomic type.

F3: Cd. Obregon. Dense planting. Visually selected using modified bulk/pedigree methodology for rust resistance, biomass, spike density, grain plumpness, etc.

F4: Toluca. Dense planting. Visually selected using modified bulk/pedigree methodology for biomass, multiple disease resistance, grain plumpness, etc.

F5: Cd. Obregon. Same as F3 or F4.

F6: Toluca. Individual head or plant selection under multiple disease pressure.


Following bulking of the final segregating generation, the selected entries begin the yield trial phase with the following sequence:

- Preliminary Yield Trial (PYT)
- Yield Trial (YT)
- Seed multiplication
- International Screening Nursery or Yield Trial
- Analysis of international data and parental stocks

This methodology is used for bread wheat and durum wheat, but is slightly different for triticale due to its genetic instability in the early generations. The methodology has permitted the pyramiding of a large number of multiple resistance genes for use against a wide spectrum of diseases within each mega-environment. This, in part, explains the high degree of performance stability of CIMMYT germplasm in international environments. Throughout the entire F2-F7 shuttle process, due importance is given to disease resistance, agronomic traits (height, lodging, maturity), yield characters (biomass, vigor, tillering, spike density, grain plumpness, etc.) and quality traits.

After one or two cycles of yield trials in Mexico, a final evaluation of disease resistance, and full-scale quality testing, the best advanced lines may qualify to enter into one of the ME-oriented international screening nurseries. The international nursery system is ME-based and disseminated to national programs only on a request basis. An individual advanced line can be subjected to international multilocational tests in 30 to 150 locations within a particular ME. National programs and CIMMYT outreach breeders play an important role in germplasm evaluation and dissemination of data to the CIMMYT base for analysis. The best performing lines are further selected for recombination in the crossing program. This "ritual", which has been repeated now for the last 29 years (equal to 54 breeding cycles), has built genetic diversity based on cycling and incorporation of the best performers, identified and confirmed in a global setting. This successful breeding enterprise is a truly joint venture between the cooperating programs and CIMMYT - and it could not be otherwise.
Targeted breeding mega-environments (MEs)

The CIMMYT Wheat Program defined 12 individual mega-environments. These 12 MEs encompass roughly 200 millions hectares of global wheat area of which 100 million lie in the developing world.

A mega-environment is defined as a broad, not necessarily contiguous area, occurring in more than one country and frequently transcontinental, defined by similar biotic and abiotic stresses, cropping-system requirements, consumer preferences, and, for convenience, by a volume of production. Germplasm generated for a given ME is useful throughout it, accommodating major stresses, but perhaps not all the significant secondary stresses.

Thus, within an ME, we address millions of hectares with a certain degree of homogeneity as it relates to wheat, while leaving responsibility and attention for agroecological domains at the microlevel within the ME directly up to the respective National Crop Improvement program. Twelve MEs involving spring wheats (ME1-ME6), facultative wheats (ME7-9) and winter wheats (ME10-ME12) had been defined. These are described below, listing the general area, one or more typical locations, the major diseases and the common abiotic stresses. Spring wheats cover almost 80 million ha in the developing countries, and facultative and winter wheats almost 25 million hectares.

Spring wheat mega-environments

ME1: Irrigated, temperate; 32 million ha; 99% bread wheat (BW). Optimally irrigated, low rainfall areas. The climate during the growing period ranges from temperate in winter to conditions of late heat stress in more continental regions.
Area: Primarily in Asia, Africa, and Mexico.
Typical: Cd. Obregon, Mexico; Ludhiana, India.

There are four major sub-MEs:
ME1FE: Optimal environment; only rust may be a serious problem.
ME1KB: Karnal bunt is present.
ME1HT: (Late) heat occurs during the grain-filling stage.
ME1SL: Soil/water salinity hinders growth.

ME2: High rainfall; 10 million ha; 75% BW.
Temperate environment with an average of more than 500 mm of rainfall during the cropping cycle.
Area: Concentrated in West Asia and North Africa (WANA), the highlands of East Africa, and Central America, plus the Southern Cone and Andean Highlands of South America.
Typical: Toluca, Mexico; Sevilla, Spain.
Diseases: Rusts, septorias, fusarium, BYDV.

ME3: Acid soils; 1.7 million ha; 100% BW.
Soils have pH < 5.5. Temperate environment with an average of more than 500 mm of rainfall during the cropping cycle.
Area: Mostly in Brazil, the Himalayas, and Central Africa.
Typical: Cruz Alta, Brazil.
Diseases: Rusts, septorias, fusarium, BYDV.
Abiotic: Unavailability of phosphorus, and toxic levels of aluminum and manganese are major constraints.
ME4: Low rainfall; 21.6 million ha; 67% BW.
Less than 500 mm of water are available for the crop.

There are three major sub-MEs:
ME4A: 10 million ha; 53% BW.
Winter rain followed by late, Mediterranean-type drought.
Typical: Aleppo, Syria.
Abiotic: Post flowering moisture and heat stress.

ME4B: 5.8 million ha; 100% BW. Early winter drought followed by late summer rain.
Typical: Marcos Juarez, Argentina. Mostly in Southern Cone.
Abiotic: Predominantly preflowering water stress.

ME4C: 5.8 million ha; 74% BW. Crop growth depends largely on soil-stored moisture after monsoon rains.
Typical: Dharwar, India.

ME5: High temperature; 7.1 million ha; 100% BW. Mean temperature of the coolest month is >17.5°C.
Area: Primarily located between 23°N and 23°S, below 1000 masl.

There are two major sub-MEs:
ME5A: Humid environment; 3.9 million ha.
Typical: Joydebpur, Bangladesh.
Diseases: Several and severe.

ME5B: Dry environment; 3.2 million ha.
Area: Semi-arid regions, where all wheat is irrigated.
Typical: Wad Medani, Sudan.
Diseases: Almost nonexistent.

ME6: High latitude; 5.4 million ha; 100% BW. Spring planted, where winters are too severe for plant survival; January mean temperature < -10°C.
Area: Certain regions above 42°N in Northeast Asia. About 20 million ha in the former USSR are also in ME6.
Typical: Harbin, China.

Facultative wheat mega-environments

ME7: Optimal environment, irrigated. Precipitation during the growing season is lacking.
Area: Facultative region I of China.
Typical: Zhenzhou, Anyang in Henan Province.
Diseases: Stripe rust, leaf rust, powdery mildew.
Abiotic: Moderate cold.

ME8: High rainfall. More than 500 mm of rainfall during the cropping season.

There are two major sub-MEs:
ME8A: Photoperiod sensitive.
Area: Southern Chile, Western Pacific NW, USA.
Typical: Temuco, Chile; Corvallis, Oregon, USA.
Diseases: Stripe rust, leaf rust, septoria, powdery mildew, fusarium, root rots.
Abiotic: Moderate cold, waterlogging.

ME8B: Photoperiod neutral.
Area: Thrace, SE Europe, SE USA.
Typical: Edirne, Turkey.
Diseases: Stripe and leaf rust, powdery mildew, fusarium, root rot. Sunni pest.
Abiotic: Moderate cold, waterlogging.

ME9: Semi-arid. Less than 500 mm of water are available for the crop.
Area: Mediterranean Europe; transitional altitudes in West Asia and North Africa (WANA); Atlas Mountains, Morocco; Southern Argentina; South Africa; Southern Great Plains, USA.
Typical: Eskisehir and Dyarbakir, Turkey; Tehran, Iran; Balochistan, Pakistan.
Diseases: Bunts, smuts, saw fly, Hessian fly, Sunni pest, yellow rust.
Abiotic: Moderate cold, frost, drought, heat, micronutrient deficiencies and/or toxicities.

**Winter wheat mega-environments**

ME10: Optimum environment, irrigated.
Area: Winter wheat region II of China.
Typical: Beijing, China.
Diseases: Rusts, powdery mildew, BYDV.
Abiotic: Cold, rapid grain-fill required.

ME11: High rainfall. More than 500 mm of rainfall during the cropping cycle.

There are two major sub-MEs:

ME11A: Photoperiod-sensitive.
Area: NW Europe, eastern USA.
Typical: Cambridge, UK.
Diseases: Stripe rust, leaf rust, powdery mildew, septoria, fusarium, eyespot, BYDV.
Abiotic: Cold, waterlogging.

ME11B: Photoperiod neutral.
Area: Eastern Europe, Russia, Ukraine, Midwestern USA.
Typical: Martonvasar, Hungary; Lovrin, Romania.
Diseases: Stripe rust, leaf rust, powdery mildew, septoria, fusarium, BYDV.
Abiotic: Cold winter.

ME12: Semi-arid. Less than 500 mm of water are available for the crop.
Area: Northern Great Plains, USA; Central Plateau, Turkey; Iran; Afghanistan; Russia; eastern Europe.
Typical: Kansas, USA, Eskisehir and Konya, Turkey; Tabriz, Iran.
Diseases: Stripe rust, leaf rust, stem rust, soil pathogens.
Abiotic: Cold, drought, terminal heat, micronutrients deficiencies and/or toxicities.
The International Winter Wheat Improvement Program: Objectives and Achievements

H.-J. Braun, 1 A. Morgounov, 1 H. Ketata, 2 H. Ekiz, 3 M. Kambertay, 4 M. Keser 5 and N. Zencirci 6

Introduction and historical background

Of the 105 million ha of wheat in less developed countries (LDC), winter and facultative wheats cover around 25 million ha. Whereas spring wheat yield increased significantly since the beginning of the “Green Revolution” in the late 60’s, winter and facultative wheat yields increased at a much slower rate in the LDC, except for China and Turkey, in the past decades.

 CIMMYT’s involvement in utilizing winter wheat germplasm goes back to the 1960s when the winter x spring crossing program was initiated in Chile by Dr. Ruper and then continued at Davis, California, USA. The program was later transferred to Oregon State University (OSU). CIMMYT has had a dynamic spring x winter crossing program since 1972 and shared spring x winter crosses with OSU. CIMMYT exploited this germplasm towards the spring side, while Oregon State used the F1 to topcross with winter wheats to enhance winter wheat germplasm for the Third World. In 1971, CIMMYT became directly involved with Turkey’s winter wheat improvement program through its association with the Rockefeller Foundation/Government of Turkey (GOT) wheat research program. This association resulted in the introduction of new germplasm and the development of new agronomy practices. At the end of the project in 1982, Turkey had doubled its wheat production.

Based on this experience, the GOT and CIMMYT initiated a joint venture, “An International Approach to Winter Wheat Research,” in 1986. The objective of the International Winter Wheat Improvement Program (IWWIP), jointly coordinated by the Turkish National Research Program and CIMMYT, is to develop broadly adapted, disease resistant, high yielding winter wheat germplasm for the winter and facultative wheat growing areas in West Asia and North Africa (WANA) and to facilitate germplasm exchange among the winter wheat programs of the world. Recently the target area was expanded to include the Central Asian Republics (CAR).

Parallel to the joint Turkey/CIMMYT IWWIP, ICARDA operated the highland cereal breeding program from Aleppo, Syria. After the IWWIP was reviewed in 1990, the reviewers recommended merging these two breeding programs. The two programs were thus combined to form the joint Turkey/CIMMYT/ICARDA International Winter Wheat Improvement Program (IWWIP).

Wheat production in the target area

The immediate target area of the IWWIP is mainly ME 9 (moderate cold, semi-arid, with less than 500 mm available water) and ME 12 (severe cold, semi-arid, with less than 500 mm available water). ME 8b (more than 500 mm available water) and developing wheats for irrigated areas are also important. A detailed

description of CIMMYT's mega-environments is given by Rajaram (1995). Wheat production in WANA and CAR countries is given in Table 1. Kazakhstan is not included into the total, since more than 10 million tons of its total production of 12 million tons come from spring sown photoperiod sensitive spring wheats, an area which has not been addressed by CIMMYT. Winter/facultative and spring wheat each account for around 50% of total bread wheat (Triticum aestivum L.) production. Turkey and Iran, the main winter wheat producer, alone account for more than 50% of total wheat production in WANA and CAR.

Importance of winter x spring crosses

The systematic exploitation of winter x spring crosses has been a major objective of the International Winter x Spring Program, which evolved from the activities carried out at CIMMYT, Oregon State University, ICARDA and more than 150 national programs. Spring x winter crosses are made in Toluca, Mexico. The F1s are divided into three portions: one portion stays in Mexico to be used for back and top crossing to spring wheats. Spring wheat lines derived from this program, the Veerys being the most famous family, today cover more than 5 million ha. More than 75% of all CIMMYT advanced lines have a winter wheat in their pedigree. The other two portions are sent to Oregon State and the Turkey/CIMMYT/ICARDA program in Turkey. These two programs exploit the potential towards the winter side by back or top crossing to winter wheat cultivars. Oregon State University concentrates on developing long cycle, often photoperiod sensitive winter wheats, while the Turkey/CIMMYT/ICARDA program stresses selection of early maturing facultative and winter wheats.

In particular for WANA and CAR, winter x spring crosses have great potential, since:

- The winterhardiness requirement of germplasm for most areas of WANA where winter wheat is cultivated is relatively low when compared with that of germplasm targeted for the Central Great Plains of the US or Northern Ukraine and Russia.
- Several once widely cultivated varieties selected from landraces are of the facultative type.
- Many recently released cultivars in Turkey and, to some extent, in Iran and Afghanistan originated from spring x winter crosses (Table 2).

Structure of the IWWIP

Table 3 provides details on the screening of breeding materials.

Crossing—Around 15% of the annual 1000-1200 crosses are straight winter x spring crosses, 35% are winter x spring x winter crosses and around 50% are winter x winter or winter x winter topcrosses. Crossing is done in Izmir, Syria, and Mexico.

Segregating populations—The F2 populations are screened for winter hardiness (Erzurum) and disease resistance (ICARDA, Ankara, Adana, Izmir). Based on the performance at these locations, F2 populations are bulked at Cumra. F3 are space planted at Eskisehir. Plots are irrigated and inoculated with yellow rust. Individual heads are selected for head row planting in Cumra. Selected F4-derived head rows (around 4000) are cut in bulk.

In addition, promising F3 populations selected at Oregon for earliness and disease resistance are sent to Turkey. Initially, advanced lines from Oregon State University (45° N) were tested in Turkey (40° N). Due to photoperiod sensitivity, these lines were often too late for rainfed wheat areas in WANA. Through this F3
approach it is possible to select for earliness and two cycles of selection at Oregon have resulted in a high
frequency of populations with resistance against several diseases, in particular yellow rust. Lines selected
from these populations are sent back to Oregon after three cycles and outstanding cultivars are included in
the Winter x Spring Nursery for international distribution.

Advanced lines and yield trials—After seed screening, around 1500 F4 derived entries enter an
unreplicated yield trial. Observation nurseries are grown at Izmir and ICARDA for screening against yellow,
leaf and stem rusts, and common bunt. Quality traits measured are protein, sedimentation, test weight and
1000 kernel weight. Around 500 lines are tested per year in replicated yield trials at four locations and in an
observation nursery for disease screening at four additional locations. Selected lines from the yield trial will
be distributed in the Facultative and Winter Wheat Observation Nursery (FAWWON, see below) and are
further tested in the advanced yield trial (AYT). The highest yielding lines in the AYT are then distributed in
the Elite Yield Trial (see below).

Special nurseries—A disease resistance nursery, consisting of lines with good resistance against rusts
and common bunt, is distributed to cooperators on request.

International nurseries

The Facultative and Winter Wheat Observation Nursery (FAWWON)—Germplasm development for the
target area and facilitating germplasm exchange among winter wheat breeding programs are important
tasks of the IWWIP. The main vehicle used is the FAWWON, which consists of lines developed within the
Turkey/CIMMYT/ICARDA IWWIP, plus cultivars and varieties submitted by national programs, university
programs or private companies. The FAWWON allows cooperators to screen their lines in a wide array of
environments and to share their germplasm with other breeders. Testing of submitted entries in Turkey is
minimal and the genetic variability within the FAWWON is purposely kept high. Cultivars for inclusion in the
FAWWON have been submitted by breeding programs in Afghanistan, Bulgaria, China, Croatia, France,
Germany, Hungary, Iran, Italy, Romania, Russia, Switzerland, Turkey, Ukraine, USA, and Yugoslavia.
Thanks to this nursery, many breeders have access to germplasm which would not have otherwise been
available to them. Since 1985, the number of cooperators receiving the FAWWON and its predecessor, the
International Winter Wheat Screening Nursery (IWWSN), increased from 18 initially to nearly 150 in more
than 50 countries. Since the collapse of the USSR, links with breeding programs in Armenia, Azerbaijan,
Dagestan, Georgia, Kazakhstan, Kyrgyzstan, Lithuania, Russia, Turkmenistan, Tajikistan, Ukraine and
Uzbekistan have been established. Several programs from these countries have agreed to share their
germplasm and submitted cultivars for international distribution. The germplasm included in the FAWWON
is distributed under the code of ethics published in the Annual Wheat Newsletter.

Due to plant quarantine regulations, the FAWWON cannot be sent directly to cooperators in the US and
Canada. To overcome this restriction, potential FAWWON entries are sent to Oregon State University for
multiplication (Oregon State University has a permit to grow material from Turkey) and consequent
distribution to North American cooperators.

Elite Yield Trial and FAWWYT—The Elite Yield Trial for irrigated and rainfed conditions, consisting of 25
entries each, was initiated in 1994 and is distributed to around 25 cooperators. The main target areas are
wheat growing regions of WANA and CAR. The Facultative and Winter Wheat Yield Trial (FAWWYT),
consisting of 25 entries, is distributed from Mexico. The main target areas of the FAWWYT are
environments with more than 500 mm available water.
Today these nurseries - FAWWON, EYT and FAWWYT - together with the International Spring x Winter Screening Nursery distributed by Oregon State University, are the only internationally distributed winter and facultative wheat nurseries. This represents a significant reduction compared to one or two decades ago, when there were about 10 international nurseries.

**Disease screening**

The most important diseases in the target areas are yellow rust (*Puccinia striiformis*), common bunt (*Tilletia foetida* and *T. canes*), followed by leaf rust (*Puccinia recondita*) and root rots.

**Yellow rust**—The occurrence of virulent races for Yr 9 in WANA in 1991 combined with unusually high rainfall during the last years has caused severe yellow rust epidemics in Afghanistan, Iran, Pakistan, Syria, and Turkey, and has made yellow rust the most damaging disease in these countries. To identify resistant cultivars, artificial inoculation and multi-location testing are employed. Lines are tested in Syria, Iran, Turkey and Romania against the prevailing races. In particular, performance in the FAWWON is used to identify outstanding lines for crossing. In Turkey, virulence was found for the genes shown in Table 4. More than 25 different races were found in Iran (Torabi, pers. comm.)

**Common Bunt**—Screening of advanced lines for bunt resistance is done at ICARDA, Izmir, and Ankara. F3 populations having at least one highly common bunt resistant parent are screened at Eskisehir. The inoculum used at ICARDA consists of a 1:1 mixture of *Tilletia laevis* and *T. tritici*. The races identified are T-11 and L-9 (occurring worldwide), plus three previously unidentified races, T-31 of *T. tritici* and L-18 and L-19 of *T. laevis* (Ismail et al., 1995). None of the tested common bunt isolates was virulent against Bt 5, 6, 7, 8, 9, 10, 11 and p (O. Mamluk, pers. comm.).

**Insects**

Suni bug (*Eurygaster spp.*) is probably the single most important factor damaging wheat quality in Turkey and several other countries. The insect damages wheat quality by injecting a gluten-destroying enzyme during grainfill. Suni bug occurs mainly in Iran, Romania, Russia, Turkey and Ukraine, but has also been reported from several other WANA countries. Wheat samples with more than 2-3% damaged grains cannot be used for bread making. Breeding insect resistant wheat cultivars whose gluten would not be affected by the insect’s enzyme is at present not possible due to the lack of genetic variability within bread wheats and alien species.

**Quality**

Emphasis is given to developing white seeded wheat cultivars with a high 1000 KW and high test weight. The quality requirements vary greatly for the wide range of wheat products in the region, but development of harder wheats with good bread making quality is emphasized. All lines used for crossing have been screened for their HMGW bands.

**Micronutrient disorders**

Unknown at the beginning of the IWWIP in 1986, micronutrient disorders, in particular zinc deficiency and, to a lesser degree, boron toxicity, were identified as important wheat production limiting factors on the Central Anatolian Plateau (CAP) of Turkey. Based on the analysis of more than 1500 soil samples,
Eyüpoglu et al. (1993) showed that around 50% of arable soils on the CAP are zinc deficient, containing less than 0.5 mg kg$^{-1}$ DTPA extractable zinc. Results from FAO soil surveys indicate that other WANA countries may have similar, but as yet unrecognized, soil problems (Sillanpää, 1982). Zinc application increased grain yields of wheat cultivars on the CAP by 10-500%. The yield response of wheat cultivars with good and poor adaptation to zinc deficient soils is given in Table 5.

Selection of zinc efficient cultivars is done in collaboration with the NATO-funded Science for Stability Programme at Cukurova University, Adana, the Transitional Zone Agricultural Research Institute in Eskisehir and the International Cereal Research Institute in Konya. The present work is concentrating on identifying new sources of zinc efficiency and understanding how it is inherited.

**Released cultivars**

The IWWIP has been distributing wheat germplasm to national programs since 1986. Several cultivars from the international nurseries have been selected for release or have been granted permission for seed production. These lines are listed in Table 6.

**References**


Turkey’s National Winter Cereal Project

Nusret Zencirci

Introduction

Activities on cereals in the Republic of Turkey should be investigated in two eras: 1) Pre-project era - before 1969, and 2) Project era - after 1969.

Pre-project era

Agricultural research activities in the Turkish Republic began just after the foundation of the republic in 1923. Seed improvement and experiment stations were established in Ankara, Eski_ehir, Istanbul, Adapazary, Erzurum, and Samsun to deal mainly with wheat research. Early studies were to breed wheat and barley cultivars via selections from local germplasm, find out proper tillage practices and rotation systems. In breeding, crossing was also applied to improve better varieties. With these efforts, some wheat and barley varieties improved are the following: Sivas 111-33, Köse 220-39, Melez 13, Ak 702, Akba_ak 073-44, Kunduru 1149, and Tokak 157-37.

Project era

By 1969, efforts on cereals were carried out by the institutes working independently. In 1969, the Wheat Research and Training Project was initiated to centralize wheat research in Turkey. Later in 1976, barley activities were brought under this umbrella and the project was named Winter Cereals Research and Training Project.

Growing zones and institutes in Turkey

Two zones generally occur in Turkey: the spring wheat zone and the winter-facultative zone.


Spring Zone: Yzmir, Adapazary, Adana, Samsun, and Diyarbakyr Institutes. Samsun and Diyarbakyr Institutes work both in spring and winter-facultative zones.

Project staff

A total of 86 scientists work in the different sections of project: 46 breeding, 6 pathology, 10 quality, 20 agronomy, and 4 agricultural economics. Out of 86 scientific staff, there are 25 PhDs, 18 MScs, and 43 BScs.

The Project collaborates with various organizations i.e., universities in and outside of Turkey: Oregon, Kansas, and Nebraska State Universities of USA; International Centers: CIMMYT and ICARDA.

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1 Central Research Institute for Field Crops, P.O. Box 226, Ulus, Ankara, Turkey.
Selected activities and accomplishments

Continuing efforts on cereals research have resulted in the following:

Cultivars improved

*Bread wheat:* Besoztaya 1, Bolal 2973, Kyraç 66, EdeCh, Porsuk 2800, Cumhuriyet 75, Sakarya 75, Orso, Lancer, Haymana 79, Gerek 79, Kyrkpynar 79, Ata 81, Gonen, Yzmir 85, Atay 85, Marmara 86, Cukurova 86, Kaklic 88, Dogu 88, Yuregir 89, Karasu 90, Gun 91, Murat 1, Seri 82, Dojankent 1, Agri 'S', and Kop 'S'.

*Durum wheat:* Kunduru 1149, Dicle 74, Gediz 75, Çakmak 79, Tunca 79, Gökgöl 79, Diyarbakyr 81, Ege 88, Sham 1, Kyzyltan 91, and Salihi 92:

*Barley:* Cumhuriyet 50, Yercil 147, Gem, Kaya, Hamidiye, Obruk 86, Anadolu 86, Bulbul 89, Ergnel 90, Bilgi 91, _ahin 91, TARM 92, Bornova 92, and Yesevi 93.

Pathology

This section carries out research on tracing cereal diseases nationwide, identifying new sources of resistance, and tracking of race patterns of wheat rust diseases.

Quality

The quality section screens breeding material for desired quality parameters, defines appropriate blend type for bread flour, and characterizes Turkish wheat cultivars via gliadin bands produced by PAGE.

Agronomy

The agronomy section defines proper growing techniques for wheat-fallow and wheat-legume rotation systems and investigates yield components for increased yield.

Agricultural economics

This discipline identifies local farming systems and constraints to high yield to propose solutions to farmers.
Introduction

The utilization of spring wheat germplasm, as a source of disease resistance, lodging and heat tolerance, high yield and superior grain quality is of great interest in winter bread wheat breeding. In the history of breeding in the former USSR there are many examples when such crosses produced new winter wheat varieties or valuable parental material. Varieties Novoukrainka 63 and Bezostaya 2 were developed from winter x spring crosses by academiCian P.P. Lukyanenko. Bezostaya 2 consequently served as one of the parental forms in the pedigree of well-known variety Bezostaya 1 (Lukyanenko, 1973). Winter and spring wheat hybridization in the Plant Breeding and Genetics Institute (PBGI, Odessa) resulted in new wheat varieties such as Promin, Zirka and popular commercial variety Obriy (Lyfenko, 1987). The new widely grown variety Albatros Odesskiy combines semidwarf stature and superior grain quality with high yield potential. It was selected from a cross between American spring wheat Red River and local varieties.

In PBGI, crosses between new spring wheat germplasm from CIMMYT and local bread wheat varieties were initiated in 1982. Since then we have studied the agronomic performance and combining ability (in top crosses) of 563 entries. Our investigation has led us to the following conclusions:

1. Spring bread wheat germplasm is a valuable source of disease resistance (leaf and stem rusts, Septoria spp.), early maturity and high yield in breeding winter wheat varieties for southern Ukraine.

2. Not every spring wheat line showing maximum expression of a trait can serve as an effective donor in crosses.

3. The frequency of frost resistant genotypes in segregating populations deriving from winter x spring crosses depends both on the expression of frost resistance in the winter parent and the genotype of the spring parent, especially its Vrn gene constitution and ability to tolerate low temperatures.

Fifteen spring wheat lines were selected from CIMMYT germplasm based on their outstanding combining ability for different traits (Table 1). These entries are being widely used in the winter wheat crossing program. While utilizing winter x spring crosses in the breeding program, the efficiency of different crossing schemes between the two parental pools was investigated (Table 2). Analysis of data from Table 2 leads to the following conclusions:

1. In reciprocal winter x spring crosses, the frequency of frost resistant genotypes is higher if the winter wheat is used as the female parent. However 3.6% of the crosses used in the experiments showed opposite results.

2. Backcrosses to winter parents (S x W) x W increase the frequency of frost resistant genotypes in segregating populations but sharply decrease the probability of selecting genotypes morphologically similar to the spring parents.

1 Plant Breeding and Genetics Institute, 3 Ovidiopolskaya Road, Odessa, 270036 Ukraine.
3. Double crosses F1(S x W) x F1(S x W) were found to be less effective in breeding winter germplasm.

4. Better results in breeding work with winter x spring wheat crosses may be achieved by using the interrupted backcross, when contrasting lines are selected in F5-F7 and crossed with the winter parent.

The involvement of spring wheat germplasm in hybridization with local winter varieties changed the biological properties of winter lines selected from these crosses. The changes involve growth rate and plant development in autumn and early spring.

In our study, the apex served as an indicator of plant development rate. Growth intensity was determined by the percent increase in dry biomass. Plant samples of the first autumn observation were taken 15 days after complete germination (three-leaf stage) and the second, after the end of autumn vegetation (tillering stage). The first spring sampling was done at the beginning of spring vegetation and the second, 20 days later. Analysis of yield and yield components was done using standard procedures. Frost resistance was studied by direct freezing (Kirichenko, 1962).

Day length sensitivity of the lines included in the experiment was determined by the delay in heading under the short day when plants were grown in growth chambers with long (20 h) and short (12 h) photoperiods from germination till heading. Vernalization requirements were studied using the method of split vernalization of seedlings with 10-day intervals. Seedlings were exposed to temperatures of 0-2°C with continuous light. Statistical data analysis was done in the PBGI computer center.

The coefficients of correlation were calculated between growth rate and plant development parameters in autumn and early spring and vernalization requirements, sensitivity to photoperiod, frost resistance and grain yield for F5-F7 lines (Tables 3 and 4).

Significant correlation was observed between autumn growth rate and frost resistance, as well as between frost resistance and dry matter accumulation at the end of autumn vegetation (Table 3). Frost resistance was positively correlated with the intensification of autumn tillering ($r=0.78...0.66$) and negatively with the increase of dry matter during autumn vegetation ($r=-0.67...-0.49$). It could be concluded that genotypes varying in frost resistance accumulated biomass in autumn by different means: frost resistant genotypes, by more tillering and frost sensitive genotypes, by tiller growth.

Frost resistance was negatively correlated with autumn development rate ($r=-0.68$) and positively with vernalization requirements ($=0.59-0.65$). The relationship between autumn development rate and vernalization requirements was negative ($r=-0.54$). The correlations between day length sensitivity and autumn development and likewise between day length sensitivity and frost resistance were not significant. Therefore, it can be concluded that the necessity of vernalization in autumn influenced the intensity of autumn development and frost resistance in winter wheat.

The relationship between spring growth rate and plant development, day length sensitivity and vernalization requirements on one hand and grain yield under commercial planting rate on the other allows us to make certain assumptions (Table 4). Grain yield has a positive correlation with intensity of spring development ($r=0.68$) and with dry biomass 20 days after the renewal of spring vegetation ($r=0.47$). At the same time intensity of spring development correlates negatively with day length sensitivity ($r=-0.57$) and
with vernalization requirements ($r=0.39$). The correlation between day length sensitivity and grain yield was not determined.

The relationship between plant productivity, spring growth rate and plant development showed that kernel weight per spike was positively related to intensity of spring development ($r=0.51$) and with dry biomass 20 days after the beginning of spring vegetation ($r=0.47$). Number of grains per spike was negatively correlated with the intensity of spring tillering ($r=-0.40$) but 1000 kernel weight showed a positive correlation ($r=0.43$). The number of productive tillers per unit area was found to be negatively related to spring plant development ($r=-0.49$).

By summarizing the data we came to the conclusion that a genotype combining high yield with good frost resistance under conditions in southern Ukraine must have slow development in autumn and intensive early spring growth.

The data discussed here allow us to propose the model of a variety based on intensity of plant development, day length sensitivity and vernalization requirements. Genotypes with slow development in autumn but intensive early spring growth should have high vernalization requirements along with relative neutrality to day length. This combination in a genotype does not delay early spring development, which is determined by high vernalization requirements.

Crosses between winter varieties with high vernalization requirements (55-60 days) and sensitivity to photoperiod, and spring germplasm that has a relatively neutral reaction to day length, result in the segregation of intermediate genotypes with alternative combinations of adaptive traits (Table 5). Moreover, these results demonstrate that lines with alternative combinations of day length sensitivity and vernalization requirements were developed in the recombination process at a rather low frequency: 0.95-12.5%. The character may not appear in segregating generations if it is not fully expressed in the winter parent. The effect of spring parents on the frequency of high yielding segregants with the desired combination of vernalization and photoperiod response was studied. Higher frequency of favorable segregants was observed in crosses with the line Veery#5 as compared to Ciano 79. These differences probably occur due to the specificity of genetic control of vernalization and day length sensitivity.

Preliminary data on the inheritance of vernalization response in F2-F4 generations of winter x spring crosses show that this trait is recessive (Table 6). For example, the differences between winter wheat variety Odesskaya 16 and spring line Veery #5 exposed to 40 days of vernalizing temperature are determined by three genes.

The study of the inheritance of photoperiod sensitivity in F1s of winter x spring crosses showed incomplete dominance of insensitivity. Analysis of F2 populations demonstrated that spring variety Ciano 79 and winter variety Skorospelka 3b have one dominant gene $Ppd3$, while varieties Odesskaya 16 and Mironovskaya Yarovaya have three recessive ppd genes (Table 7). This conclusion is valid since there was no segregation for day length sensitivity in the crosses between these varieties. The segregation for day length response in F2 populations derived from crosses between Skorospelka 3b and Mironovskaya Yarovaya indicates that the nature of inheritance of photoperiod reaction in winter x spring crosses does not affect growth habit.
The data presented here allowed us to come to the following conclusions:

1. Crosses between winter wheat varieties and spring wheat lines received from CIMMYT may serve as a prospective method to create the variability for breeding winter wheat in the Ukrainian steppe zone. Data on the combining ability of agronomically important traits should be taken into account in selecting parents for winter x spring crosses.

2. The main problem in breeding winter x spring crosses is to obtain winter genotypes with sufficient level of frost resistance. The frequency of winter genotypes in such crosses depends on the presence of particular Vrn genes in spring genotypes. The level of frost resistance depends on the frost resistance of winter parents and to some extent on spring parents.

3. High yielding frost tolerant winter genotypes can be selected from winter x spring crosses if they combine high vernalization response with relative neutrality to day length.

References


Table 1. Spring bread wheat lines widely used as donors of agronomically important traits.

<table>
<thead>
<tr>
<th>Line</th>
<th>KWP</th>
<th>PTP</th>
<th>KWS</th>
<th>KNS</th>
<th>1000KW</th>
<th>PW</th>
<th>LRR</th>
<th>SRR</th>
<th>PMR</th>
<th>SR</th>
<th>BMQ</th>
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<td>MN 73157</td>
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<tr>
<td>CIANO 79</td>
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<td>Strain 114</td>
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<td>F1281/LOL</td>
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<td>KLT</td>
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<td>BCI/PVN</td>
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<tr>
<td>Veery #5</td>
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</table>

* - valuable source of a trait
** - very valuable source of a trait

KWP - kernel weight per plant; PTP - productive tillers per plant; KWS - kernel weight per spike; KNS - kernel number per spike; 1000KW - 1000 kernel weight; PW - plant weight; LRR - leaf rust resistance; SRR - stem rust resistance; PMR - powdery mildew resistance; SR - Septoria resistance; BMQ - bread making quality.

Table 2. Efficiency of different crossing schemes between winter and spring wheat varieties in winter wheat breeding, 1985-1990.

<table>
<thead>
<tr>
<th>Crossing scheme</th>
<th>F2 populations</th>
<th>F5-F7 lines</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>number</td>
<td>frost resistance, %</td>
</tr>
<tr>
<td>S x W</td>
<td>36</td>
<td>54.4</td>
</tr>
<tr>
<td>W x S</td>
<td>53</td>
<td>63.1</td>
</tr>
<tr>
<td>(SxW) x S</td>
<td>76</td>
<td>28.6</td>
</tr>
<tr>
<td>(SxW) x W</td>
<td>59</td>
<td>79.8</td>
</tr>
<tr>
<td>(F1SxW)x(F1SxW)</td>
<td>37</td>
<td>51.9</td>
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<tr>
<td>S x W(F5-F7) x W</td>
<td>85</td>
<td>86.4</td>
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</table>
Table 3. The relationship between autumn growth rate, plant development and vernalization response, sensitivity to day length, frost resistance, 1985-1986.

<table>
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<tbody>
<tr>
<td>Growth rate</td>
<td>0.17</td>
<td>0.25</td>
<td>0.05</td>
<td>-0.34</td>
<td>0.18</td>
<td>-0.16</td>
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<tr>
<td>Autumn tillering</td>
<td>0.65**</td>
<td>0.51**</td>
<td>0.13</td>
<td>0.27</td>
<td>0.78**</td>
<td>0.66**</td>
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<tr>
<td>Dry weight</td>
<td>0.48**</td>
<td>-0.06</td>
<td>-0.07</td>
<td>-0.42**</td>
<td>-0.67**</td>
<td>-0.49**</td>
</tr>
<tr>
<td>Development rate</td>
<td>-</td>
<td>-0.54**</td>
<td>-0.11</td>
<td>-</td>
<td>-0.68**</td>
<td>-</td>
</tr>
<tr>
<td>Vernalization response</td>
<td>1.00</td>
<td>1.00</td>
<td>-0.02</td>
<td>1.00</td>
<td>0.65**</td>
<td>0.59**</td>
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<tr>
<td>Day length sensitivity</td>
<td>-0.02</td>
<td>1.00</td>
<td>1.00</td>
<td>0.07</td>
<td>0.02</td>
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</tbody>
</table>

* Significant at 0.05 probability level
** Significant at 0.01 probability level

Table 4. Relationship between spring growth rate, plant development and sensitivity to day length, vernalization response, grain yield under commercial planting, 1986-1987.

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Growth rate</td>
<td>-0.26</td>
<td>-0.09</td>
<td>-0.62**</td>
<td>0.08</td>
<td>0.30</td>
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<tr>
<td>Dry weight (10 plants)</td>
<td>-0.44**</td>
<td>-0.36</td>
<td>-0.49**</td>
<td>-0.09</td>
<td>0.34</td>
</tr>
<tr>
<td>Dry weight (10 stems)</td>
<td>-0.54**</td>
<td>-0.34</td>
<td>-0.56</td>
<td>-0.05</td>
<td>0.47*</td>
</tr>
<tr>
<td>Intensity of development</td>
<td>-</td>
<td>-0.39*</td>
<td>-</td>
<td>-0.57**</td>
<td>0.68**</td>
</tr>
</tbody>
</table>

Table 5. Possible combinations of day length sensitivity and vernalization response in F5-F7 lines deriving from winter x spring crosses, 1987-1989.

<table>
<thead>
<tr>
<th>Parent or cross</th>
<th>Number of lines</th>
<th>Response to day length</th>
<th>Response to vernalization</th>
<th>Frequency of lines, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Odesskaya 16</td>
<td>-</td>
<td>high</td>
<td>low</td>
<td>-</td>
</tr>
<tr>
<td>Chaika</td>
<td>-</td>
<td>high</td>
<td>medium</td>
<td>-</td>
</tr>
<tr>
<td>CIANO 79</td>
<td>-</td>
<td>low</td>
<td>low</td>
<td>-</td>
</tr>
<tr>
<td>Veery#5</td>
<td>-</td>
<td>low</td>
<td>low</td>
<td>-</td>
</tr>
<tr>
<td>Odesskaya 16/CIANO 79</td>
<td>315</td>
<td>high</td>
<td>high</td>
<td>10.48</td>
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<td>high</td>
<td>0.95</td>
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<td></td>
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<td>high</td>
<td>low</td>
<td>5.40</td>
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<td>high</td>
<td>83.17</td>
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<td>476</td>
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<td>high</td>
<td>17.86</td>
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<td>7.35</td>
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<td>73.11</td>
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<tr>
<td>Chaika/CIANO 79</td>
<td>386</td>
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<td></td>
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<td>Chaika/Veery#5</td>
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<td>12.5</td>
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<td></td>
<td>low</td>
<td>low</td>
<td>87.5</td>
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Table 6. Inheritance of the vernalization response in F2-F4 populations from winter x spring crosses, 1987.

<table>
<thead>
<tr>
<th>Cross and generation</th>
<th>Number of plants</th>
<th>Segregation ratio</th>
<th>$X^2$</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>total</td>
<td>headed</td>
<td>delayed heading</td>
</tr>
<tr>
<td>F2 Odesskaya16/Veery#5</td>
<td>289</td>
<td>283</td>
<td>6</td>
</tr>
<tr>
<td>F3 Odesskaya16/Veery#5</td>
<td>338</td>
<td>312</td>
<td>26</td>
</tr>
<tr>
<td>F4 Odesskaya16/Veery#5</td>
<td>347</td>
<td>303</td>
<td>44</td>
</tr>
<tr>
<td>F2 Chaika/Veery#5</td>
<td>284</td>
<td>284</td>
<td>-</td>
</tr>
<tr>
<td>F4 CIANO 79/Chaika</td>
<td>329</td>
<td>329</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 7. Segregation of F2 winter x spring populations for response to short day.

<table>
<thead>
<tr>
<th>Cross</th>
<th>Number of plants</th>
<th>Segregation ratio</th>
<th>$X^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>total</td>
<td>neutral</td>
<td>sensitive</td>
</tr>
<tr>
<td>Odesskaya16/CIANO 79</td>
<td>122</td>
<td>90</td>
<td>32</td>
</tr>
<tr>
<td>Odesskaya16/Mironovskaya Yarovaya</td>
<td>109</td>
<td>-</td>
<td>109</td>
</tr>
<tr>
<td>Skorospelka 3b/CIANO 79</td>
<td>100</td>
<td>100</td>
<td>-</td>
</tr>
<tr>
<td>Skorospelka 3b/Mironovskaya Yarovaya</td>
<td>131</td>
<td>101</td>
<td>30</td>
</tr>
</tbody>
</table>
Role of International Wheat Nurseries in Genebanks at Odessa’s Plant Breeding and Genetics Institute

N.A. Litvinenko¹ and G.M. Subota¹

World practice corroborates academician N. Vavilov’s conclusions (Vavilov, 1935) concerning the necessity to use in breeding work all wheat species and varietal diversity as parental materials. It further demonstrates that breeding success depends on availability of valuable germplasm for crosses (Borlaug, 1968; Lukyanenko, 1973). Unique plant collections were created in order to solve this problem and maintain genetic diversity. These collections are located, for example, in the Vavilov Institute (Russia), the National Center of Plant Genetics Resources (Ukraine), the USDA Germplasm Collection, and the Central Institute of Plant Genetics Research (Germany). In some countries germplasm centers have joined together to produce interesting breeding materials through cooperative work. For example, the Nordic Genebank in Sweden brought together breeders from five countries. Breeding centers like CIMMYT in Mexico, ICARDA in Syria and CIMMYT outreach offices in Turkey, are working with their colleagues from USA and other countries on developing wheat germplasm for different agroecological zones of the world.

Considerable contribution to wheat diversity is made by the cereals genebank of the Plant Breeding and Genetics Institute in Odessa. Research on plant genetic resources for the arid steppes of Ukraine started here more than 20 years ago. During this time we have collected, tested and included in the genebank about 14,000 cultivars and breeding lines. There have been 8,329 bread wheat entries and 151 winter durum wheat entries, 1,034 bread wheat and 104 spring durum wheat entries, 1,378 winter barley and 1,764 spring barley entries, and 734 winter triticale and 48 spring triticale entries sent to the Institute by other research institutes, seed-producing companies and, in particular, by international centers (CIMMYT, Mexico and CIMMYT, Turkey).

The cooperative system of breeding and genetic research coordination in eastern European countries have been destroyed and the International Winter Wheat Program IWWPN (USA) closed. Due to this, the germplasm exchange with CIMMYT and ICARDA became of greatest importance for renewing the collection of the genebank in our institute. So, since 1992 from Turkey (Turkey-CIMMYT-ICARDA International Winter Wheat Improvement Program) we have received four FAWWON nurseries (Facultative and Winter Wheat Observation Nursery) containing 614 entries of different geographic origin. After 2-3 years of trials in the steppe of Odessa region the following germplasm was selected from FAWWON and recommended to the breeding programs: 38 early genotypes, 52 with high kernel weight, 23 high-yielding lines, 68 with high sedimentation value and 65 with high protein content.

Under artificial inoculation we found 20 sources of resistance to powdery mildew, 50 resistant to leaf and 40 to stem rusts. It must be mentioned that in our zone the greatest interest for breeding had early samples from China (series “Ca”, “Zhong”, “Jyng” etc.) and others, especially combining earliness with other important characters like high yield (87 ZHONG 215, JYNG5418, Nongda 146), high kernel weight (more than 50 g) (Nongda 146, ZHONG MAX 89, JYNG 411), high protein content (JYNG 411, Nongda 146, 87 ZHONG 291), resistance to powdery mildew (JYNG 5418) and to leaf rust (86ZHONG 2186). High yield and high kernel weight were observed in lines from Bulgaria (602-156-22 with resistance to leaf rust).

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Romania (F472-N-3-12, Fundulea 4, F4141-W-1-1, F4105-W-2-12, F2498, F338; the last four had also high sedimentation value), as well as some lines from Turkey, Mexico, USA, and Syria. High grain quality in our tests was observed in entries from USA (Kari, Arapahoe, TAM108), in entries created jointly with CIMMYT breeders (varieties TAMEX, ABILENA) and lines with well-known source of quality NE7060 (USA) in their pedigrees.

Results of disease evaluations demonstrated availability of powdery mildew resistance in some lines from Bulgaria (6219-2K, 969-69) and nine lines from Romania (F4754-W-1-1, F900-K, F362-K-2-121). Perfectly free from infection was cross ICWN840451-4AP-2AP-OAP (Syria). Bulgarian line 602-156-22 was very resistant to leaf rust in two FAWWON nurseries. The same level of resistance was demonstrated by Bulgarian variety Typagna and lines from Kansas (KS 87116), Colorado (CO 820026), Nebraska (NE 83496), etc. Resistance to stem rust was observed in line F362-K-2-121 (Romania), varieties Typagna (Bulgaria), Zadruga (Yugoslavia), some Mexican and Turkish lines, six lines from Syria and a line from USA N88L090 with high protein content. High-yielding Bulgarian line 2139-65-3 was especially valuable combining resistance to the three above mentioned pathogens. Bulgarian line 5976-1K with combined resistance to leaf and stem rusts was also interesting.

Thus, the study of the winter wheat entries from FAWWON under conditions in southern Ukraine demonstrated valuable diversity representing the achievements of wheat breeding in the world. The situation is different for spring bread and durum wheat in the Odessa steppes. Previously there were breeding programs for these crops and some drought tolerant tall varieties resistant to wheat fly (Oscinella, Phorbia) and cereal leaf beetle were released (bread wheat Zhuravka and durum Nakat). Due to the harsh ecological conditions of the last decades, this breeding program was terminated but spring wheat germplasm was widely used in winter wheat breeding. Spring wheat nurseries from CIMMYT represent valuable material for winter wheat improvement. Since 1982 our Institute has received 58 nurseries containing 7,437 entries ranging from F2 populations to elite lines.

The results of our trials showed that all spring wheat entries were significantly affected by air and soil drought, had poor tillering, sterile spikes and high degree of pest damage, all of which prevents the realization of their genetic potential. Under favorable moisture conditions of 1991, CIMMYT lines (Opata, Cumpas 88, Bacanora 88) outyielded the local check (Zhuravka, yield 3.16 t/ha) by 37-55%. Similarly, CIMMYT durum lines ROH/FG/SILL and RISSA outyielded local check Nakat (yield 3.11 t/ha) by 23-27%. However, the same lines suffered greatly from severe drought the following year. In 1993 the only bread wheat variety which reached Zhuravka’s yield level was Bacanora 88. The yield of durum wheat in the 21st and the 22nd EDYT nurseries was very low: 1.22-1.75 t/ha.

The analysis of bread making quality demonstrated that local check Zhuravka had the best sedimentation value among high yielding lines with red grain. Entries Wardett (USA), Sandra, Linda (Czech Republic) were close to it and JAC 24, Buck Patagon, Norkin Churrinche, Up 262, PVM were inferior in quality. The best genotypes identified during the screening of international germplasm were given to the breeders. Improved breeding material was created by crossing this germplasm with local varieties. The spring and winter bread wheat, durum, barley and triticale nurseries distributed by CIMMYT are of great interest for the breeding programs in our institute.

In conclusion, we would like to emphasize the need for developing and intensifying collaboration between our institute and international breeding programs at CIMMYT and ICARDA for the mutual benefit of all
involved parties. We should have regular mutual exchange of germplasm, jointly carry out research on adaptation to different ecological environments, and rapidly exchange information on the results of the trials.

We wish to acknowledge the cooperation of our colleagues at CIMMYT, ICARDA and other international centers.

References

Breeding Winter Durum Wheat Using Global Germplasm Collections

A.J. Palamarchuk

The historical development of farming in Prichernomorsky steppe region of Ukraine is associated with the cultivation of local landraces of spring durum wheat. It was a very important crop in XVI-XVIII centuries. Varieties of spring durum wheat were sown under the local names "Arnautka", "Beloturka", "Kubanka" and others (Orlov, 1922; Yakushin, 1922). These landraces performed extremely well under the drought condition of Prichernomorsky steppe. Landrace Arnautka, for instance, formed a large vitreous amber grain highly valued on international markets (Flyaksberger, 1935). However, the yield potential of this variety was very low (0.4-1.0 t/ha). On farm experiments in the region showed that winter durum wheat produce 1.5-2 times higher yield compared to spring type. At the end of XIX century the agronomists tried to introduce winter durum wheat varieties from Dagestan to Ukraine. In steppe and forest steppe regions of Ukraine adaptation of introduced varieties was poor due to inadequate frost resistance and winter-hardiness (Protopopov, 1887).

Taking into account these unsuccessful introduction attempts many researchers began to create new crop - winter durum wheat on the basis of interspecific crosses between Triticum aestivum L. and Triticum durum Desf. (Koboltova, 1931; Shulyndin, 1934; Lukyanenko, 1936; Kirichenko, 1953; 1959). The first varieties of this crop were created by Academician F.G. Kirichenko in Plant Breeding and Genetics Institute (Odessa). The first varieties Michurinka and Novomichurinka followed by Rubezh and Odesskaya jubilejnaya were released in the beginning of the 60s. However, these varieties were not widely grown due to poor yield - 20-30% lower than winter bread wheat varieties. World experience demonstrated that yield of a wheat plant can be increased by developing intensive semidwarf varieties (Borlaug, 1958; Vogel et al., 1963)). In the Plant Breeding Institute we used the induced mutant Krasnodarsky dwarf 1 and spring durum wheat Oviachic 65 (Mexico) as sources of semidwarf stature. The crosses between winter durums and Oviachic 65 were very successful and resulted in the release of the first local semidwarf varieties of winter durum such as Parus and Korall Odesskiy. They performed extremely well in the regional yield tests in 1977-1980. These two varieties were widely released in the southern regions of Ukraine and Russia (Kirichenko et al., 1960). The comparative study of the old and new semidwarf winter durum wheats demonstrated that the yield level of this crop increased by 1.75-1.91 t/ha (Table 1). The combination of improved agronomy and higher yield potential of new varieties resulted in the increase of yield by 2.53-2.84 t/ha compared to the first variety and by 0.7-1.01 t/ha compared to the preceding variety.

Significant increase in the yield of new winter durum varieties was obtained due to improved resistance to lodging and better redistribution of assimilates between grain and vegetative part of the plant. Aisberg odesskiy became one of the most popular varieties of winter durum practically in all the regions of the ex-USSR being released in 23 regions of Ukraine, Russia, Kazakhstan and Kirghistan. This variety definitely contributed to the introduction of winter durum wheat into the areas where spring durum was cultivated earlier such as the North of Central Asia (Kazakhstan, Kirghizstan), the forest zone of Ukraine and Volgograd region of Russian Federation.

Further improvement of winter durum wheat largely depends on improvement of agronomically important traits and adaptive properties. It is necessary to use in the crosses the varieties with high yield potential, resistance to major diseases and good technological qualities similar to those of spring durum wheat. The
characteristics of some recent winter durum lines confirm the value of the world diversity of durum wheat. Good results in increasing yield potential were obtained with the help of spring durum wheats from CIMMYT - Mexicali 75, Javaros 79, Altar 84 and others. Resistance to leaf and stem rust, powdery mildew was incorporated into recent lines using varieties Yuma, Vermum, Endura. High quality lines were obtained through crosses with varieties Tignis, Aldura, Creso, Trinacria and others.

Thus, the results of hybridization involving world germplasm collection of durum wheat resulted in the creation of a set of varieties with high yield potential, excellent technological and macaroni qualities of grain coupled with resistance to major diseases and wide of adaptation.

References


Koboltova, E.A. 1931. Winter wheat in Middle Volga Region. Seed Production, no. 17 (in Russian).


Table 1. Grain yield of the historical set of winter durum wheat varieties yield trial at PBGI; preceding crop: black fallow, 1987-1993.

<table>
<thead>
<tr>
<th>Group</th>
<th>Varieties</th>
<th>Years of production</th>
<th>Mean yield t/ha</th>
<th>Increase (t/ha) over group 1</th>
<th>Increase (t/ha) over preced. group</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Michurinka</td>
<td>1960-1968</td>
<td>3.25</td>
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<td>-</td>
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<tr>
<td></td>
<td>Novomichurinka</td>
<td>1963-1970</td>
<td>3.35</td>
<td>-</td>
<td>0.10</td>
</tr>
<tr>
<td>2</td>
<td>Rubezh</td>
<td>1969-1975</td>
<td>3.36</td>
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<td>Odesskaya jubilejn.</td>
<td>1972-1980</td>
<td>3.58</td>
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<td>0.28</td>
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<tr>
<td>3</td>
<td>Parus</td>
<td>1983-</td>
<td>5.05</td>
<td>1.75</td>
<td>1.58</td>
</tr>
<tr>
<td></td>
<td>Koral odesskiy</td>
<td>1985-</td>
<td>5.21</td>
<td>1.91</td>
<td>1.74</td>
</tr>
<tr>
<td>4</td>
<td>Aisberg odesskiy</td>
<td>1990-</td>
<td>5.83</td>
<td>2.53</td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td>Alyi parus</td>
<td>1993-</td>
<td>6.14</td>
<td>2.84</td>
<td>1.01</td>
</tr>
</tbody>
</table>
The gene pool of wild wheat species as well as that of *Aegilops* and *Dasypyrum* species can enrich the cultivated wheat with many valuable genes. Scientists have discovered in these species the presence of genes determining resistance to a number of diseases and pests, genes for high tolerance to salt and aluminum, ability to adapt to changing environmental conditions, high nitrogen assimilation, ability to develop vesicular-arbuscular mycorrhiza which promotes assimilation of phosphorus from hardly accessible sources (we observed this in *Triticum beoticum* Boiss.). All wild wheat relatives have high level of protein in grain and pass it the crosses with cultivated wheat. The genes responsible for high bread-making quality are located on the D genome (*Ae. tauschii*), U genome (*Ae. umbellulata*), M genome (*Ae. comosa*) and their polyploid derivatives. All species and forms of genus *Aegilops* contain gluten proteins and produce grain with high gluten content. It was discovered that cytoplasm of various wheat and *Aegilops* species have certain influence on the expression of agronomic traits of alloplasmic lines of wheat and in a number of cases improved them. These and other facts proves the necessity of extensive study of the usage of wheat wild relatives in practical breeding.

In general, crosses between bread and durum wheats with polyploid species of *Aegilops* and wild wheats are most successful. The crossability of diploid *Aegilops* species, *T. boeoticum* and *Triticum urartu* as well as *Dasypyrum villosum* with tetraploid wheat species, in particular with durum wheat, is good. However, it is difficult to obtain hybrids with the hexaploid wheat unless special methods such as embryo culture is applied. One way of improving crossability was shown by G.D. Karoechenko (1935) i.e., to raise the ploidy level of one of the parents.

In collaboration with Drs. I. Odintsova and M. Gashimov (Vavilov Institute) we carried out crosses using tetraploid forms of *T. beoticum*, *T. urartu* or *Ae. tauschii* (2n=28) instead of diploids. The tetraploids were cordially provided by the Academician of Armenian Academy of Sciences Prof. P.A. Gandilyan. The other parent represented cultivated varieties of *T. aestivum* (Omskaya 9, Bezostaya 1, Siete Cerros) as well as accessions of *T. petropavlovskyi*, *T. compactum*, *T. sphaerococcum*, *T. macha*. The seed set in these crosses varied from 11 to 50% and the viability of seeds from 65 to 90%. Thus, duplication of the chromosome set of one-grain wheats and *Ae. tauschii* allowed to obtain sufficient number of hybrid seeds in crosses between these forms and hexaploid wheat species. Naturally, the number of grains per hybrid in wide crosses is of prime importance in increasing the exchange of genetic material between the species involved.

The other way for transferring genes from a wild species into wheat is crossing them with artificial amphidiploids obtained using these species. We used 10 amphidiploids (2n=42), in which the genomes of *Ae. tauschii*, *Ae. speltoides*, *Ae. umbellulata*, *Ae. ventricosa*, *T. boeoticum*, *Dasypyrum villosum* were combined with the genomes of the tetraploid wheats - *T. timopheevii*, *T. miltitae*, *T. dicoccum*, *T. persicum*. The amphidiploids were crossed with cultivars of bread and durum wheats. The hybrid seed set varied from 7 to 80% depending of the combination and the viability of hybrid seeds - from 20 to 95%.
Backcrossing of the hybrids with their hexaploid parent results in the phenotype of cultivated wheat already in BC4. In the backcross progeny derived from the cross between _T. beoticum_ (4x) and _T. aestivum_ there were 1-5% of lines immune to powdery mildew and leaf rust - the trait absent in the hexaploid parents but present in monococcum wheats.

One of the most powerful mechanisms for spontaneous exchange of genetic material in wide crosses is the suppression of homeologous chromosome pairing by ph1 genes and other genetic systems. The suppresser genes are present in some plants of the populations of _Ae. speltoides_, _Ae. mutica_ (Riley et al., 1961). Weaker effects were demonstrated by the genes discovered in accessions of _Ae. longissima_, _Ae. caudata_ (Mello-Sampayo, 1971) and _Ae. tauschii_ (Ekingen et al., 1977). Utilization of gene-suppressers present in these five species allows to increase considerably the frequency of chromosome exchange and consequently transfer useful traits from wild species into cultivated wheat.

The next stage in creating transgressive forms is selection of the desirable genotypes in the recurrent selection scheme. Effectiveness of such selection can be increased by using gametocidal (Gc) genes which are present in _Ae. caudata_, _Ae. cylindrica_, _Ae. triuncialis_ (Endo, Katayama, 1978), _Ae. longissima_ and _Ae. sharonensis_ (Endo, 1985). The mechanism of Gc genes action is that during gametogenesis in hybrids carrying this gene(s) only gametes possessing the gene will survive and the gametes non-carriers of Gc-genes are eliminated. If Gc-genes are linked to the genes of valuable traits the selection for these traits is realized automatically on the gamete level and being repeated in the following generations. Such transfer of the genes of resistance to leaf rust and powdery mildew linked to Gc genes was made by crossing amphidiploid _T. dicoccum-Ae. speltoides_ with spring bread wheat cultivars Saratovskaya 29, Omskaya 9, and Irtyshanka 7 (Odintsova et al., 1991). The bread wheat lines obtained from these crosses are efficient donors of immunity to leaf rust and powdery mildew characterized by easy transfer of the traits to progeny in crosses with bread wheats.

Further study of the genetic potential of wild relatives of wheat will open new trends and methods for use in breeding. In this respect it becomes very important to collect and conserve the gene pool of the wild species mentioned above which are grown in the Mediterranean countries. Collaboration of wheat scientists from different countries may be very fruitful.

References


Breeding Durum Wheat for Grain Quality

V.S. Golik, P.H. Yurchenko, K.M. Sclyarevsky, and V.Z. Iodkaevsky

The V. Ya. Yuriev Institute of Plant Production in Kharkov, Ukraine, has been carrying out breeding of *Triticum durum* Desf. since 1910. Twelve varieties have been created and released in Ukraine and Russia during 84 years of breeding work: Arnautca Kochina 190, Hordeiforme 802, Narodnaya, Kharkovskaya 3, Kharkovskaya 7, Kharkovskaya 15, Kharkovskaya 17, Kharkovskaya 21, Kharkovskaya 23, Kharkovskaya 37, Kharkovskaya 46 and Collectivnaya 2.

The most important varieties for production were Narodnaya and Kharkovskaya 46. The variety Narodnaya had good macaroni quality; the grain yield was 4.5 t/ha and it was cultivated for 32 years, beginning in 1947. The maximum cultivated area was 0.9 million ha. The variety Kharkovskaya 46 has good macaroni quality and adaptation to stress environments. It has been used in production since 1957 with a maximum cultivated area of 4.6 million ha in 1969. At present spring durum wheat breeding for grain quality is carried out according to the following scheme:

F1 - F4 - In collection, hybrid and breeding nurseries (BN) of the 1st and 2nd year, parental and breeding materials are visually evaluated for the following characters: grain virtuousness, granularity, uniformity and color.

F5 - F7 - In BN of the 2nd year and preliminary yield trials, grain characters, color of semolina and dough are estimated visually.

F8 - F10 - During advanced yield trials, the complete analysis of macaroni quality is done (Anon., 1988). The varieties Kharkovskaya 37 and Saratovskaya zolotistaya are used as checks.

In 1995 150 parental forms of durum wheat were planted in a crossing block. They were classified by 14 characters including yield components, dough color, baking quality and protein content. In 1990-1992 the parental material (69 varieties) was compared with the check Kharkovskaya 37 for 69 characters, including 15 grain quality parameters. Kharkovskaya 37 had the following parameters (three-year average): productivity - 299 g/m² (LSD - 46 g/m²), protein content in grain - 13% (LSD - 0.8%), gluten content - 26.0% (LSD - 2.1%); dough color score of Saratovskaya zolotistaya was 3.5 points.

The productivity of the best samples was equal to that of the checks. The following varieties had the best grain quality parameters: Kharkovskaya 7 and line 77-607, line 77-235 (protein and gluten content); Rugby and Wascana (protein, gluten and pigment content); Edmore (gluten and pigment content). These varieties and lines represent very valuable parental materials for crosses aimed at quality improvement.

The results of macaroni quality evaluation in 1993-1994 showed that the color of dry macaroni made out of Saratovskaya zolotistaya was 4.5 and its overall score was 2.4. The same parameters for the best varieties or lines from the Institute were respectively 3.5-4.0 and 1.9-2.2. Moreover, five lines with a dough color score of 5.0 were selected in BN of the 2nd year.
In 1974 the Institute submitted the variety Kharkovskaya 5 for a state variety release yield trial; its grain had very good baking and macaroni quality (Melnikov et al., 1972). However, it was not released. Research aimed at developing new durum varieties combining good baking and macaroni quality has been conducted since 1976.

In 1986 varieties Kharkovskaya 13 and Kharkovskaya 15 were submitted for the State Variety Release Yield Trial. Kharkovskaya 15 was released and is now a national check for the Ukrainian steppe zone.

Every year some 10-15 lines with similar grain quality are studied in breeding nurseries. Line 81-371 (Sas 449/Kharkovskaya 5/Kharkovchanka 1) was one of the best lines in complex evaluation compared to 5 checks in 1992-1994 under variable agronomy practices (Table 1). This line significantly outyielded checks after all three preceding crops. Moreover, dough strength and overall baking quality were equal or slightly inferior to the best bread wheat variety Kharkovskaya 93. The gluten content in grain of the line 81-371 was equal to that of varieties Kharkovskaya 13 and Kharkovskaya 15 which are similar in quality and considerably inferior to other checks because their grain absorbs less water. As far as the protein content is concerned, this line is inferior to Kharkovskaya 93. So line 81-371, with a considerable yield advantage, is equal in quality parameters to similar durum varieties and is close to bread wheat variety Kharkovskaya 93 in baking quality. It will be submitted for the State Variety Release Yield Trial.

In the future the durum wheat breeding program envisages creating: 1) varieties of typical durum wheat with grain yield equal to Kharkovskaya 23, grain quality equal to Saratovskaya zolotistaya, and good stress tolerance (equal to Kharkovskaya 46); and 2) dual purpose varieties with excellent macaroni and baking quality.

References


Table 1. Yield and grain quality of *Triticum durum* after different preceding crops.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Khark.6</th>
<th>Khark.93</th>
<th>Khark.37</th>
<th>Khark.13</th>
<th>Khark.15</th>
<th>81-371</th>
<th>Mean</th>
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<tbody>
<tr>
<td><strong>Preceding crop: black fallow</strong></td>
<td></td>
<td></td>
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<tr>
<td>Yield, t/ha</td>
<td>5.10</td>
<td>4.78</td>
<td>5.12</td>
<td>5.29</td>
<td>4.89</td>
<td>5.81</td>
<td>5.163</td>
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<tr>
<td>Protein content, %</td>
<td>12.4</td>
<td>14.8</td>
<td>14.1</td>
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<td>13.8</td>
<td>13.7</td>
<td>13.93</td>
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<tr>
<td>Gluten content, %</td>
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<td>36</td>
<td>33</td>
<td>27</td>
<td>29</td>
<td>29</td>
<td>31</td>
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<tr>
<td>Dough strength, W</td>
<td>207</td>
<td>336</td>
<td>127</td>
<td>261*</td>
<td>281*</td>
<td>364</td>
<td>263</td>
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<td>Loaf volume, ml</td>
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<td>527</td>
<td>383</td>
<td>547</td>
<td>463</td>
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<td>487</td>
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<td>4.0</td>
<td>2.2</td>
<td>4.4</td>
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<td>3.6</td>
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<td>Yield, t/ha</td>
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<td>4.89</td>
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<td>12.5</td>
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<tr>
<td>Gluten content, %</td>
<td>31</td>
<td>36</td>
<td>29</td>
<td>24</td>
<td>24</td>
<td>25</td>
<td>28</td>
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<tr>
<td>Dough strength, W</td>
<td>192</td>
<td>366</td>
<td>83</td>
<td>200*</td>
<td>105*</td>
<td>275</td>
<td>204</td>
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<tr>
<td>Loaf volume, ml</td>
<td>510</td>
<td>540</td>
<td>377</td>
<td>500</td>
<td>453</td>
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<td>3.8</td>
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<td>3.5</td>
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<td>Yield, t/ha</td>
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<td>3.33</td>
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<tr>
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<td>13.0</td>
<td>11.5</td>
<td>11.6</td>
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<td>11.9</td>
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<td>32</td>
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<td>23</td>
<td>23</td>
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<td>26</td>
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<tr>
<td>Dough strength, W</td>
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<td>295</td>
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<td>196</td>
<td>128</td>
<td>244</td>
<td>192</td>
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<td>Loaf volume, ml</td>
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<td>477</td>
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<tr>
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<td>3.8</td>
<td>2.6</td>
<td>2.6</td>
<td>3.8</td>
<td>3.6</td>
<td>3.4</td>
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</table>

* - two year data; ** - LSD - 2.8 t/ha; *** - LSD - 3.3 t/ha.
The National Center for Plant Genetic Resources of Ukraine has collected and summarized information on the geographical and genetic origin of nearly 700 entries of *T. aestivum* possessing wheat-rye translocations 1BL/1RS and/or 1AL/1RS. Some of these cultivars (more than 400) have been studied in field and laboratory experiments of the National Center. Seeds of most entries are being conserved.

Rye chromosome 1R is now present in many commercial cultivars and breeder lines, mainly as the 1RS translocation. Cultivars that carry the translocation demonstrate high yield potential and wide adaptation as well as disease and pest resistance. Due to this combination of traits, these cultivars cover large areas in many countries of the world. Cultivars with the 1BL/1RS translocation have comparatively poor baking properties, despite high protein content.

The short arm in the 1BL/1RS translocation was found to carry genes for stem rust resistance (*Sr31*), leaf rust (*Lr26*), yellow rust (*Yr9*) and, possibly, gene *Pm8* for powdery mildew resistance. The gene *Pm8* is believed to be linked to rust resistance genes (Bartos, 1993).

Investigations carried out in the 1930s by two German scientists played an important role in the dissemination of cultivars having the wheat-rye translocation in the 1970s and 1990s. G. Riebesel used Petkus Rye in wheat breeding and G. Katterman used it in triticale.

The first commercial variety with the 1BL/1RS translocation was selected from Dr. G. Riebesel's lines. Salzmunder Bartweizen was released in 1957 (it had synonyms: Halle 14-14, ST 14-14, Neuzucht 14-14 etc.). The first selection from the lines of Dr. G. Katterman - Markus was released in 1963. Since then, about 90 winter wheat cultivars derived from these lines were commercially grown in a number of countries in Western and Eastern Europe and North America (Tables 1, 2).

Data in Tables 1, 2 and 3 were collected from many references, including publications by Bartos et al., 1973; 1985; 1987; 1990a; 1990b; 1993; 1994; 1995; Rabinovich, 1972; Mettin et al., 1973; 1978; Zeller, 1973; Zeven et al., 1976; 1991; Catalogue..., 1983; 1991; 1992; Sharma et al., 1983; Wheat varieties..., 1986; Beschreibende sortenliste..., 1987; 1991; Heun et al., 1987; Limpert et al., 1987; Dorofeev et al., 1987; McIntosh et al., 1988, 1995; Roelfs, 1988; Villareal, Rajaram, 1988; Babajantz. 1990; 1990; Lyfenko et al., 1990; Martynov et al., 1990; Roelfs et al., 1992; Bartos, 1993; Seidler et al., 1994; Baezinger et al., 1995.

While preparing this publication, we assumed that a genotype possesses the 1BL/1RS translocation if the reference mentions the results of electrophoresis of gliadines or identified the genes for rust resistance (*Sr31*, *Lr26*, *Yr9*) and powdery mildew (*Pm8*).

Ukrainian wheat varieties Mirleben, Mironovskaja 27, Mironovskaja 30 and Mironovskaja 61 derived from G. Riebesel's lines (Catalogue..., 1991) are being cultivated on considerable areas in Ukraine and Russia.

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descendant of MironovskaJa 61, new cultivar Mona was released in the Czech Republic in 1994 and Trane in 1995. It carries the 1BL/1RS translocation and differs from cultivar Mona, which has the same translocation, but is more resistant to powdery mildew and yellow rust races virulent to Yr9 (Bartos, et al., 1995). The Romanian varieties Lovrin 10 and Lovrin 13 (both have Neuzucht in pedigree) were used in breeding a number of lines in the 1990s in Syria, Turkey and China. Lines NE91648 and NE91651, derivatives of Lovrin 13 (Baenziger et al., 1995), will be possibly released in 1996 in the USA. More than 50 derivatives of CIMMYT line Alondra (German cultivar Weique in pedigree) were released in 12 countries in the 1980s and 1990s.

German cultivar Apollo, released in the 1980s in four European countries, is a derivative of Riebesel and Katterman lines. There are many cultivars which have the wheat-rye 1BL/1RS translocation: Albrecht, Arber, Kniros, Palur, Trone (80-90s, Germany), Flamingo (90s, Denmark), Delta, Weneda (70-80s, Poland), Don-Xie 3, Don-Xie 4, Fen-Kang 2, Fen-Kang 8, Jan 7770-4, Jing-Dan 106, Lu-Mai 1, Yl78-7078 (China) and others but we do not know their pedigree and the source of translocations. On the other hand, there are more than 20 cultivars which have 1BL/1RS translocations but their pedigree does not indicate the source of translocations.

The remarkable example of the utilization of Dr. G. Riebesel's lines by Russian scientist P.P. Lukyanenko began in the mid 1950s at Krasnodar Agricultural Research Institute (now named after P.P. Lukyanenko). In the 70s cultivars Aurora, Kavkaz and Bezostaja 2 were created under his leadership - all three from the cross Neuzucht/Bezostaja 4//Bezostaja 1. His varieties Skorospelka 35 and Predgornaya 2 also have Neuzucht in their pedigree. Dr. P.P. Lukyanenko (1967) wrote at that time: "New cultivars combine disease resistance with high yield potential, lodging resistance, good grain quality and other valuable traits. There are no winter wheat varieties with the high yield and resistance to different rust species in the world collection. That is why we consider these new cultivars to be valuable parental material for breeding rust resistant winter and spring wheat cultivars for other zones of the Soviet Union." The reality has surpassed all his expectations.

In 1958, three years after Dr. P.P. Lukyanenko began using G. Riebesel's lines in wheat breeding, V.N. Remeslo at Mironovka Experimental Breeding Station near Kiev (now named after V.N. Remeslo) received descendants of G. Riebesel's lines, wheat-rye hybrids (WRH), which were used to create new germplasm - the best variety Mironovskaya 10 - Mironovskaya 264/WRH 48-49(ERSP 2107)//Bezostaja 1 (Remeslo et al., 1976).

Cultivars Aurora and Kavkaz (and three other cultivars) were not widely cultivated in the USSR or in European and Asian countries during the 70s and 80s. Aurora and Kavkaz, which covered 2 million ha in the USSR, became susceptible to a new biotype of leaf rust race 77 in 1973. After that the area under these cultivars was reduced. These two varieties served as parents for a number of cultivars released in the 70s and 80s in the USSR. One of them—Mironovskaya 10—was selected in 1973, and when Aurora and Kavkaz became highly susceptible to leaf rust it did not lose its value. In 1979-1991 in Ukraine, Russia and Kazakhstan five varieties were created and two of them—Mironovskaya 28 and Kustanayskaya winter (Komsomolskaya 56)—were released in the 90s. At the same time, varieties Aurora, Kavkaz and Skorospelka 35 were being used in a number of countries in Europe, Asia, North and Latin America either as parents or for production (Table 3).

Pedigree analyses of 172 cultivars and lines developed from CIMMYT germplasm and released only in the 90s in 30 countries (Semidwarf... , 1995) show that 60% of entries have parents with the wheat-rye 1BL/1RS
translocation. These are Kavkaz, Aurora, Alondra and/or their derivatives Veery (VEE) and Bobwhite (BOW). Recently Veery derivatives (based on a Kavkaz cross) have become very popular: Genaro 81 (GEN) 81, Glenson 81, Ures 81, Seri 82, Tody (VEE/BOW), Loxia (BOW/GEN).

The 1-5 FAWWON (Facultative and Winter Wheat Observation Nursery) distributed by CIMMYT/Turkey in 1991-1995 contained nearly 700 entries from 17 countries. Among 505 cultivars and lines which have pedigrees listed in the FAWWON, 214 entries (45%) are descendants of wheats with the 1BL/1RS translocation. Among them are 16 derivatives of Lovrin 10 and Lovrin 13, 16 of Alondra, 29 of Aurora, 136 descendants of Kavkaz, including 51 derivatives of VEE, 46 of Seri 82 and 12 of Siouxland from USA. There are only four descendants of Amigo that have the 1AL/1RS translocation.

According to The et al. (1992) and Sebesta et al. (1994a, 1994b, 1994c), the variety Amigo was released in 1976. Its pedigree is Teewon (Ag. elongatum in pedigree)/triticale 8 x Gaucho (Chinese spring/rye Insafe F.A.+ colchicine)/63PC42-4/Teewon Sib. Amigo with the 1AL/1RS translocation carries two genes for stem rust resistance. One of these genes is associated with a rye chromosome 1RS segment carrying Sec 1 protein marker and presumably gene Gb2 for resistance to greenbug biotypes A, B and C. The mildew resistance gene designated Pm17 in Amigo is different from Pm8 present in the 1RS chromosome segment deriving from Petkus rye (Heun et al., 1990). Genes Sr24 and Lr24 were inherited by Amigo from Ag. elongatum. Amigo is also resistant to wheat curl mite (Eriophyes tulipae Keifer) (Sebesta et al., 1994b).

The lines from Oklahoma GRS 1201 (1AL/1RS translocation) released in 1992 and GRS 1205 with an entire rye chromosome (1RL/1RS) substituted for wheat chromosome 1A have inherited resistance to greenbug biotypes B, C, E, G and I from rye. The pedigree of both lines is short wheat selection/Scout/rye Insafe F.A. Amigo and GRS lines carry different alleles at Sec 1 locus. GRS 1201 also carries stem rust resistance genes Sr5, Sr7b and Sr17, but is susceptible to wheat curl mite and powdery mildew (Porter et al., 1993).

The following commercial varieties were released in the USA using Amigo and its derivatives as parents in the 80s and 90s: Century (Oklahoma), TAM 107, TAM 200, TAM 201 (Texas), Nekota, Neobara (Nebraska), OH 416 (Ohio). In addition, variety Embrapa 16 was released in Brazil and a number of breeding lines were created in the Great Plains of the USA.

Another carrier of the wheat-rye translocation - accession ST-1 (in pedigree wheats Norin 40, Aobakomugi and Petkus rye), which was introduced from Japan and characterized by leaf rust resistance, consists of two distinct morphological biotypes. One biotype possessed the 1BL/1RS chromosome with genes Lr26, Sr31, Yr9. The second biotype carried a new gene, Lr45, located on the large segment of the rye chromosome transferred to wheat: chromosome 2A - 2AS/2RS.2RL (McIntosh et al., 1995). Despite the homeology of the 2A and 2R chromosomes and the high level of compensation provided by the translocation, Lr45 was not normally inherited and is probably associated with agronomic deficiencies that will prevent its exploitation in breeding. Nonetheless, isogenic line RL6144 (Thatcher*7/ST-1) possessing Lr45 was created.

The wheat-rye 2BS/2RL translocation present in the variety Hamlet derived from a cross between Champion rye and hexaploid wheat. It possesses gene H21 which protects against Hessian fly biotype L, the most virulent biotype presently found in Kansas (Lee et al., 1995).

We suppose that in the next century the frequency of varieties with wheat-rye translocations will not decrease taking into consideration that they are being widely used in both intra and interspecific crosses. The confirmation of this can be pedigrees of cultivars Pasian 90 and Rohtan 90 recently released from CIMMYT material in Pakistan. Genaro 81 with 1BL/1RS and A. distichum participated in the cross. CIMMYT
lines Cugap and Mayoor, resistant to foliar blight in Nepal (Bhatta et al., 1995), Chiria 1 and Chiria 7 (in pedigree Alondra, Glenson 81 - both with 1BL1RS and *Ae. curvifolium*). Leaf rust resistant line from USA - KS94WRGC32 (TAM107-1AL,1RS*2//KS8010-1-4-1-1BL,1RS/TA 359 - *T. beuticicum* in 1994 demonstrated grain yield 12 and 20% higher compared respectively to TAM 107 and Karl 92, two leading cultivars in Kansas (Cox et al., 1995).

References


### Table 1. European and North American derivatives of Riebesel lines.

<table>
<thead>
<tr>
<th>Country</th>
<th>Variety</th>
<th>Year of release</th>
<th>1B/1R presence</th>
</tr>
</thead>
<tbody>
<tr>
<td>England</td>
<td>Beaver, Haven, Hengehog, Hornet</td>
<td>1970-90</td>
<td>+</td>
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<tr>
<td></td>
<td>Admiral, Conveyor, Hornet, Wand</td>
<td>1960-90</td>
<td>-</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Clement, Mildress, Nautica</td>
<td>1960-70</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Donata, Donjon, Vasco</td>
<td>1970-80</td>
<td>-</td>
</tr>
<tr>
<td>Germany</td>
<td>Almus, Apollo, Orlando, Saladin, Weique, Wentzel, Winnetou</td>
<td>1960-80</td>
<td>+</td>
</tr>
<tr>
<td>Czech Rep.</td>
<td>Mona</td>
<td>1994</td>
<td>+</td>
</tr>
<tr>
<td>Romania</td>
<td>Lovrin 10, Lovrin 12, Lovrin 13, Lovrin 24, Lovrin 41</td>
<td>1970-80</td>
<td>+</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>Burgas 1, Burgas 2</td>
<td>1970</td>
<td>+</td>
</tr>
<tr>
<td>Mexico</td>
<td>Alondra</td>
<td>1974</td>
<td>+</td>
</tr>
<tr>
<td>Chile</td>
<td>Cunco INIA, Dalcachue INIA, Laurel INIA, Perquenco INIA, Talafen, Temu 39-76</td>
<td>1970-80</td>
<td>-</td>
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* - identified; ** - supposed from pedigree

### Table 2. European and North American derivatives of Katterman lines.

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<td>England</td>
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<td>Netherlands</td>
<td>Ricardo, Trident</td>
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<td>Switzerland</td>
<td>Bernina, Forno, Tamaro</td>
<td>1980</td>
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<td>Austria</td>
<td>Flamulus, Gabrinus, Pantus, Titus</td>
<td>1980</td>
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<tr>
<td>Slovakia</td>
<td>Branka</td>
<td>1988</td>
<td>+</td>
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<td>Chile</td>
<td>Austro BAER, Impacto BAER</td>
<td>1980</td>
<td>-</td>
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* - identified; ** - supposed from pedigree
Table 3. Derivatives of Russian cultivars Aurora, Kavkaz and Skorospelka 35.

<table>
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<th>Variety</th>
<th>Year of release</th>
<th>1B/1R presence</th>
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<td><strong>Derivatives of Aurora</strong></td>
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<tr>
<td>Poland</td>
<td>Koda, Lanca</td>
<td>1980</td>
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<td>Slovakia</td>
<td>Amika, Agra, Danubia, Istra</td>
<td>1970-80</td>
<td>+</td>
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<td>Hungary</td>
<td>GK Odzi, GK Szemes, GK Sagvari</td>
<td>1970</td>
<td>-</td>
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<tr>
<td>Romania</td>
<td>Fundulea 29, Transilvanya 1</td>
<td>1970-80</td>
<td>+</td>
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<tr>
<td>Romania</td>
<td>Fundulea 4, Singron</td>
<td>1980-90</td>
<td>-</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>Abnutis, Kaloyan, Kardam, Kurbat, Pieta</td>
<td>1970-80</td>
<td>+</td>
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<tr>
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<td>Dunavka, Jantor, Janos, Momchil, Pjaspa</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Rosica, Rusalka podobrena, Trajana</td>
<td>1970-80</td>
<td>-</td>
</tr>
<tr>
<td>Slovenia</td>
<td>Pitoma, Siroka, Sloboda</td>
<td>1980</td>
<td>-</td>
</tr>
<tr>
<td>Croatia</td>
<td>Dukat, Granka</td>
<td>1980</td>
<td>-</td>
</tr>
<tr>
<td>Serbia</td>
<td>Apatinka, Jugoslovia, Kozara, Lichanka, Pomoravka, Somborka, Slaparka, Slizanka, Sutejska, Zelengora, Zemunka</td>
<td>1970-80</td>
<td>+</td>
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<tr>
<td></td>
<td>Banatka niska, Ionija 89, Jednota, Kaljevica, Lasta, Nova posavka, Pansevka, Podunavka 1, Podunavka 2, Sansevka, Subotanka</td>
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<td>Belarus</td>
<td>Nadzeja</td>
<td>1987</td>
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<td>Ukraine</td>
<td>Chersonskaja 153</td>
<td>1979</td>
<td>-</td>
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<td></td>
<td>Vympel odesskiy</td>
<td>1995</td>
<td>-</td>
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<tr>
<td>Russia</td>
<td>Zernogradka 2</td>
<td>1980</td>
<td>+</td>
</tr>
<tr>
<td>USA</td>
<td>NE89528, HBF0551-137 (KS), TX90D9277</td>
<td>1980-90</td>
<td>-</td>
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<tr>
<td></td>
<td>Tens lines including N87L207, N88L243, NE90625, OK83398</td>
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<td>+</td>
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<tr>
<td><strong>Derivatives of Kavkaz</strong></td>
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<td></td>
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</tr>
<tr>
<td>Austria</td>
<td>Amadeus, Campus, Compact</td>
<td>1980</td>
<td>-</td>
</tr>
<tr>
<td>Slovakia</td>
<td>Butin, Ilona, Iris, Livia, Roxana, Solaris, Vlada</td>
<td>1970-90</td>
<td>+</td>
</tr>
<tr>
<td>Hungary</td>
<td>Martonvasar(MV) 14, MV15, MV17;</td>
<td>1970-80</td>
<td>+</td>
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<td></td>
<td>GK Zombor</td>
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</tr>
<tr>
<td></td>
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<td>1980-90</td>
<td>-</td>
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<tr>
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<td>1970-80</td>
<td>+</td>
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<tr>
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<td>Marija, Zltanka</td>
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<tr>
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<tr>
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<td>Skopjanka, Stema</td>
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<td>1980</td>
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<td>Ukraine</td>
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<td>1990</td>
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<td>USA</td>
<td>Siouxland, Rawhide, Siouxland 89, OH 876, NE89526, HBF0551-137, TX90D9297</td>
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<td>More lines, including NE89526, TX90V6328, TX90V6329, TX91V3139</td>
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<td><strong>Derivatives of Skorospelka 35</strong></td>
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<td>Tertel, Tervel</td>
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<td>Balkan, Novosadska Brkula, Posavka 1, Posavka 2, Iskra, Podunavka 3</td>
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<tr>
<td></td>
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* - identified; ** - supposed from pedigree
More than 50 wheat (*Triticum aestivum* L.) cultivars have been developed at the Mironovka Wheat Institute in Kiev, Ukraine, including seven spring wheats. Twenty-one varieties have been cultivated on a large scale, of which 11 winter wheat cultivars are being currently cultivated in Ukraine, the Baltic states and other countries of the Commonwealth of the Independent States. They are Mironovskaya 808, Mironovskaya jubileinaya, Mironovskaya 40, Mironovskaya 61, Mironovskaya 27, Mironovskaya 28, Mironovskaya 30, Mironovskaya semi-intensive, Mironovskaya awned, Mirleben, Volgogradskaya 84 and one spring wheat cultivar: Mironovskaya yarovaya. Nine winter wheat cultivars and one spring wheat cultivar are being tested in the Ukrainian State Variety Release Yield Trials at present. Some are also being officially tested in Russia, Belarus, Moldova and the Baltic states.

Various methods were used in the breeding program in the Institute. The first variety Ukrainka 0246 was developed in Mironovka by selection from the landrace Banatka introduced from Hungary. The second generation of varieties (Mironovskaya 264, Kievskaya 893 and Mironovskaya 808) was developed using the method of V.N. Remeslo: transformation of spring type wheats into winter type. Cultivars Artyomovka and Narodnaya, which used to be widely grown in Ukraine, as well as Ukrainka from southern Kazakhstan, were used as initial material for transformation. It should be noted that spring wheat cultivars were developed in Southern Kazakhstan on the basis of Ukrainka 0246. While developing the third generation of cultivars different breeding methods were used. Very successful varieties, Mironovskaya jubileinaya, Illichovka and Mironovskaya 25, were developed by individual selection from segregating populations derived from crosses with wheats from the Northern Caucasus of Russia (Bezostaya 4, Rannyaya 12).

In the early 1970s, new methodological approaches and development of breeding materials by hybridization of spring forms with winter ones, interspecific and intergeneric crosses, utilization of experimental mutagenesis, breeding work under bilateral international programs with Germany (GDR), Czechoslovakia, Poland, Bulgaria and Hungary were initiated. Breeding process thanks to international cooperation and with the research assistance of wheat department of the Vavilov Institute of Plant Industry (VIR) started to accumulate the world diversity of wheat germplasm. This made it possible to develop the fourth generation of wheat cultivars being used in production now and occupying about 25% of wheat area in Ukraine as well as being cultivated in the CIS.

Among the cultivars of the fourth generation, Mironovskaya 61 is the most widely spread. It was developed in the framework of a joint program with breeders from Germany. The entry 6508/74 brought from Germany was crossed with Illichovka following the individual selection within the framework of the same program. Variety Mirleben was developed by selection from cross 16208/83 (Line 24833-75//Gaines/6*Mir.808/3//Alcedo) (Germany) under Mironovka conditions. The method of recurrent selection from lines of hybrid origin proved to be productive. The cultivar Mironovskaya ostistaya (awned) was created by individual selection from the line Eritrospermum 4736 which in turn was obtained by individual selection from population deriving from a cross between spring wheat Narino 59 from Colombia and winter wheat Mironovskaya 30 (intravarietal selection from line Lutescens 10795), subsequently Mironovskaya 27 which

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1. V.N. Remeslo Mironovka Wheat Institute, p/o Tsentraineo, Mironovka dist., Kiev reg., 256816 Ukraine.
is based on a cross Lutescens 6915/Lutescens 6538. In this cross the line Lutescens 6538 brought in germplasm from Germany which was selected under local conditions. The elite plant of the new cultivar Mironovskaya 33 was selected from the line Lutescens C.h 172/90 developed from a cross between Lutescens E.g.32/82 (Maris Templar/Illichovka) and Lutescens C.h.6/82 (population from Czechoslovakia - NS984/Kavkaz/Roazon selected under Cercospora herpotrichoides From infection).

Using transformation of growth habit the following varieties were created: Mironovskaya 40, from Mexican spring wheat Siete Cerros 66; Mironovskaya 29, from BT-2288 (Tunisia); and Mironovskaya 34, from Kommunar (Krasnodar, Russia). Individual selection from segregating populations was the main method used in developing the fourth generation of varieties. Nine new winter wheat cultivars were produced on the basis of crosses between local germplasm and foreign advanced material. As mentioned above, Mironovskaya 27 was developed with the help of a breeding line from Germany. Mironovskaya 28 was produced from a cross between the local line Lutescens 7696 and Krasnodarskaya 57 from the Northern Caucasus region of Russia. Cultivar Mironovskaya semintensive was developed from hybrid Maris Templar/Illichovka. With the help of winter wheat germplasm from Czech Republic and Slovakia (SK-2542, KM 610, Vala), varieties Mironovskaya 62 (Illichovka/SK-2542), Mironovskaya 64 (Mironovskaya yubileinyaya/KM610) and Mironovskaya 32 (Vala/Illichovka/Mironovskaya 27) were developed. The cultivar Mironovskaya 63 (Donskaya semidwarf/Lutescens 9217) has in its pedigree Donskaya semidwarf wheat developed at the Don Breeding Center (Russia) and Lutescens 9217. The latter was developed in Mironovka by individual selection from a population obtained by crossing a breeding line from the Institute in Hadmersleben (Germany) and Yershovskaya 3, a wheat from the Volga region of Russia. Cultivar Mirich (Lutescens 8133/Yantar//Mironovskaya 27) was developed with the help of Bulgarian cultivar Yantar. To develop variety Mironovskaya 31 (Lutescens 7792/F 29-76//Erytrospermum 7820), Romanian germplasm (F 29-76) was used.

Among the spring wheat cultivars developed in Mironovka two were obtained by transformation of growth habit (winter wheat into spring): Mironovskaya yarovaya from Mironovskaya 808, and Mironovskaya rannyaya from Rannyaya 12 (Northern Caucasus, Russia). Other spring cultivars were produced on the basis of hybridization. Mironovskaya 3 and Mironovskaya 4 were selected from a cross between spring wheat Siete Cerros 66 and winter cultivar Lutescens 3067 (developed by transformation spring wheat entry from India into winter wheat). Spring x winter cross Nanno 59/Jara//Mironovskaya 808 appeared to be very successful and resulted in cultivar Mironovskaya krupnozernaya. Variety Mironovskaya 5 was selected from cross MME-10-8-5/2*Mironovskaya yarovaya. New cultivar Myronivchanka was developed on the basis of a cross between German line Weihenstephan 14 selection with winter wheat Mironovskaya 808 and is currently being tested in the State Variety Release Yield Trial.

As one can see while developing spring cultivars wheat germplasm from Russia, Germany, Mexico, Colombia and India were used along with landraces and modern lines.

When discussing the utilization of foreign wheat germplasm in Mironovka Institute, it should be noted that winter wheat cultivars developed here were also being frequently used in breeding programs in many countries. As Rabinovich (1992) pointed out, more than 60 winter wheat varieties were developed with the participation of Ukrainka 0246 in 1930-1970 including more than 30 in Ukraine. Thus, genes from this cultivar are also carried by such well-known cultivars as Belotserkovskaya 198 and Bezostaya 4 from which famous Bezostaya 1 was developed. With the immediate participation of Mironovskaya 808 more than 140 winter wheats varieties were produced and 30 of them were cultivated in the territory of the former USSR.
including six spring wheats. More than 50 varieties currently cultivated in seven countries of Europe, Canada and Chile are offspring of Mironovskaya 808. Varieties Mironovskaya 264, Mironovskaya jubileinaya, Illichovka and others were also successfully used as parents. Since the 1960s about 250 wheats have been developed with the participation of Mironovka wheats including 30 spring genotypes. There are 120 varieties among them in the world which are being used for grain production. Some foreign offspring of Mironovka wheats were singled out as valuable breeding material.

Of the Mironovka wheat cultivars mentioned in this paper, more than 10 were developed with the help of foreign germplasm which has early Mironovka cultivars in its pedigree, i.e. Ukrainka 0246 and Mironovskaya 808. In general, we have noted such a peculiarity in developing Kiyevskaya 893. Seven more cultivars (Mironovskaya jubileinaya, Illichovka, Mironovskaya 25, Mironovskaya 33, Mironovskaya 28, Mironovskaya 63 and Mirich) also possess Ukrainka 0246 in their pedigree via utilization of Bezostaya 4 and its derivatives. Mironovskaya 808 is present in the pedigree of foreign wheats: line 16208/83 from Germany (parent of Mirleben), Severodonskaya from Russia (parent of Mironovskaya 63), Vala from the former Czechoslovakia (Moisson/Mironovskaya 808, parent of Mironovskaya 32), Krasnodarskaya 57 (Krasnodarskaya 39/Krasnodarskaya 6//Bezostaya 2/Mironovskaya 808, parent of Mironovskaya 28).

Utilization of foreign germplasm in breeding of Mironovka cultivars first of all was connected with the necessity of introducing the following characters: short stature, resistance to fungal diseases, improved spike potential. These traits have been successfully transferred into modern Mironovka winter wheat cultivars. New cultivars are characterized by short stem, better resistance to diseases, fertile spike and high 1000 kernel weight. In breeding winter and spring wheat germplasm from Russia, Germany, Hungary, Bulgaria, Czech Republic, Slovakia, England, France and other countries is being widely used. Cultivars with resistance to fungal diseases combined with short stature are most interesting.

Within the past few years direct contacts have been established with wheat breeders from the International Wheat and Maize Improvement Center (CIMMYT). This has made it possible to implement exchange of new varieties with CIMMYT. Material received from CIMMYT needs to be thoroughly studied. Analysis of pedigrees of introduced germplasm shows that only few entries were developed with participation of Mironovka cultivars or their derivatives.

The contribution of germ plasm from Europe is also relatively small. It is interesting to note the presence in the pedigree of CIMMYT entries wheats from North America. Many of them are offspring of Turkey, Tenmarg, Oro, Nebred, Kanred, Cheyenne and other varieties which derived from landrace Krymka imported late last century by immigrants from Russia to Kansas. Large scale utilization of winter x spring crosses which involve germplasm of different genetic and geographic variability is extremely useful for improving both winter and spring wheats.

As far as CIMMYT spring wheat is concerned, the very early lines are of particular interest for our environment. These are represented by the following crosses: TUI, BAGULA, ATTILOA, ROLLER, PRINIA, SHA 7/KAUZ, SHA 7/PRL/VEE#6, LIRA/PRL/VEE#6, LIRA/TAN, MILAN/AMSEL, KAUZ/PRL/VEE#6, F6.74/BJN/SIS/3/LIRA, GIM/KAUZ, BUC/BJY/PRL/VEE#6, CNO79/PRL/CHIL, AGA/4*YR/4*IMV/3/SHA7, F12.71/COC/CNO 79/3/MILAN, AMSEL/TUI/CUL/ACAN, MLT/TUI/TUI and others. Most spring wheat entries are intermediate early and intermediate in maturity.
The combined resistance to leaf rust and powdery mildew of spring wheat lines was revealed in crosses MILAN, TNMU, FILIN, LIRA/SHA5, MILAN/WUH1, GLEN/BOW//TRAP#1, F60314.76/MRL/CNO79, BJY/COC. Good resistance to leaf rust can be found in most entries. Most spring wheat entries reveal intermediate or low intermediate resistance to powdery mildew. Practically all the material is short representing dwarf and semidwarf forms. In the field conditions of the forest-steppe zone of Ukraine, about 25% of CIMMYT spring wheat lines were equal to checks in yield and a few exceeded checks in favorable years.

CIMMYT spring wheat lines selected for earliness, fungal diseases resistance, yield potential and other traits are used in breeding work to carry out intravarietal, individual, negative and bulk selections. They are also involved in crosses with spring and winter wheats to develop new spring wheat germplasm for Ukrainian conditions. The very best entries combining at least three useful characters (short stature, earliness, resistance to fungal diseases and others) are being used in winter wheat breeding programs.

Very vast and diverse material is represented in CIMMYT’s facultative wheat nursery. As far as growth habit is concerned, there are materials varying from typical spring ones to strictly winter. On the basis of vernalization requirements, this material can be subdivided into spring and winter materials. In order to do this one can use controlled conditions in artificial climate to ensure vernalization regime for 30 days and enhanced development during growth periods. Under field conditions one can differentiate wheat into spring and winter lines when sown in early spring. Late spring sowing ensures heading and formation of seeds only in typical spring lines: semi-winter and winter lines do not produce seeds under such conditions. Wheat planting within dates which are optimal for winter wheat will cause total death of typical spring wheat and some semi-winter lines in years with severe cold weather. Therefore, the material should be divided into two parts at the beginning of testing. The first part is to be sown in early spring period; while observing heading stage, one should identify typical spring lines (they head simultaneously with spring checks), semi-winter (heading is delayed 4 or more days) and winter ones (failure to head). Based on the results of heading, the second set of seeds can be conditionally divided into spring and winter lines that can subsequently be utilized in breeding spring and winter wheats. In some cases the best samples are being used in breeding both types of varieties.

In 1994-1995 more than 1000 entries of winter and facultative wheat from the nursery EPCME7WF were studied. One set of seeds was sown in spring 1994 (April 22). Under the conditions of short vernalization period, significant differences for heading date were observed. Thus, particular selections from the cross 1D13.1/MLT (PYTME7WF-47) and PI/FUNO*2//VLD/3/CO723595 (PYTME7WF-1116) headed very early, just before June 20. Several (or most) selections from crosses Batera, Monarcha, HYS/CNDR//VEE#5, AG/ASN//ATR/3/SRS35 headed on June 21-25. Most materials headed later than June 26 and termination of heading was observed at the end of July. The same nursery being sown in spring 1995 fully confirmed the results of the previous year. About half of the material planted in 1994 failed to head. These entries were planted in autumn for the forthcoming 1995 winter crop. The results obtained show that most of these lines demonstrated winter hardiness comparable to local checks: varieties Mironovskaya 808, Mironovskaya 61 and Donskaya semi-dwarf. It should be noted though that the winter of 1994-95 was not severe. Among the best crosses were ORIGMA, PYN, BWD, KS81306, TAM105.R, TURKEY13, 84.40022, RECITAL, NEMURA/SPB, SAULESKU#26, BILINMIYEN 85.6, GP 3357, OK 82282, MVR 9, MVR 12, PLISKA, IENA, IPP010, CO72.3839//T-R, HYS/R37/GHL121, NAI 60/HEINE VII//BUC, NAI 60/HEINEVII//BUC/3/F 59.71/GHK, SDY/SERI, WRM/4/FN3*TH//K58/2*N/3/MY54/N10B//AN/5/PEL 72380/ATR 71 and others. Under conditions typical for winter wheat growth in Mironovka, most of these entries headed simultaneously with
Mironovskaya 61 (intermediate maturity) or with differences of two-three days. A number of entries headed 3-6 days later than Mironovskaya 61 and could be classified as a late maturing group. This group includes selections from NEMURA, some selections from ORIGMA, SDY/SERI, NEMURA/SPB and the majority of selections from TL.75.2534, 494J6.11. BWD, 84.40023.

On the whole when characterizing CIMMYT germplasm for other traits, it should be noted that the overwhelming majority of entries are short (plant height 65-85 cm) when sown both in spring and in winter. However, plant height varied from 55 to 103 cm. Most samples have intermediate or high resistance to leaf rust (5-7-9 scores). For powdery mildew and septoria resistance, intermediate, low-intermediate and low (5-3-1 scores) estimates prevail. Particular selections, however, were noted for high resistance to powdery mildew (7-9 scores) and high-intermediate resistance to septoria (7 score). Some selections from the following crosses were characterized by resistance to three mentioned diseases (powdery mildew, leaf rust and septoria). Resistance scores are given in brackets: PYN17717/BOW (7-7-5), VORONA/SERI(5-9-5), TJB916.46/CB 306/2*MHB/3/BUC(5-9-5), PYN(5-7-7), BWD(5-7-5), OK81306 (7-7/9-5/7), TAM105.R (5-7-9-7), TX73V203*3/AMI (5-7/9-9-7), TAM 200 (9-7-9-7), TX86 V1405 (7/9-7-7), STOZHER (9-9-5), R37/ GHL1/21 (5-7-7), BILIMMIYEN 85.6 (5-7-7), CSM/ODESSK. 51/T101 (5-9-7), SDY*3/AMI(9-9-7), TX71A1039.V1*3/AMI (7/9-9-7). Utilization of CIMMYT wheat germplasm as parental material for developing winter wheat varieties in Mironovka is connected with resistance to major diseases.

The winter hardiness of the material mentioned above as well as of winter/facultative germplasm from Turkey distributed through the Facultative and Winter Wheat Observation Nursery (FAWWON) is good. Most entries (about 75%) survived very well (85-99%) under the favorable conditions of winter 1994-1995. The check varieties in the 4th FAWWON demonstrated the following winter survival rate: local check Mironovskaya 61 - 94%, Bezostaya 1 - 88%, SERI 82 - 47%, BOLAL - 90%, GEREK 79 - 88%, ATAY 85 - 91%. However, laboratory studies of frost tolerance by the method of seedling freezing (Samygin method) in comparison with the cultivars Mironovskaya 28 (medium-high frost tolerance) and Mironovskaya 40 (low-intermediate frost tolerance) showed that only a few entries achieved the level of the hardy check. Overwhelming number of entries were inferior to Mironovskaya 40 in frost tolerance. The best one among CIMMYT checks turned out to be GEREK, which was similar to Mironovskaya 40 but inferior to Mironovskaya 28.

The extensive study of CIMMYT wheat germplasm shows the possibility of using it as the source of earliness, resistance to fungal diseases (mainly to leaf rust) and spike productivity. These characters combined with semidwarf stature increases their breeding value. The truly diverse germplasm from CIMMYT both genetically and geographically makes it possible to select parental material with other valuable traits such as grain quality. At present the best CIMMYT spring wheat entries with a combination of useful agronomic characters are undergoing replicated yield tests. At the same time, the best spring and winter/facultative wheat entries have been included in the crossing program to develop new spring and winter wheats varieties for the conditions of Ukraine.

References

Developing Winter Wheat Germplasm of Woodlands Ecotype

Yu.V Olshanski, I.K Kotko, L.N Sheredeko, and V.P. Andriyash

During the past two decades harmful diseases of winter wheat capable of decreasing yield by 30% and more have spread widely on the right-bank forest-steppe zone and the woodlands of Ukraine. These are septoria, certain types of roots rots, powdery mildew and enzyme-mycosis depletion of grain. Their invariable epiphytotics revealed the absence of resistant genotypes in the assortment of winter wheat varieties cultivated in the region. Due to this a great number of cultivars were introduced into the region, including poorly adapted ones. Suffice it to say that more than 20 cultivars have been included in the state variety register list in this zone. This multivarietal phenomenon affects all-state systems of elite seed production negatively.

The lack of breeding material resistant and/or tolerant to above mentioned diseases and adapted to woodland conditions represents a major breeding challenge. Since 1980 much attention has been paid to disease resistance, along with productivity and grain quality. Up to 3000-5000 entries were screened annually, including 300-800 from collection nurseries.

It was found that among materials being used in the breeding process there are no genotypes which are absolutely resistant to root rots and septoria. Therefore one should only consider the degree of susceptibility which does not cause serious yield losses. For most types of root rots and septoria, a level of 10-20% was established and for powdery mildew, 25-30%. In 1981-1988 two cultivars relatively resistant to most aggressive diseases were identified (Table 1). In addition varieties Capelle Desprez, VPM-1, Roazon (France); Walda Holma (Sweden); Vaia, Slavia (Czech Republic), Remus, Pivot (Germany); Fuzz, Oasis, Arthur (USA), some accessions of T. spelta, Aegilops cilindrica; wheat-Aegopyron and wheat-Aegilops intermediate forms also demonstrated some resistance. However, when being crossed many of them cause problems due to poor winter hardiness and bread making properties. Cultivars from Mironovka Wheat Institute as well as those from Russia (Tambovitsa 12, Don 85, Severnaya zarya) and Ukraine (Donetskaya 48, Kharkovskaya 50, Strumok Odesskiy) are the best parents for crossing.

The weather conditions of 1994 allowed excellent differentiation for winter hardiness; data for some entries identified are presented in Table 2. The combination of traits mentioned above makes it possible to develop new breeding material representing woodlands ecotype.

A number of resistant varieties and lines have been developed by the department of breeding and seed production of the Ukrainian Academy of Agrarian Sciences. These are Polesskaya 87, Polesskaya 90, 7126-93 developed under artificial disease inoculation (Table 3).

Variety Polesskaya 90 has been released in the region of Kiev Breeding Center. It is characterized by high disease resistance with comparatively insignificant advantage in yield over the check (+0.22 t/ha). The grain quality of this variety is very good and it is classified as valuable quality wheat. It does not need chemical treatment against diseases and therefore is environmentally safe. The area planted under Polesskaya 90 totals about 50,000 ha.

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**Conclusions**

1. Research conducted in 1980-94 indicates that high and stable yields in the woodland zone of Ukraine can be obtained by cultivating varieties resistant to diseases and tolerant to stresses associated with extreme humidity of soil and air.

2. Screening of local and foreign germplasm allowed us to identify entries resistant to unfavorable local conditions. Crossing these genotypes with winter hardy and good quality varieties resulted in breeding materials with the right combination of desirable traits.

3. Newly released variety Polesskaya 90 possesses complex resistance to diseases and tolerance to specific conditions of the woodland zone. Its cultivation ensures environmentally friendly grain production. This variety will serve as a basis for future wheat improvement for the woodland zone of Ukraine.

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Table 2. Winter hardiness and other traits of the best entries identified in 1994.

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<table>
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<tr>
<th>Variety</th>
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<th>Yield (t/ha)</th>
<th>+ to check</th>
<th>Bread score</th>
<th>Winter survival (%)</th>
<th>Septoria</th>
<th>Leaf rust</th>
<th>Loose smut</th>
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<tr>
<td>Mironovskaya 61</td>
<td>4</td>
<td>5.71</td>
<td>-</td>
<td>4.0</td>
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<td>80</td>
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<td>70</td>
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<td>Polesskaya 87</td>
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<td>0.88</td>
<td>3.8</td>
<td>70</td>
<td>60</td>
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<tr>
<td>Polesskaya 90</td>
<td>4</td>
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<td>0.22</td>
<td>4.3</td>
<td>60</td>
<td>40</td>
<td>30</td>
<td>20</td>
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<tr>
<td>Polesskaya 92</td>
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<td>6.25</td>
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<td>3.9</td>
<td>80</td>
<td>70</td>
<td>50</td>
<td>50</td>
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<tr>
<td>7126-93 (Mironovskaya awned/1161-80)</td>
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<td>7.01</td>
<td>0.66</td>
<td>3.8</td>
<td>70</td>
<td>40</td>
<td>10</td>
<td>40</td>
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<tr>
<td>1411-93 (1161-80/mixture of pollen of Donskaya semidwarf + Zernogradka 6 + Donskaya int)</td>
<td>2</td>
<td>6.74</td>
<td>0.33</td>
<td>4.6</td>
<td>60</td>
<td>60</td>
<td>80</td>
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Chernobyl Radiomutants Obtained from Winter Wheat
Belotserkovskaya 47

L.A. Burdenyuk

Induced mutagenesis along with hybridization is used to develop breeding materials with a combination of useful agronomic characters. Since 1925 work by Nadson and Phillipov on yeast, by Meter on Drosophila and by Delone on wheat showed that exposure to radiation produces mutations. Many chemical and radiomutants have been obtained since then. According to investigations only 20% of mutations are useful; the rest are either freaks of nature or low yielding forms. Since frequency of induced mutations is by far higher than that of spontaneous mutations, one can improve a particular trait of a genotype without changing its other traits.

Four winter wheat cultivars—Beloserkovskaya 47, Polesskaya 70, Mironovskaya 808 and Kiyanka—were exposed to severe radiation at all stages of development due to being planted in 1986 and 1987 in the disaster area of the Chernobyl nuclear power plant. In 1988 harvested seeds were turned over to Belotserkovskaya Breeding Station to be studied by Academician L.M. Grodzinsky.

Radiobiological response of somatic and sexual cells affected by radionuclide pollution is connected to external and internal gamma radiation induced by radioactive isotopes as they are incorporated into wheat tissues (Grodzinsky et al., 1991). Differences were found among responses to radiation of cultivars and particular progenies. In this publication we describe only variations occurring within six generations of Belotserkovskaya 47 progeny. This variety is awned with white chaff and red grain. In the first cycle after radiation exposure (1989-90), 40 progenies of this variety appeared to be uniform in their morphology and biology, i.e. awned and homogenous in height, close to the original genotype but at the same time different from it by a slightly squarehead spike. Since in subsequent generations the squareheadness persisted (i.e. variation was genetic), we subsequently called it a mutation: BTS 47 squ. The rest of progenies were also squareheaded but segregated for the presence of awns with 1-20% of plants being without awns and with normal spike. Moreover, the single spike progenies of BTS 47 squ differed in height (variation 85-108 cm). In M3 all families that were heterozygous for awns and height were sown in head row. Control BTS 47 was sown along with mutants but never segregated awnless plants and was homogeneous for plant height. In M3 (1990) 11% of families out of 1030 continued to segregate awnless and semi-awned plants with asymmetric awns of various lengths and plant heights. All 15 awnless progenies segregated in M3 into awnless, semi-awned and awned plants, but awned families also segregated into the same type of plants. Segregation persisted until M7.

Watkins and Elerton (1940) reported that 5-6 genes control the presence of awns in wheat. Biffen (1906) demonstrated the dominance of the awnless type of spike. A somewhat different type of inheritance is observed after exposure to radiation. Altered characters such as awnless spike are inherited as recessive traits. As reproduction continues, the number of plants carrying the recessive genes in homozygous state increases in selfpollinating crops. In our case the number of awnless forms should increase. Radiation effects, however, complicated segregation in such a way that single head progenies of awnless and semi-awned mutants selected in M4 and M5 continued to segregate. For instance, awned mutant 20426 BTS 47

1 Belaya Tserkov Experimental Breeding Station, Belaya Tserkov, Ukraine.
squ produced 2% awnless plants in M3, which in M4 segregated 36% awned ones. Radiation seems to have changed the effects of a number of genes controlling the expression of awns.

Radiation effects are associated with the variety's genome. The ancestors of BTS47 are awned cultivar BTS 198 and awnless Bezostaya 1. One can suggest that when affected by radiation, parental genes are expressed. A wider range of mutations have been produced in BTS 47 squ progeny 765/89. As well as other BTS 47 squ, it segregated 3% awnless forms in M2 which in subsequent generations segregated into awned, semi-awned and awnless plants. But in M3 3 awnless spikes taken from the same plant produced various progenies: numbers 20045 and 20041 segregated awned and awnless plants while 20047 produced 85 awnless speltoides and 15 awned speltoides. In M6 and M7 speltoides segregated into speltoides, normal types and squarehead types with and without awns. The appearance of T compactum and T speltoides types in the mutant progeny may indicate that recessive c and s genes when exposed to radiation turned into dominant C and S. In one case the change of gene c into C produced T compactum, and in another the change of s into S resulted in the T spelta type. The T spelta type, in heterozygous state after self-fertilization, segregated T aestivum and T spelta types: cS - cs - cs + Sc. The same is true for T compactum mutations: Cs - cs - cs + CS. Speltoid S gene may be present consistently in bread wheat in the recessive state and not manifested in conventional intraspecific crosses but is expressed under extraordinary conditions, e.g. radiation exposure.

Abundant morphological variation after radiation exposure suggests the possibility of positive mutations occurring for productivity and other characters. Mutants of BTS 47 squ constant for morphological characters were tested in a preliminary yield trial using the initial variety as a check (Table 1).

At present more than 1000 BTS 47 squ mutants are being studied. Most of them are characterized by a combination of negative traits such as low yield, poor winter hardiness and low gluten quality. At the same time, homogeneous lines with particularly valuable characters (short, stiff straw, good root rot resistance and high gluten content) have been singled out and are being used as parents.

References


<table>
<thead>
<tr>
<th>Entry</th>
<th>Awns*</th>
<th>Heading date</th>
<th>Plant height (cm)</th>
<th>Leaf rust (%)</th>
<th>Winter survival score</th>
<th>Yield (t/ha)</th>
<th>Gluten content (%)</th>
<th>Gluten quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTS 47</td>
<td>+</td>
<td>05.06</td>
<td>79</td>
<td>12</td>
<td>3.3</td>
<td>4.1</td>
<td>34</td>
<td>76</td>
</tr>
<tr>
<td>20038</td>
<td>+</td>
<td>03.06</td>
<td>85</td>
<td>12</td>
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<td>6.4</td>
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<td>93</td>
</tr>
<tr>
<td>20038</td>
<td>-</td>
<td>08.06</td>
<td>77</td>
<td>14</td>
<td>4.0</td>
<td>3.8</td>
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<td>85</td>
</tr>
<tr>
<td>765</td>
<td>+</td>
<td>02.06</td>
<td>83</td>
<td>6</td>
<td>4.0</td>
<td>6.6</td>
<td>36</td>
<td>93</td>
</tr>
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<td>765</td>
<td>Com.</td>
<td>08.06</td>
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<td>6</td>
<td>1.0</td>
<td>3.9</td>
<td>49</td>
<td>113</td>
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<tr>
<td>765</td>
<td>Spe.</td>
<td>08.06</td>
<td>102</td>
<td>3</td>
<td>1.8</td>
<td>6.2</td>
<td>41</td>
<td>101</td>
</tr>
<tr>
<td>20006</td>
<td>-</td>
<td>06.06</td>
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<td>30</td>
<td>2.5</td>
<td>2.1</td>
<td>35</td>
<td>111</td>
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<tr>
<td>20006</td>
<td>+</td>
<td>04.06</td>
<td>87</td>
<td>18</td>
<td>3.0</td>
<td>5.0</td>
<td>33</td>
<td>90</td>
</tr>
</tbody>
</table>

* +: awned; -: awnless; Com.: compactum; Spe: speltoides.
The Role of Breeding in Increasing Winter Wheat’s Yield Potential

V.V. Shelepov

The substantial increases in winter wheat yields observed over the past 30 to 40 years can be attributed to the development and introduction of new cultivars, availability of high quality seed and technological advances. However, data used for estimating the role of new cultivars in these increases are contradictory. Scheffer et al. (1985) reported a 15-20% yield increase in Germany as a result of genetic improvement, Laslo Bala (1983), a 40-42% yield increase in Hungary, Duvick (1986), 50% in USA and Austin et al. (1989), 59% in England.

Winter wheat cultivars developed at the Mironovka Wheat Institute and released during a period of several years were yield tested to estimate the role of breeding in increasing yield and to determine which yield components contributed to yield increase. Cultivars developed at the Institute were conditionally divided into pre-war varieties (Ukrainka 246) and those released in the 70s (Mironovskaya 808 and Illychovka) and 80s (Mironovskaya 61, Mironovskaya 27 and Mironovskaya 28).

As a result of 60 years’ breeding efforts, yield potential of varieties released in the 80s (Mironovskaya 28) increased by 3.06 t/ha when compared with Ukrainka 246 (Table 1). Moreover, in unfavorable years (1990-1992) a greater difference in yield was observed. The question is: which yield components contributed most to yield increase, tillering capacity plus higher number of spikes per unit area or higher number of grains per spike?

While studying stand establishment during five years we found that post-war cultivars practically at all stages had higher density of stand per unit area than Ukrainka 246 (Table 2). We failed, however, to establish a clear-cut relationship between stand establishment and yield for all the varieties. Mironovskaya 28, for instance, in spring at all stages had less stem reduction. At the beginning of harvest, stand density was 712 productive stems per m² which was 274 spikes more than produced by Ukrainka 246.

During the most favorable years (1988, 1989, 1992), wheat went into winter in optimal stage of growth and development: prostrate type with 4-6 tillers per plant from which 2-3 developed simultaneously (2nd stage). In the 1990 and 1992 crop, only 1-3 tillers out of 1-4 shoots formed developed. The number of plants per unit area for each cultivar was about the same, i.e., 221-223 plants/m². Mironovskaya 61 was the exception: 256 plants/m² survived.

By breeding we succeeded in increasing not only the total number of stems per unit area but the number of productive tillers as well. This is particularly pronounced in varieties Mironovskaya 28 and Mironovskaya 27, which had 2.6-2.9 fertile tillers per plant. Plant height decreased considerably in new varieties, which improved their lodging resistance. Ukrainka 246 and Mironovskaya 808 had an average lodging resistance score of 1-3, while Mironovskaya 61 and Mironovskaya 28 had 7-9.

While analyzing the components of spike productivity, it was revealed that during the breeding process we had basically failed to change spike length and the number of spikelets per spike. However, the number of

1 V.N. Remesio Mironovka Wheat Institute, p/o Tsentrinoe, Mironovka dist., Kiev reg. 256816 Ukraine.
grains per spike and spikelet as well as grain weight have increased considerably (Table 3). For example, the number of grains per spike in Mironovskaya 61 and Mironovskaya 27 was 35.9-36.6, which is 7.7-10.0 grains higher than in Ukrainka 246. The increase in tillering ability, spike fertility and grain weight per spike resulted in increased grain weight per unit area. In varieties Mironovskaya 28 and Mironovskaya 27, it was practically twice as high as in Ukrainka, i.e., five-year averages were 693 and 754 g/m² respectively as compared to 394 g/m².

Based on the results presented here a general conclusion can be drawn that through breeding we succeeded in increasing yielding potential of cultivars in the 70s by 0.75-1.52 t/ha (22.4-45.5%) and in the 80s, by 0.52-0.97 t/ha. In comparison with Ukrainka 246, yield potential increased by 3.1 t/ha or 90%. The average yield increase per stage of breeding was 34%. Yield increase occurred due to increased number of productive tillers (32.8-35.8%), grain weight per spike (21.3-21.4%) and 1000 grain weight (9.4-21.3%).

References

Table 1. Yield potential of winter wheat cultivars in advanced yield trials in 1988-1992; preceding crop: peas.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Year of release</th>
<th>Mean yield (t/ha)</th>
<th>Yield increase compared to Ukrainka 246 (t/ha)</th>
<th>Previous variety (t/ha)</th>
<th>(%)</th>
<th>(%)</th>
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<tbody>
<tr>
<td>Ukrainka 246</td>
<td>1926</td>
<td>3.34</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Mironovskaya 808</td>
<td>1963</td>
<td>4.09</td>
<td>0.75</td>
<td>22.4</td>
<td>0.77</td>
<td>18.8</td>
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<tr>
<td>Illychovka</td>
<td>1974</td>
<td>4.86</td>
<td>1.52</td>
<td>45.5</td>
<td>0.97</td>
<td>19.9</td>
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<tr>
<td>Mironovskaya 61</td>
<td>1989</td>
<td>5.83</td>
<td>2.49</td>
<td>74.5</td>
<td>0.97</td>
<td>19.9</td>
</tr>
<tr>
<td>Mironovskaya 27</td>
<td>1992</td>
<td>5.88</td>
<td>2.54</td>
<td>76.0</td>
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<td>0.1</td>
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<tr>
<td>Mironovskaya 28</td>
<td>1994</td>
<td>6.40</td>
<td>3.06</td>
<td>91.6</td>
<td>0.32</td>
<td>8.8</td>
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Table 2. Number of tillers and plants per m², and number of tillers per plant in released cultivars.

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<tr>
<th>Variety</th>
<th>Number of tillers/m² at stages</th>
<th>No. of plants/m²</th>
<th>No. of tillers/plant</th>
<th>Plant height (cm)</th>
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<tr>
<td></td>
<td>V</td>
<td>VII</td>
<td>X</td>
<td>XII</td>
</tr>
<tr>
<td>Ukrainka 246</td>
<td>963</td>
<td>598</td>
<td>460</td>
<td>438</td>
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<td>1253</td>
<td>764</td>
<td>707</td>
<td>574</td>
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<td>Illychovka</td>
<td>1211</td>
<td>661</td>
<td>559</td>
<td>515</td>
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<td>Mironovskaya 61</td>
<td>1170</td>
<td>772</td>
<td>690</td>
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<td>Mironovskaya 27</td>
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<td>Mironovskaya 28</td>
<td>1364</td>
<td>944</td>
<td>746</td>
<td>712</td>
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</table>


<table>
<thead>
<tr>
<th>Variety</th>
<th>Spike parameters</th>
<th>Grain weight (g)</th>
<th>1000 K.W. (g)</th>
<th>Grains per spikelet</th>
<th>Grain yield (kg/ha)</th>
<th>Harvest index (%)</th>
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<tr>
<td></td>
<td>Length (cm)</td>
<td>No. of spikelets</td>
<td>No. of grains</td>
<td>1.39</td>
<td>3937</td>
<td>33.9</td>
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<tr>
<td>Ukrainka 246</td>
<td>8.9</td>
<td>8.6</td>
<td>25.9</td>
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<td>30</td>
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<tr>
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<td>8.8</td>
<td>18.8</td>
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<td>19.2</td>
<td>30.3</td>
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<td>35.9</td>
<td>1.21</td>
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<td>8.4</td>
<td>17.3</td>
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<td>1.94</td>
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<td>7.8</td>
<td>16.3</td>
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<td>1.68</td>
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Physiology and Biochemistry Research Aid in Winter Wheat Breeding

A.Yu. Shalin, G.V. Mazilnikov, and V.A. Vlasenko

The main objective of the plant physiology and biochemistry department of the Mironovka Wheat Institute is to make wide scale routine assessments of winter wheat and barley entries at different stages of breeding for frost and drought resistance, yield potential and grain quality. Simultaneously research is being done to identify parameters that condition genotypic adaptability and stress tolerance as well as to develop new methods and procedures for laboratory or laboratory/field evaluation and selection.

Evaluating winter wheat germplasm for frost resistance is a top priority in the department. Each year the more than 600 winter wheat and barley entries that enter different stages of yield testing are all screened for frost resistance. Developed by Tumanov 1968 and modified at the Mironovka Wheat Institute, the main screening method is direct freezing of plants in boxes. The planting is conducted in late September. Soil moisture is maintained at 60-70% of its total moisture capacity. As a rule, the germplasm is frozen twice: in late December-early January when the level of hardening reaches its peak, and in February-March. The objective is to determine the length of the dormancy period, i.e. resistance to early warm weather and the subsequent return of frost. The boxes are placed outside on wooden planks 5-7 cm above the surface of the sod layer. During winter temperature conditions in the boxes are similar to field conditions, or more severe, with the temperature decreasing to -16-17°C. Such conditions allow frost resistance of a large number of winter wheats to be evaluated without freezing them in growth chambers. The decrease in temperature (up to -16-17°C) kills most genotypes but makes it possible to single out individual plants with outstanding frost resistance that are used to develop winterhardy germplasm. Similar frost resistance evaluation is also conducted on new varieties of winter crops submitted to the Ukrainian State Commission of Variety Testing and Release.

Investigations are conducted to study the contribution of a number of physiological and biochemical systems to winterhardiness of a set of winter wheat cultivars from various ecological regions. The data indicate that the following physiological parameters are important in determining frost resistance: osmotic potential of cells, status of cell walls, structure of cytoplasm proteins and level of energy exchange.

A complex evaluation of winter wheat breeding materials for drought resistance was recently conducted. The importance of screening for this trait is determined by the tendency of climate to be even more arid in the central and northern regions of Ukraine. Some entries from competitive yield trials were identified as being more or less drought resistant (in comparison with sensitive cultivars) based on the following parameters:

1. Duration of the period from seedling emergence to third leaf. The value of this index is inversely correlated with drought resistance: the shorter the period, the higher the drought resistance. The method was developed at the physiology and biochemistry department based on the results of a study by Rotmistrov (1910) who showed that the relative rate of root penetration into the soil corresponds to the rate of above ground biomass development. Screening is conducted under artificial climatic conditions in the soil, which provides high precision and reproducibility of results.

1 V.N. Remeslo Mironovka Wheat Institute, p/o Tsentralne, Mironovka dist., Kiev reg. 256816 Ukraine.
2. Chlorophyll fluorescence of flag leaf induced by helium-neon laser beam (15 mV). Leaf segments are exposed to radiation by 1P-01 installation the same day field sampling is done (control), followed by another exposure after drying for 24 hours in a shaded room at room temperature (test). The entries with minimal deviation of fluorescence curve parameters under test conditions compared with the control are considered to be more drought resistant.

3. Direct evaluation of drought tolerance under severe drought. This is achieved by using an artificial drier design that provides forced ventilation of root area in soil up to a depth of 1.5 m. Practically each year irrespective of weather conditions this allows simulations of severe drought. From resumption of vegetation in spring until complete maturity, soil moisture content in a 1-m layer decreases from 120-140 mm to 5-10 mm. In control the minimum moisture content reaches 40-50 mm. The level of drought resistance of the studied genotypes is determined by the decrease in grain yield under drought. The coefficient of correlation between the results of field and laboratory experiments is about 0.70±0.10 depending on the conditions of the year.

One of the department’s top priorities in recent years has been implementation of project 0.2.04.05/008-93. It aims to develop a long-term system of seed preservation by freezing and periodically renewing their viability under artificial climatic conditions for the National Genetic Resources Bank of Ukraine. This is important in view of environmental degradation coupled with the irreversible reduction in genetic diversity and the current trends in modern breeding, which can lead to a loss of genotypes carrying valuable characters. The work is financed by the Ukrainian State Committee for Science and Technology.

To develop the basis for predicting winter wheat characters contributing to yield, source-sink relations were studied, emphasizing the contributions of the root system, flag leaf and spike. Based on these results, it is proposed that comparative evaluation of yield potential be based on the following scheme:

1. From stem elongation to heading, the functional status of the root system (the volume of root exudate) and the level of auxins in spike and flag leaf should be determined.

2. From anthesis to wax maturity, the ratio of auxins in spike and flag leaf should be determined. In a number of cases, evaluation can be limited to determining the spike auxin/flag leaf kinetin ratio at one of the stages mentioned above.

In addition to the investigation mentioned above, winter wheat breeding materials are evaluated for association of dry matter weight and grain yield. Each year more than 1000 samples are analyzed for protein content using the near infrared spectroscopy method.

The main objective of the department now is to develop and implement a system for doing comprehensive evaluations of breeding materials for a number of useful traits and characteristics.

References

Phytopathological Characteristics of Winter Wheat Germplasm Resistant to Major Pathogens

L.A. Zhivotkov and A.N. Kovalyshina

The increase in the area planted under genetically uniform agricultural crops makes ideal conditions for the spread of virulent forms of pathogens that can cause epiphytotics. Leaf rust, powdery mildew, bunts, root rots, *Septoria* spp. and *Fusarium* head blight are the most widely spread diseases in the forest-steppe zone of Ukraine.

Under favorable conditions these diseases may cause yield losses of more than 50% (Krivchenko, 1982; Mochalova, 1978; Novokhatka, 1978, 1979). Moreover, these diseases cause significant deterioration of bread-making quality (Blokhin et al., 1972; Novokhatka, 1979, 1983). Therefore, developing effective plant protection methods is an urgent breeding task.

The most effective method of disease control is breeding resistant cultivars. To do this effectively, the genetics of resistance must be understood. The virulence genes of regional pathogen populations should be monitored continuously to identify the efficiency of resistance genes. Each year about 800 entries from wheat collections are screened under artificial inoculations of leaf rust, powdery mildew, bunts, root rots, *Septoria* spp. and *Fusarium* head blight, which aids in finding new sources of resistance to major pathogens.

The composition of a leaf rust pathogen population was studied on a set of isogenic lines. It was determined that the local leaf rust population is represented by the following virulence genes: 1, 2a, 2b, 2c, 3, 10, 11, 14a, 16, 17, 18, 20, 21, 23, 26, 27, and 30. Genes effective against leaf rust in the forest-steppe zone of Ukraine were *Lr9, Lr19* and *Lr24*. Under artificial inoculation the following genotypes expressed resistance: Arthur 71, Riley 67, Abe, Transfer - *Lr9*, Agrus, Flex - *Lr19*, Blueboy 11, Osage - *Lr24*, as well as entries whose resistance was determined by hybrid analysis. These are 203-238 (*Lr9* and *Lr26*) and Frederik (*Lr29*). Previously unknown resistance genes are supposed to be present in C-3b-27-4 and H-40b-11-1 (Lr X and Lr X2), Co7250-49, Co7250-61, Co7250-82, Mc Dermit and Lindon (Lr X3 and Lr X4) as well as in Nova Banatka (Lr X5 and Lr X6). Varieties Biserka, NS14-65 and Sanya were used as donors of adult plant resistance. Varieties Biserka and NS14-65 are similar in their response to the pathogen and protected by a number of minor resistance genes. Variety Sanya has one major and one or two minor genes. One gene of variety Sanya is allelic and identical to *Lr13*.

Previously unknown resistance genes are present in Lovrin 32 (Lr X7 and Lr X8), 0-74-8-2 (Lr X9 and Lr10), NS 1308 (Lr X11 and Lr X12), Erytrospernum 91 (Lr X13 and Lr14), Mironovskaya 40 (Lr X15 and Lr X16), Mironovskaya ostistaya (Lr X17 and Lr X18). Thus, donors of leaf rust resistance have different genes for this character and may be used in breeding programs to diversify the genetic basis of resistance.

High resistance to powdery mildew was shown by the following entries: Maris Templar, Maris Virtue, Reward, TRR-327, Bounty, Mega, Adalen, Norman, Brigant (England), Alba (Poland), Century, TAM-200, TAW-107 (USA), Rennis, Fakon (Germany), Zg 384-67 (Yugoslavia) and others. The entries from Germany, Hadmersleben 13040-85, Hadmersleben 6686-85, and Hadmersleben 20581-84, manifested high
resistance to the local population of powdery mildew coupled with high winter hardiness. While studying the composition of the powdery mildew population, it was determined that race 66 was dominant and that the effective genes against the local population are $Pm4$ and $Pm3b$.

Under artificial inoculation entries from the USA Sel.3432, Sel.104, Rodeo, Set M - 65-31-57 (Bt 9), Turkey C.I. 1558-13 (Bt 4), Sel. M - 66 - 23 (Bt 10) and cultivar Zarya (Bt 7) had high resistance to common bunt. Using hybrid analysis it was determined that line Lutessence 6628 possesses genes $Bt12$ and $Bt13$ for common bunt resistance and line Erythrospermum 5021 carries $Bt14$. Varieties Frederick, P 10061, Agrus, Biserka, Olimpia, Zarya, and Mirleben demonstrated complex resistance to bunt, powdery mildew and leaf rust. While studying the pathogen population in the forest-steppe zone of Ukraine, it was concluded that 

$Tilletia caries$ is a predominant species of bunt. It is known that immunity to $Cercosporella$ does not exist among wheat cultivars. For a long time French cultivar Cappelle Desprez was an example of the highest resistance among wheats to this disease. Later on variety VPM-1 was identified as resistant, possessing genes from $Aegilops ventriosa$, while variety Roazon combines the resistance of VPM and Moisson.

Among entries from collections, relative resistance to $Pseudocercosporella herpotrichoides$ was manifested in lines from Germany: Hadmersleben 1.4614-86 and Hadmersleben 5366-86. Lines Hadmersleben 7051-84 and Hadmersleben 3130-83 from Germany and lines R5.1/Rescler/81618, (VPM/Capelle) 10,1PV (France) have resistance to $Cercosporella$ and $Septoria$ spp. English cultivar Rendezvous was characterized by resistance to $Cercosporella$, powdery mildew, leaf rust and $Septoria$ spp.

While studying the composition of species causing root rots in winter wheat, it was concluded that practically all known species of fungi occur on Ukrainian territory, namely: $P. herpotrichoides$, $Fusarium$, Alternaria, Giosporium lolliei, Gladosporium herbarum, Acremanium sole rotigenum, Gliocladium roseum, and Helminthosporium sativum. The material collected indicates that the most widespread pathogen is $P. herpotrichoides$, which comprises 40% of the isolates studied. About a quarter (24%) of the population is represented by $Fusarium$ spp., of which the most frequently occurring $F. avenaceum$ and $F. graminearum$ make up 3.5%, $F. culmorum$, 3.3%, $G. lolliei$, 04%, $A. alternata$, 6.5%, $G. roseum$ and $G. herbarum$, 6%. The other pathogens are rare.

In the territory of Vinnitsa, Zhitomir and Khmelintsk regions, $P. herpotrichoides$ is predominant. In Kiev and Lvov regions, root rots on winter wheat are caused by both $Cercosporella$ and $Fusarium$. $Pseudocercosporella herpotrichoides$ and $Fusarium$ spp. have been singled out here in equal percentages. In Cherkassy and Ternopol regions, $Fusarium$ species were predominant.

In the forest-steppe zone of Ukraine, $Septoria$ on winter wheat may occur in two forms: leaf blotch ($Septoria tritici$ Rob. ex Desm.) and glume blotch ($Septoria nodorum$ Berk.). Leaf blotch is more harmful. As revealed by a study on $S. tritici$, this species is highly virulent. The following entries were found to be resistant under artificial inoculation by $Septoria$ leaf blotch: Tuller, Century (USA), Bert, Norman, Vaggenner (England), Hadmersleben c.h. 8754-83, Nimbres, Rennis, Tawel - 15 (Germany), Carifen - 12 (Hungary). Though $S. nodorum$ is known to be a spike disease, the pathogen attacks all above ground parts of the plant. It was revealed that the grain from susceptible plants is shrunk and has lower weight. One thousand kernel weight decreases from 60 g to 12.4 g, depending on the genotype. The decrease in grain weight varied from 0.5% to 40.9%, also depending on the genotype. The tolerance of varieties should be investigated. For instance, under severe attack varieties Mironovskaya 28, Mironovskaya 40, and Lutescens E.g. 101-81 showed decreased grain weights of 0.8, 0, and 0%, respectively.
Resistance to \textit{S. tritici} is manifested in the following entries: Atlas 66, Tuller (USA), Palur, Septoria 129-86, Septoria 187-86, Septoria 21-88, Septoria 54-88, Septoria 135-88, Septoria 1305-87, and Carsten VI (Germany). Resistance to both \textit{S. tritici} and \textit{S. nodorum} was found in German entries Palur and Septoria 129-86 and cultivar Tuller (USA).

No genotypes with absolute resistance to \textit{F. graminearum} (numerical score 9) were found under artificial inoculation. The following entries demonstrated resistance (numerical score 7): Camp-Remy, Bizet K.F. (France); St 2186 (USA); Ko (Poland), Citadel (Holland); Erythrosperrnum 24132 (Ukraine), TAW 5466-77, Hadm. (20581)84, TAW 1.39482-79 (Germany), and Nobeoka bozu (Japan). Considering that \textit{Fusarium} attacks spike and consequently reduces yield and 1000 kernel weight, the tolerance of resistant genotypes was studied. The following entries showed 0% reduction: Bizet RF, Nobeoka bozu, and Lutescens 20932; line MV-1088 from Hungary showed yield reduction of 30.8%. As mentioned before, \textit{F. graminearum} is widely spread in Ukraine.

On the basis of work conducted a program of winter wheat breeding for resistance to major diseases (leaf rust, powdery mildew, bunt, root rots, \textit{Septoria} spp. and \textit{Fusarium}) was initiated. Lines with complex resistance to three or four diseases have been developed and are currently under study:

Rendezvous//Lut.E.g.37-82/Lut.C.h.1-82,
Lut. E.g.39-82/Lut. C.h.4-82//Lut. P.r.42-83,
Rendezvous/Mironovskaya yubleynaya,
Lut. E.g.71-85//TP 309A/Mironovskaya yubleynaya,
Lut. E.g.39-82/Lut. C.h.4-82//Lut. P.r.15-83a,
P.I.170911/Ilychovka//Lut. C.h.85-86.

As a result of long term efforts in breeding for resistance, two winter wheat cultivars—Mironovskaya poluintensivnaya (semi-intensive) and Mironovskaya 33—have been developed.

References

Use of Genetic Methods in Winter Wheat Breeding

G.S. Kolyuchaya,¹ N.V. Bulavka,¹ and V.T. Kolyuchy¹

The main objective of the genetics department of Mironovka Wheat Institute is to apply current genetic methods for broadening wheat genetic variability and to develop effective screening and selection methods for a number of useful traits. At present the work is conducted in three main directions: 1) utilization of genetic systems controlling chromosome pairing in wide crosses; 2) the genetics of winter hardiness, and 3) utilization of protein markers in genetics research and breeding.

Researchers seeking to expand the genetic diversity of wheat are turning their attention to distant species and genera of the Triticinae subtribe. Despite partial homeology between the chromosomes of wheat and its wild relatives, it is necessary to utilize genetic systems that control chromosome pairing mechanisms to increase the efficiency of wide crosses. Studies of genetic affinity and the peculiarities of chromosome pairing are needed to target the introgression of alien genetic material.

On the basis of the ph gene effect of a mutant form of Vavorit winter wheat (A. Jiura), F2-F6 populations from crosses with Triticum spelta, T. compactum, T. turgidum, T. dicoccum, and T. zhukovskii were produced. Phenotypic instability of the F1s was followed by genetic instability expressed in variation in a number of chromosomes in somatic cells, significant infringement of microsporogenesis, and high levels of pollen and spike sterility. The first signs of stabilization appeared in the F3-F4 generations; this tendency was later consolidated.

Subsequent artificial and natural selection aimed at eliminating gametes lacking vitality and low fertile genotypes enables genetic stabilization of the material and results in increased pollen and spike fertility. From F5 onwards a significant number of genotypes with a combination of useful traits was selected and is being tested in breeding nurseries.

The Aegilops genus is genetically similar to wheat. Various Aegilops species are often used to transfer resistance to leaf rust, powdery mildew and Fusarium into the wheat genome. In our experiments, which involved using the ph gene in intergeneric crosses, the mutant Favorit was used. Aegilops truncialis (1809), Ae. columnaris (1514 and 1995), Ae. triaristata Will (1432), and Ae. cylindrica Host (1810) served as pollinators. Crosses Favorit/Ae. columnaris (23.5%) and Favorit/Ae. cylindrica (14.3%) had the highest seed set: 23.5 and 14.3%, respectively. For all crossing combinations, 320 caryopses were produced in total. The plants produced by embryo culture were vernalized in test-tubes and grown in growth chambers. The presence of the Aegilops genome in hybrids was revealed by morphological traits such as a specific antocyanous color of tillers and pubescence of leaf blades. The plants had intermediate phenotype. The chromosome number in M1 meiosis was 35. Backcrossing proved to be inefficient and single caryopses were obtained.

It is evident that to stabilize the genome of wheat-Aegilops hybrids and simultaneously utilize genetic systems controlling chromosome pairing, it is necessary to use polyploidy and routinely produce amphidiploids.

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Breeding aimed at developing winter wheat cultivars with high yield potential is not always combined with the enhancement of traits such as winter hardiness and frost tolerance. Inheritance studies are essential for breeding successfully for these traits and the department of genetics is studying the inheritance of frost hardiness. More than 90 crosses involving genotypes with various levels of frost tolerance were produced. The freezing of plants in boxes was carried out in December, January and March following the beginning of early spring thaw to determine frost resistance under various temperatures in hardened plants. Selection of positive transgressions in segregating populations seems to be more likely when frosts are applied in December and January. However, to produce highly winter hardy forms, freezing after early spring thaw of plants is recommended. Freezing temperature was chosen to be somewhat lower than critical—varying from -12 to -16°C depending on the duration and depth of the preceding thaw.

To breed for frost hardiness it is necessary to have parents with high tolerance to this stress and developing such parents is one of the objectives of our work. Crosses were made to estimate the combining ability of 15 genotypes previously selected for frost-hardiness. All 15 genotypes were crossed with four testers. The following frost resistant lines were found to successfully transfer the character to its progeny: 770 (Krasnodarskaya 39/Houzer), 806 (Albidum/Krasnodarskaya 39), 815 (Albidum 114/Houzer), 524 (Bezenchukskaya yubileinaya/Akhtyrchanka), 352/5 and 352/7 (Krasnodarskaya 39/Mironovskaya 808).

Research dealing with the utilization of protein markers in winter wheat genetics, breeding and seed production is also conducted in the department using gliadin markers. It was found that wheat cultivars as a rule are polymorphic for gliadin loci as a result of mechanical mixture or heterogeneity. Genetic principles for identifying allelic variants of gliadin blocks are used to establish criteria for the purity of genotypes. We have found that bread wheat cultivars and biotypes possessing the 1B/1R translocation (GLI 1B3 block) show a higher frequency of spontaneous offtypes. Laboratory experiments have shown that this is caused by the higher level of mutability.

In various experiments it was demonstrated that individual allelic variants of gliadins correspond to agronomically important traits, namely, yield potential, 1000 kernel weight, sedimentation value, plant height, gluten and protein content, and dough quality.

Wheat yield and adaptation depend on associations of interacting genes. Particular cases of non-allelic interaction of genetic factors marked by gliadin loci were revealed. Within a genotype, genes (or gene clusters) with no direct effect on yield may act as modifiers of a gene controlling a particular character. Genotypes with recombination between genetically linked markers are characterized, as a rule, by poor yield performance. In segregating populations when recombined homozygous combinations of non-allelic genes are formed, a decrease in yield is more likely to occur compared to segregants which preserve parental gene combinations. In man-made wheat populations, following some years of reproduction an unusual combination of genetic markers was revealed resulting in enhanced adaptation. Results of genetic studies being carried out by the department are widely used in winter wheat breeding.

The use of genetic systems controlling chromosome pairing in interspecific and intergeneric crosses made it possible to produce lines of interest for breeding. Several donors of frost tolerance were produced as a result of experiments on the inheritance of the character. The study of association between gliadin markers and agronomically important genes resulted in superior adaptation and maximum expression of useful characters. Populations created by the department provide breeders with materials that can successfully enhance breeding efficiency when choosing parents for crosses and conducting selections.
Classification and Expression of Chasmogamous Pollination of Bread Wheat

A.A. Korchinsky

The percentage of chasmogamous (open-pollinated) florets as a criterion of cross-pollination in wheat can be based on the number of anthers extruded from a floret at flowering. Under comparatively stable soil-climatic conditions, this character is inherited and may serve as a criterion for classifying genotypes into three major types.

Genotypes with more than 50% chasmogamous florets and a high degree of anther extrusion were classified as predominantly chasmogamous (Type I). Genotypes with more than 50% chasmogamous florets and variable degrees of anther extrusion were classified as combined type (Type II). Genotypes with fewer than 50% chasmogamous florets were classified as Type III - predominantly cleistogamous (closed).

The study was conducted to evaluate the degree of chasmogamous flowering depending on homozygocity levels of genotypes, temperature fluctuations and light conditions. Using four generations of controlled inbreeding by isolating spikes with glassine bags during flowering (S⁻S⁻), plants were selected for maximum expression of two traits—total number of chasmogamous florets and number of florets with three dehisced anthers. Analysis of S⁻S⁻ generations showed that expression of chasmogamy increased with inbreeding in some genotypes and changed little or remained unchanged in others (Table 2). The increase in chasmogamy was especially observed in Type I genotypes. With Krasnodar Dwarf an increase occurred only in the S⁻ generation. With Tom Pouse chasmogamy did not change with inbreeding. The behavior of such genotypes indicates the presence of genes inhibiting chasmogamous flowering.

The change in chasmogamous flowering with inbreeding in Type I genotypes indicates polygenic control of this trait. Epistatic-additive gene interaction may regulate the inheritance of this character since as genotypic homozygocity increases, the effect of additive genes increases; this results in maximum expression of chasmogamous flowering with increased generations of inbreeding.

Two types of variability for chasmogamous flowering were identified. The first type was characterized by negligible variation. The second type involved completely variable expression of the trait. Variety Tom Pouse, for instance, exposed to a short photoperiod (10 hours) changed the type of chasmogamous flowering from III to I (Table 3). High temperatures (> 38 °C) may have induced Kavkaz to change the type of chasmogamous flowering from III to II.

In Bezostaya 1, the type of flowering changed from II to I in S, due to inbreeding. The variety Heines did not change the type of flowering through S, but variability in the degree of chasmogamous flowering was observed (Table 3).

The genetic basis of such changes results from changes in gene interaction. Genes with pleiotropic effect act as modifiers under some conditions and as major genes under other conditions. As for the change in the formula of chasmogamous flowering, some epistatic interactions (between non-allelic genes) in hexaploid

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wheats are more easily transformed into new ones under the influence of environmental factors due to greater flexibility of their polygenic system. In particular, it concerns the function of inhibitor genes. It is the decrease in the activity of these genes which determines the change in chasmogamous flowering.

Table 1. Classification of chasmogamous-cleistogamous flowering.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Type of flowering</th>
<th>% of florets</th>
<th>% of florets with dehisced anthers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>chasmogamous</td>
<td>cleistogamous</td>
</tr>
<tr>
<td>Miron. 808</td>
<td>I</td>
<td>94.4</td>
<td>5.6</td>
</tr>
<tr>
<td>Bezostaya1</td>
<td>II</td>
<td>70.2</td>
<td>29.8</td>
</tr>
<tr>
<td>Heines</td>
<td>II</td>
<td>62.1</td>
<td>37.9</td>
</tr>
<tr>
<td>Kavkaz</td>
<td>III</td>
<td>42.2</td>
<td>57.8</td>
</tr>
<tr>
<td>Aurora</td>
<td>III</td>
<td>33.6</td>
<td>66.4</td>
</tr>
<tr>
<td>Tom Pause</td>
<td>III</td>
<td>7.6</td>
<td>92.4</td>
</tr>
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</table>

Table 2. Expression and maximum limits of chasmogamous flowering.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Type of flowering</th>
<th>Inbreeding generation</th>
<th>% of chasmogamous florets</th>
<th>% of florets with x dehisced anthers</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x = Three</td>
</tr>
<tr>
<td>Mironov. 808</td>
<td>I</td>
<td>S_0</td>
<td>94.4±1.5</td>
<td>61.6±1.2</td>
</tr>
<tr>
<td></td>
<td>I</td>
<td>S_1</td>
<td>99.2±0.6</td>
<td>82.3±0.6</td>
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<tr>
<td>Krasnodar Dw.</td>
<td>II</td>
<td>S_0</td>
<td>54.9±1.8</td>
<td>15.3±0.5</td>
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<tr>
<td></td>
<td>II</td>
<td>S_1</td>
<td>69.4±0.8</td>
<td>20.1±0.4</td>
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<tr>
<td>Tom Pause</td>
<td>III</td>
<td>S_0</td>
<td>7.6±0.5</td>
<td>3.9±0.3</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>S_1</td>
<td>6.7±0.3</td>
<td>3.6±0.1</td>
</tr>
</tbody>
</table>

Table 3. Changes in the formula of chasmogamous flowering depending on environmental factors or inbreeding generation.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Type of flowering</th>
<th>Environmental factors</th>
<th>% of chasmogamous florets</th>
<th>% of florets with x dehisced anthers</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x = Three</td>
</tr>
<tr>
<td>Tom Pause</td>
<td>III</td>
<td>control</td>
<td>7.6±0.9</td>
<td>3.9±0.5</td>
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<tr>
<td></td>
<td>I</td>
<td>day 1</td>
<td>63.1±1.4</td>
<td>37.8±0.9</td>
</tr>
<tr>
<td>Kavkaz</td>
<td>III</td>
<td>control</td>
<td>42.2±1.4</td>
<td>7.1±0.2</td>
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<tr>
<td></td>
<td>II</td>
<td>t=38°</td>
<td>67.3±1.3</td>
<td>18.3±0.7</td>
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<tr>
<td>Bez.1</td>
<td>II</td>
<td>control</td>
<td>70.2±0.5</td>
<td>12.2±0.4</td>
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<tr>
<td></td>
<td>I</td>
<td>14</td>
<td>89.1±0.5</td>
<td>66.0±0.5</td>
</tr>
<tr>
<td>Heines</td>
<td>II</td>
<td>control</td>
<td>62.1±1.9</td>
<td>24.9±0.7</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>14</td>
<td>79.3±0.9</td>
<td>43.8±0.5</td>
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