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# Chapter 1

## Triticale—An Update on Yield, Adaptation, and World Production[1]

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### ABSTRACT

Many natural barriers interfere with the development of functional new species from wide crosses. Among the major hurdles in the development of triticale (X *Triticosecale* Wittmack) were cross-incompatibility, embryo starvation, hybrid necrosis, sterility, cytogenetic malfunction, and associated endosperm malformation. By 1950, scientists had discovered ways to overcome or avoid most of the barriers and thus paved the way for triticale breeding programs. Since 1968, considerable progress has been made at the International Maize and Wheat Improvement Center (CIMMYT) in improving agronomic characteristics, seed quality, disease resistance, yield potential, and range of adaptation. Maximum grain yields in the Yaqui Valley of Mexico have increased from 2358 kg/ha in 1968 to over 8763 kg/ha in 1979. A single check cultivar of triticale ('Mapache') was included among 50 of the best wheat [*Triticum aestivum* (L.) em Thell.] cultivars in the 1977–1978 International Spring Wheat Yield Nursery (ISWYN). Out of the 71 locations around the world reporting data, Mapache was first in grain yield, averaging 4212 kg/ha. The top wheat cultivar, Nacozari, produced 4020 kg/ha. Mapache's resistance to rusts, smuts, mildew, and *Septoria tritici* Rob. ex Desm. is better than most wheats. Only in *S. nodorum* (Berk.) Berk. and scab were the reactions similar to those of the average wheat cultivars. Endosperm malformation still adversely influences test weight and flour quality, but progress toward well-filled kernels is being made.


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Some of the more recent and important aspects of triticale (X *Triticosecale* Wittmack) improvement are reviewed in this chapter. Considerable research had been done on triticale before serious breeding work started. For those interested in earlier research, Müntzing (1979) has published an excellent review. A major thrust was provided when John O'Mara (1948) used hybridization, embryo culture, and colchicine treatment to produce a primary hexaploid triticale from the cross 'Stewart' durum (*Triticum turgidum* L.) × 'Prolific' rye (*Secale cereale* L.). By 1950, triticale breeding programs had become established in Hungary and the USSR and shortly after that in Madrid by Sanchez Monge, and at the University of Manitoba. Each of these programs concentrated on improving hexaploid triticale as a cultivated crop.

The first triticale cultivars were released for commercial production by A. Kiss in Hungary in 1968 under the numbers T-57 and T-64. The following year B. C. Jenkins released several cultivars such as 6TA-204, 205, 206, and 208 in the USA. 'Rosner' was the first cultivar of triticale released in Canada (in 1970).

Considerable overpromotion of seed sales by some private companies was evident in the early years, particularly in the USA. Performance of the cultivars generally failed to reach promotion promises and growers quickly became disenchanted with the crop. Universities and other breeding and research institutions, both public and private, were reluctant to undertake triticale research because of adverse publicity. Even today, research institutions in the USA and Canada are not rushing to take on triticale improvement.

Mexico fortunately escaped the adverse criticism associated with overpromotion. Financial support was provided by the Ford Foundation during the 1967–1968 crop season to develop a breeding program at CIMMYT. In 1971, the Canadian government undertook the funding of triticale improvement and research on an international basis.

Triticale production persisted in some areas of the USA as a forage and animal feed crop. Growers in areas of milder winters found that winter growth and recovery from grazing was better in triticale than among some of the other cereals. A similar situation prevailed in Argentina, southern Africa, and other areas.

The program in Mexico was directed toward developing triticale as a human food crop with major attention to developing countries. Most of these countries are located between 30° N and 30° S Lat. Since these areas have relatively short days, it was necessary to introduce germplasm that did not require the sensitivity to long days possessed by most of the ryes and many of the wheats. This degree of insensitivity to day length was transferred to triticale from the Mexican wheats.

The first replicated yield trials of triticale grown in the Yaqui Valley of Sonora were harvested in May 1968. The top strain produced 2358 kg/ha and had a test weight of 65.8 kg/hL (51.1 lb/bu). During the 1978–1979 season under similar conditions, the top triticale produced 8526 kg/ha with a test weight of 72 kg/hL. Comparable yields for wheat [*Triticum aestivum* (L.) em Thell.] during the same years would be 5442 and 7982 kg/ha and 82 kg/hL (63.7 lb/bu) test weight. Thus, during this

11-year period, the potential yield of triticale has become comparable to that of the best wheats. Test weight improvement will require more time. See the CIMMYT Information Bulletins for project summaries (CIMMYT, 1972–1977; Zillinsky and Borlaug, 1971).

## ADAPTATION IN INTERNATIONAL TRIALS

The first International Triticale Yield Nursery (ITYN) was distributed during the 1969–1970 season. Results from the early trials were quite disappointing. However, as the breeding program progressed, the performance of the lines in the ITYN improved (Table 1–1).

A single check cultivar of triticale, 'Mapache', was included among 50 of the best wheat varieties in the 1977–1978 International Spring Wheat Yield Nursery (Table 1–2). Out of the 71 locations around the world reporting data, Mapache was first in grain yield, averaging 4212 kg/ha. The top wheat cultivar, Nacozari, produced 4020 kg/ha.

The different types of triticale are adapted to a diversity of environments. Spring triticales may be grown in semitropical highlands, e.g., in eastern Africa, Ethiopia, Nepal, in Michoacan, Mexico, and in Colombia and Brazil. In these areas, acid soils, aluminum toxicity, leaf diseases, and root rots may occur. Spring types also are adapted to rainfed, sandy soils found in temperate highlands and plains, e.g., in Hungary or in Huamantla (Iberian Peninsula).

Winter and facultative triticales are widely adapted. Winter types are grown in eastern and central Europe and in the central and north central USA. Facultative spring types are grown in western Europe and in southern USA.

Forage triticales are being commercially produced in many sections of the world, including southern Africa, Argentina, northwestern Mexico, and in the southern, central, and southwestern USA.

Table 1–1. Progress in the development of high-yielding triticale selections and cultivars at CIMMYT since 1969.

| Yield in advanced trials | Selection or cultivar | Sonora Nursery† | | | ITYN‡ | | |
|---|---|---|---|---|---|---|---|
| | | Grain yield | Test wt | Plant ht | Year | Grain yield | No. of locations |
| | | kg/ha | kg/hL | cm | | kg/ha | |
| 1967–1968 | Bronco X224 | 2356 | 64.4 | 150 | 1969–1970 | 2578 | 39 |
| 1968–1969 | Arm. T909 | 3100 | 65.8 | 125 | 1970–1971 | 3272 | 17 |
| 1969–1970 | Badger PM122 | 4492 | 68.5 | 125 | 1971–1972 | 3274 | 34 |
| 1970–1971 | Arm. X308-14Y | 5490 | 65.4 | 125 | 1972–1973 | 3506 | 25 |
| 1971–1972 | Cinnamon | 5550 | 66.8 | 100 | 1972–1973 | 3409 | 25 |
| 1972–1973 | MayaII × Arm | 6300 | 70.0 | 90 | 1973–1974 | 4200 | 47 |
| 1973–1974 | Yoreme | 7000 | 71.0 | 90 | 1973–1974 | 4400 | 47 |
| 1974–1975 | Beagle | 7500 | 68.0 | 110 | 1974–1975 | 4480 | 45 |
| 1975–1976 | Mapache | 8000 | 69.0 | 111 | 1975–1976 | 4483 | 60 |
| 1976–1977 | Beagle | -- | -- | -- | 1976–1977 | 4105 | 56 |

† Northwestern Mexico.
‡ Average of all locations in the International Triticale Yield Nursery.

Table 1–2. Grain yields of Mapache triticale and spring wheat selections in the 14th International Spring Wheat Yield Trial, 1977–1978, 71 locations.

| Location | Mapache | | Best wheat |
|---|---|---|---|
| | kg/ha | Rank | kg/ha |
| Northern | 5504 | 1 | 5306 |
| Middle East | 3795 | 7 | 3916 |
| Indian Subcontinent | 3373 | 27 | 4140 |
| Asia | 3734 | 1 | 3414 |
| Eastern and northern Europe | 3921 | 4 | 4307 |
| Northern USA and Canada | 4059 | 1 | 3768 |
| Northern Mexico and southern USA | 5796 | 7 | 6029 |
| Highlands | 4979 | 1 | 4357 |
| South Cone, South America | 2707 | 1 | 2573 |
| Avg for all locations | 4212 | 1 | 4028 |

A program to incorporate winter habit and some winter haridness into triticale was started in Mexico in 1973. A nursery was grown in Toluca from November to July, and spring × winter crosses were made to reduce plant height and to improve the seed type of winter triticales. Good sources of winter hardiness were obtained from F. C. Elliott, Michigan State University; A. Kiss, Hungary; University of Manitoba, Winnipeg; A. Muntzing, Sweden; R. J. Metzger, Oregon State University; C. J. Peterson, Washington State University; and more recently from the USSR and Poland. Several of these workers, and others, have collaborated in evaluation and selection for winterhardiness and adaptation in stress environments.

Improvement in winter and facultative triticales has lagged behind improvement of spring types. Only one cycle per year can be produced, and fewer scientists have been participating in breeding programs. Recent research on winter triticales has changed this situation dramatically. Improvement in winter triticales since 1974 in both Europe and North America has been impressive.

## PRODUCTION

Estimates of areas under triticale production are difficult to obtain because such data usually are not collected or published. An attempt to develop such an estimate for a triticale workshop in Santiago, Chile, in 1978 proved to be a frustrating exercise.

Production estimates have been revised based on information supplied by scientists participating in a triticale symposium in Poland in 1979. According to A. F. Shulyndin of Karkov, the USSR has over 200 000 ha under triticale production, an area about double that of the USA. Countries having between 10 000 and 20 000 ha under production are Argentina, Canada, the Republic of South Africa, and possibly the People's Republic of China, where estimates vary from 7000 to 20 000 ha. Countries with more than 1000 ha are Australia, France, Hungary, and Mexico. Spain, Portugal, Italy, eastern Africa, and some areas of the Himalayas are just starting commercial production. Most of the present tions increased, reconstitution of the wheat genotype also occurred. The program rapidly became a wheat breeding program instead of a triticale program. Furthermore, disease susceptibility and other defects caused by genes carried on the wheat chromosomes were introduced with each additional substitution. In an effort to preserve the maximum genetic influence from the rye genome, a program was initiated at CIMMYT to develop triticale material possessing all of the rye chromosomes, realizing that the rate of improvement would be slower for some of the important characteristics, e.g., seed type and dwarfing. Two triticale cultivars, Beagle and Drira, were used as parents with the complete rye complement. Substituted strains were used as sources of better seed type, threshability, and straw strength. Selecting for the complete rye genome was based on appearance.

During the winter cycle of 1977–1978, a nursery containing 4000 $F_4$ to $F_6$ lines with the complete rye chromosome complement was grown in CIANO (Centro de Investigaciones Agricolas del Noreste [Ciudad Obregon, Sonora]). About 600 of these were advanced to the regular yield tests during the following cycle on the high plateau.

The 1977–1978 international triticale screening nursery included about 40 lines having the complete rye complement and about 300 having one or two substitutions. Cooperators from 41 locations at which this nursery was grown obtained and reported grain yield data. Strains yielding in the top 10% were listed for each trial, and 16 were identified as occurring most frequently as top yielders. Of these 16 strains, 14 had the complete rye complement, one had a single substitution, and one was a wheat check (Nacozari). In terms of adaptation over a wide range of conditions, it appears that the odds are better for selections with the complete rye genome. A major difficulty we encountered was in reducing plant height. We now have new primary octoploids with dwarfing genes from both bread wheat and rye. Octoploids are more suitable to use as parents in this type of program than either bread wheats or dwarf ryes since they possess the full rye complement. Hybrids from octoploid × hexaploid crosses have only a single D-genome set, which disappears quickly in the next few generations when grown among "complete" hexaploid triticales.

## REFERENCES

CIMMYT. 1972–1977. Results of the international triticale yield nursery. CIMMYT Information Bull. no. 1, 10, 20, 24, 32, 33, and 41. International Maize and Wheat Improvement Center, Mexico City.

Gustafson, J. P., and F. J. Zillinsky. 1973. Identification of D-genome chromosomes from hexaploid wheat in a 42 chromosome triticale. p. 225–231. *In* E. R. Sears and L. M. S. Sears (ed.) Proc. of the 4th Int. Wheat Genetics Symp., Columbia, MO. 6–11 August. Missouri Agric. Exp. Stn., Columbia.

Merker, A. 1975. Chromosome composition of hexaploid triticale. Hereditas 80:1–52.

Müntzing, A. 1979. Triticale—results and problems. Parey, Hamburg, FRG.

O'Mara, J. B. 1948. Fertility in allopolyploids. Genet. Soc. Am. Rec. 17:52.

Zillinsky, F. J., and N. E. Borlaug. 1971. Progress in developing triticale as an economic crop. Res. Bull. no. 17, International Maize and Wheat Improvement Center, Mexico City.

production is used as forage or as a feed grain. Smaller proportions are used for human food, e.g., bread, pancakes, pastries, or in the production of alcoholic beverages.

Most of the areas where triticales appear to have a production advantage over wheat are located in the zone between 30° N and 30° S Lat. However, the major areas of current production are north and south of this zone. I suspect that the production in the higher latitudes is concentrated on grazing and feed grain. Farmers in developing countries are generally more reluctant to feed grain to livestock. Furthermore, the developing countries generally lack funds and scientific staff to develop new crops. Information on utilization of triticale is unavailable, and seed production facilities are often meager. This picture is now beginning to change. In 1978, five cultivars developed from crosses made at CIMMYT were released for commercial production (Table 1–3), and considerable more interest is being shown. Some countries on each continent have cultivars under seed increase, many of which will be released for commercial production in the near future (Table 1–4).

## MAJOR GENETIC CONTRIBUTIONS

It is much easier to look back and identify the genetic combinations that contributed to the success of the program than it is to predict which combinations will be the most important in the future. Probably the most important came from triticale-wheat combinations (Table 1–5). The cultivars Armadillo and Camel and most entries in the "fertile selections" group were selected from triticale × wheat crosses.

Table 1–3. Triticale cultivars released in 1978.

| Cultivar | Location | Release source |
|---|---|---|
| Siskiyou | USA | Univ. of California, Davis |
| Welsh | Canada | Univ. of Manitoba |
| Beagle | USA | Texas |
| Rahum | Mexico | Unauthorized |
| Mexitol† | Bulgaria | S. Tzvetkov |

† A semiwinter triticale from a spring × winter cross made in Mexico.

Table 1–4. Triticale releases considered for 1979.

| Location | No. of releases | Genetic source |
|---|---|---|
| Mexico | 2 | Mapache & Bura ($M_2A$) |
| Kenya | 2 | Bacum & Bvr-Arm |
| Tanzania | 1 | Beagle |
| Australia | 2 | Early generation bulk & Drira |
| Brazil | 2 | Panda & Beagle derivation |
| Pakistan | 2 | $M_2A$ |
| Nepal | 2 | Beagle & F.S. |
| Portugal | 2 | Mapache & Beagle |
| Argentina | 1 | Forage type Beagle |
| Texas | 2 | Winter types S × W $F_2$ |

Table 1-5. Important sources of genetic improvement in the CIMMYT triticale program.

| Selection or cultivar | Rye genomic constitution |
|---|---|
| Armadillo | X308 outcross to bread wheat; 2R substituted |
| Inia × Armadillo | 2R and 4R substituted |
| (Inia × Rye)$^2$ × Arm | 2R substituted |
| Beagle | U. of Manitoba hexa × Armadillo; complete rye genome |
| Drira | (Durum-rye)$^2$ × [(Inia × rye)$^2$ × Arm]; complete rye genome |

The second most important combinations were octoploid × hexaploid crosses in which 'Inia 66' was the wheat parent. The cultivars Cinnamon, Rahum, Bacum, and Mapache were selected from a third series, Maya × Armadillo. Other important sources of breeding materials are 'Beagle', from the cross of a University of Manitoba hexaploid × Armadillo, and 'Drira', from a primary hexaploid (DR-44) crossed to derived secondary hexaploid IRA. Most recently, a new group of primary octoploids with good vigor and fertility has been developed. In the improvement of winter triticales, lines from the program of F. C. Elliott (especially line 274/320) have been excellent breeding stocks for combined sources of winterhardiness, plant height, and agronomic type. This germplasm can be found, either as selections or progenitors, in winter triticale breeding programs around the world.

## CHROMOSOME SUBSTITUTIONS

Populations arising from bread wheat–triticale crosses provide excellent opportunities for chromosome substitutions to occur. These events are most likely to happen when both wheat and triticale nurseries are close together, permitting outcrossing to occur. Armadillo, a hexaploid triticale selected in Mexico in 1968, possesses several important characteristics, the most important being fertility followed by day length insensitivity and one gene for dwarfing. Armadillo was soon observed to be so outstanding as a progenitor, that every productive strain in the CIMMYT triticale program had it in its parentage.

Perry Gustafson (Gustafson and Zillinsky, 1973) discovered that in Armadillo, a pair of D-genome wheat chromosomes had substituted for a pair of chromosomes (2R) from the rye genome. Since the CIMMYT program had many crosses involving Armadillo and frequent crosses between bread wheat and triticale, we became interested in determining the chromosome constitution of our triticale lines. Arnulf Merker, who studied under Arne Muntzing in Lund, Sweden, came to CIMMYT in 1973 to conduct the cytological investigations. Using a modified Giemsa staining technique, he identified strains having several different chromosome substitutions (Merker, 1975).

Most of the material in the CIMMYT triticale breeding program in 1974 possessed one or two substitutions. Only a very small proportion of the lines had the complete set of rye chromosomes. The reason was that progress in improving seed type and reducing plant height could be achieved more rapidly with chromosome substitutions than by the usual gene exchange. The major problem, of course, as the number of substitu-