

Triticale in Mexico

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Triticale in Mexico has been a disappointment for breeders because almost 40 years of efforts have been devoted to the improvement of this crop without significant impact on its production. Until the mid-1990s, the area planted to this species did not justify the resources that had been invested in triticale research. In 1990, the total area planted to triticale in Mexico was approximately 4 000 ha; however, in 1999, it was estimated that the state of Mexico alone planted more than 4 000 ha using old and new released varieties (Hernández and Macario, 2000). In 2001, more than 2 500 ha in the La Laguna region and southern Chihuahua region were planted to triticale using mainly forage varieties. At present, it is more likely that the area planted to triticale in Mexico is approximately 10 000 ha. The low rate of increase in triticale area before the 1990s could be explained by the lack of implementing an efficient programme of demonstration showing farmers the crop and its advantages. However, during the last five years, large plot demonstrations of triticale have been conducted with farmers in several states. The distribution of bulletins, organization of field days on farmers' plots and the production of seed and its availability have contributed significantly to the expansion of the area grown to triticale in different Mexican states. The potential surface that can be planted to triticale is estimated at 50 000 ha under irrigation and 250 000 ha under rainfed areas (Hinojosa *et al.*, 2002a).

Until recently, triticale was not given any importance by the private sector because it was not a profitable crop. Therefore, all resources required for its diffusion were supplied by the government. Triticale was initially recommended for regions where numerous environmental conditions prevail and where the standard of living is low. In those regions, the most productive crop alternative is triticale because it has been shown that the crop is better than any other grain used in the Mexican diet. In addition, triticale grains constitute an important source of energy due to the high carbohydrate content and good quality of the protein if compared with other cereal grains (Macario, 1998; Carney, 1992). Today, several private companies are promoting triticale, the new forage and grain varieties, mainly in the central and northern states of Mexico.

Demand for high-quality seed for large private farms, both dairy and beef production, in these regions has been increasing, offering good opportunities for seed companies (Lozano del Río, 2002).

The grain yields of the first triticale released in Mexico during the mid-1970s exceeded 5.8 tonnes/ha of grain under irrigation conditions, 20 percent less than the wheat varieties. At present, new triticale varieties have the same yield as new wheat varieties (more than 8.0 tonnes/ha). However, under rainfed conditions, triticale yield averages 15 percent more than wheat (Hernández, 2001). Under good rainfed conditions (700 mm/year), triticale has produced 6.5 tonnes/ha, while under low rainfed conditions (300 mm/year), triticale yields 2.5 tonnes/ha (Hernández and Rodríguez, 1998; González Iñiguez, 1991). As forage, triticale also yields more than wheat, barley and oats. Under very low rainfed conditions (196 mm/year), spring-type triticales produce significantly higher forage yields than the traditional oat cultivar Cuauhtemoc (5.3 to 7.4 tonnes/ha versus 3.4 tonnes/ha, respectively). Triticale has considerable regrowth after cutting at full-flowering stage, whereas little or no regrowth was observed in oat (Hinojosa *et al.*, 2002a). Under irrigation, diverse studies in northern Mexico showed that facultative and winter-intermediate triticales have higher dry-matter yields than other winter forage crops (oats, wheat, barley, rye and annual ryegrass). Overall, dry-matter yield of triticale ranged between 8.5 and 25.0 tonnes/ha depending on the growth habit types: spring, intermediate or winter types. In general, winter and intermediate triticales outyield spring types in forage production by approximately 30 percent. Furthermore, they provide better distribution of production across different cuttings (Lozano, 1991; Lozano *et al.*, 1998; Mergoum *et al.*, 1999). During the 1997-2001 period, a number of facultative and winter triticale lines were compared with traditional forage crops, such as oats, ryegrass, barley, wheat and rye, under various agro-ecological conditions. The results demonstrated the advantage of triticale over all these forage crops, both in terms of forage productivity and forage quality parameters. These results, combined with the ability of triticale to perform well under marginal soil conditions,

such as drought stress and low temperatures, have contributed to the increase in adoption of triticale by a number of farmers in the northern region of Mexico (Lozano, 1991; Lozano *et al.*, 1998; Mergoum *et al.*, 1999; Hinojosa *et al.*, 2002b).

TRITICALE PRODUCTION

Triticale is grown under a wide range of soil and climatic conditions, including dryland and marginal soils. Under high input and rainfall environments, the best triticales and wheats have comparable grain yield, with a slight advantage for the triticales. This advantage is much larger under dry and marginal conditions. Comparisons made with bread and durum wheat indicated that the modern spring-habit triticale genotypes yield as good as or better than the best yielding bread and durum wheats when lodging is avoided. Also, data have shown consistently the yield advantage of complete triticales compared to substituted genotypes (Sayre *et al.*, 1998). Hence, triticale is in general a sustainable crop for harsh and marginal farming systems (Estrada *et al.*, 1998). Triticale yields more than its ancestors in two types of marginal conditions: (i) highlands where acid soils, phosphorus deficiency and foliar diseases are dominant; and (ii) in the arid and semi-arid zones where drought affects crop production (Carney, 1992). In these environments, triticale can be a good substitute where maize has difficulties producing due to poor soils and a lack of rain. Under these conditions, triticale has shown many advantages over maize, wheat, barley and beans (Hernández, 2001). These environments are also the ones where social and economic problems play an important role as a result of poverty, illiteracy and malnutrition. In these specific regions, triticale could be the ideal crop, not only for its tolerance to the poor environmental conditions, but also for its high protein quality and the good flavour it provides to triticale tortillas when mixed with maize.

In the plateau of the central states of Mexico, triticale is produced under rainfed conditions. However, some farmers grow triticale during the winter, providing some irrigation or using soil residual moisture from previous rains (Hernández and Rodríguez, 1998). In the state of Michoacán, cereal-growing area altitude varies between 2 000 and 2 500 masl. In these environments, farmers grow dispersed fields in volcanic hills, valleys and special areas (Carney, 1992). The soils are predominantly deep, acid Andisols characterized by low fertility, low organic matter content (less than 3 percent) and high moisture retention capacity. The rainfall patterns in the central

highlands of Mexico are highly variable. This is reflected in the grain yields of small cereals grown in this region. These yields ranged from 1 to 6 tonnes/ha across different years. Moisture stress can last from pre-anthesis to post-anthesis (González Iñiguez, Castrejon and Venegas Gonzalez, 1996). Traditionally, triticale in these environments has been planted with a seeder or by dispersing the seed with a machine or by hand. The crop is also planted in rows similar to maize. In these regions where rain is scarce and erratic, the best system to produce triticale is in rows allowing the rain that falls to run to the low part of the row where the seed is placed, improving soil moisture for better germination and development of the plants. Smallholder farmers across the country grow triticale for its comparative advantages, including higher production, better animal nutrition and its impact on animal sub-products, such as milk and eggs. In addition, triticale straw is highly appreciated as feed for cattle and often mixed with maize stubble. Other farmers grow triticale for grain used for dairy cows, poultry and swine. Triticale was shown to constitute an excellent feed for animals because it increases daily milk production (Carney, 1992).

Under the low rainfed conditions of the arid and semi-arid regions dominating the northern regions of Mexico, triticale is resistant to most diseases, and it has a low water demand compared to other currently cultivated crops, such as maize. Therefore, triticale has substantial comparative advantages as an alternative crop for winter forage production in northern Mexico. The northern region constitutes the largest semi-arid zone of Mexico and has a large diversity of climates and soil characteristics. Alkaline soils and extreme winter temperatures with relatively low (200 to 400 mm annually) and erratically distributed rainfall during summer (May to September) are dominant in this region. The region is very important for livestock production, mainly beef and dairy cattle (Plate 1) (Lozano, 1991).

Triticale is a robust crop with high forage and grain yield potential, good nutritional quality and frost tolerance. It is a very promising alternative forage for the irrigated regions of the northern and central states of Mexico including Durango, Coahuila, Nuevo León, Sonora, Zacatecas, Aguascalientes and Chihuahua. The La Laguna region is the most important area for milk production in Mexico, whereas in Chihuahua beef and dairy cattle are dominant (Hinojosa *et al.*, 2002a). In addition, the northwestern part of Chihuahua, a large rainfed area with a yearly rainfall between 400 and 600 mm, grows more than 200 000 ha of oats (80 percent

of the total area of oats in Mexico) (Hinojosa *et al.*, 2002a). In this region, frost between September and March (10 to 60 days), with minimum temperatures as low as -18°C , can damage substantially the oat crop, which is a frost-sensitive crop compared to winter triticale. In recent years, severe droughts combined with frost as early as September have forced farmers to reduce the area planted to oat and look for new alternatives (Hinojosa *et al.*, 2002a; Lozano, 1991).

Other crop production systems involving triticale include the association of triticale with barley, oats, vetch and berseem clover in mixtures for forage use and intercropping triticale with maize, beans and chickpea. The use of mixtures of facultative or intermediate triticales with annual ryegrass during winter maximizes forage production and quality under irrigated conditions in the northern and central regions of Mexico. Facultative triticale-ryegrass mixtures surpassed, in general, their monocultures in dry-matter production (Lozano del Río *et al.*, 2002a). The most important aspect of this mixture is the relative stability of production, particularly for grazing conditions. This is a very important factor for pastures because it allows a higher and more uniform dry-matter production for longer periods (Lozano, 1991).

The main constraints for triticale production in humid regions are diseases, such as scab caused by *Fusarium* sp., bacteriosis caused by *Xanthomonas* sp., leaf spot and blights caused by *Helminthosporium* and stripe rust caused by *Puccinia striiformis*. In semi-arid regions with late heat during the growth period, as is the case in northern Coahuila, Nuevo León and Tamaulipas, however, the main disease is leaf rust caused by *Puccinia triticina* (González Iñiguez, 1991; González Iñiguez *et al.*, 1996). Under high rainfed conditions, most triticale cultivars are susceptible to sprouting causing grains to germinate in the spikes. However, there are some new varieties that have some kind of tolerance to this problem.

TRITICALE USES

In Mexico, 90 percent of the triticale production is utilized for animal feeding. With the release of a new generation of varieties, however, farmers and processors are renewing interest in producing this crop for other uses. Triticale is seen as the solution for agricultural production in areas where rain and temperatures are the main obstacles for food production (Pat and Hernández, 2001). Triticale grain is rich in some essential amino acids needed by humans. Its grain is also an important source of protein and energy that can be utilized in animal feeding and for human consumption in regions where protein sources in

human diets are very scarce or too expensive to access by poor people. This is particularly true for sources of amino acids included in meat or milk proteins needed in children's diets for better mental growth and development (Hernández and Macario, 2000; Carney, 1992).

Triticale grain is also suitable for making of all kinds of pastries, such as doughnuts, cookies, hot cakes and tortillas. In the central Mexican states, triticale is utilized for manufacturing tortillas made with 90 percent maize and 10 percent triticale. These kinds of tortillas are sweeter than when using wheat in the same proportion with maize due to the high percentage of sugar contained in triticale. Triticale grain is also used to make all kinds of breads when mixed with wheat grain, and germinated triticale grains can be a good energy source in human or animal diets. Currently, triticale grain blended with other grains is used as feed at the commercial level (Hernández *et al.*, 2001).

The northern region of Mexico, which includes the states of Coahuila, Durango, Chihuahua, Sonora and La Laguna, is very important for livestock production, mainly beef and dairy cattle. Irrigated pasture crops are widespread and used for grazing, hay or silage. In La Laguna, the most important dairy area in Mexico, the most common use of triticale is for hay or silage, while in other areas, especially Chihuahua and central-north Coahuila, grazing is more common. Until today, the traditional winter forages have been oats and ryegrass. Farmers in these regions have rapidly accepted triticale as a forage crop, basically due to its high biomass production but also because of its cold tolerance. Low temperatures often damage or restrict the growth of oat and ryegrass but do not harm triticale (Lozano, 1991; Hinojosa *et al.*, 2002b).

Results from experiments in which triticale was evaluated for dry-matter production and nutritional value demonstrated that winter/facultative triticales significantly outperformed traditional forage crops, such as oats and ryegrass (Lozano *et al.*, 1998). Experiences from the La Laguna region have shown that triticale is far more water-use efficient than oats, wheat and ryegrass, an important factor in regions where irrigation is a major constraint for forage production. After evaluating many triticale lines, several superior triticales have been identified for northern Mexico and will be released during the 2002/03 crop season.

High biological value forage is essential for the northern states of Mexico where cattle production is very important. The scarcity of water and low temperatures in winter oblige farmers to grow input-efficient crops with

profitable forage production levels to provide the forage supply needed during the winter period. In general, early- and late-winter growth habit triticales significantly outperformed the controls, ryegrass and oat, in green forage and dry-matter forage yields. Nutritional value analysis revealed high levels of protein content (PC) and adequate contents of acid detergent fibre (ADF), neutral detergent fibre (NDF), total digestible nutrients (TDN) and energy for triticale. The high forage biomass production and forage quality of triticale increase animal performance, reduce feeding costs and result in increased returns for the farmers (Lozano *et al.*, 1998). Moreover, environmentalists report that the straw of triticale, packed very well, may be used instead of bricks in the construction of houses and buildings. Triticale straw can also be a source of raw material to make hard paper or to use as bedding for cattle. It can be incorporated into the soil as organic matter to improve poor soils, and the straw can be used in the production of all kinds of mushrooms (Hernández, 2001).

TRITICALE IMPROVEMENT

The introduction and genetic improvement of triticale started in Mexico with an international research programme in 1964 (Zillinsky, 1973). Ten years later, the first two varieties, Bacum and Yoreme, were released. These varieties were well adapted to some regions in the states of Hidalgo, Jalisco, Michoacán, Zacatecas, Chihuahua, Oaxaca, Chiapas and Coahuila (Hernández, 2001). In 1974, many plots of 1 ha were planted in those states to show the farmers how the two triticale varieties performed under local conditions. Farmers were interested in triticale because it was more vigorous and had longer spikes than wheat. Despite the fact that triticale had low grain yield, low test weight, shrivelled grain, lodging and late maturity, farmers were still interested because they saw that it performed far better than wheat in poor environments.

In the 1970s, a farmer in the state of Michoacán noticed that feeding dairy cows with triticale grains increased the production of milk. The farmer maintained producing triticale. In 1978, in the small town of Erongaricuaru in Michoacán, production of triticale on more than 50 ha was used to make whole-grain bread in some bakeries. That town became famous for its bread made with triticale (Carney, 1992; Hernández, 2001).

Since 1974, many cultivars have been developed by the International Maize and Wheat Improvement Center (CIMMYT), which is one of the 16 organizations constituting the Consultative Group for International

Agricultural Research (CGIAR). These cultivars have been evaluated and released by Mexican research programmes (Instituto de Investigación y Capacitación Agropecuaria, Acuícola y Forestal del Estado de México [ICAMEX], Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias [INIFAP], Universidad Autónoma Agraria Antonio Narro [UAAAN] and Universidad Autónoma del Estado de México [UAEM]) to be cultivated in different regions of the country. The triticale cultivars that have had more impact on production are: Navojoa, Eronga, Huamantla, Jilotepec, Secano, AN-31 and AN-34. These last two varieties are forage-type, winter or intermediate genotypes utilized mainly for multiple cuts for hay, silage or grazing (Lozano del Río *et al.*, 2002b; Lozano del Río *et al.*, 2002c). More recent varieties released for grain production are Milenio-TCL3 (Mergoum *et al.*, 2001a), Siglo-TCL21 (Mergoum *et al.*, 2001b) and Supremo-TCL2000 (Hernández *et al.*, 2001). These recently released triticale cultivars have improved grain yield and plumpness, resistance to lodging and shattering, a shorter cycle to maturity, higher fertility and test weight and reduced plant height. The variety Siglo-21 has been cultivated widely, allowing its seed to be multiplied faster and in large quantities to supply farmers' demand. More than 1 000 tonnes of seed have been sold in the state of Mexico to plant more than 6 500 ha. Seed in the state of Mexico is produced by the state research institute (ICAMEX) and by several small farmers. Some of these farmers commercialize their seed through the government programme Kilo por kilo (see chapter "Triticale marketing: strategies for matching crop capabilities to user needs"); other seed producers have their own market, and they sell seed to their neighbours (Hernández, 2001). The seed produced by ICAMEX in the state of Mexico is commercialized through the government programme Kilo por kilo and sold to some farmers from other states, such as Jalisco, Puebla, Tlaxcala and Guanajuato. The Universidad Autónoma Agraria Antonio Narro (UAAAN) in Coahuila in northern Mexico has released most of the triticale utilized as forage. The seed of these forage-type varieties is sold by private enterprises in the northern and central states of Mexico (Lozano del Río, 2002).

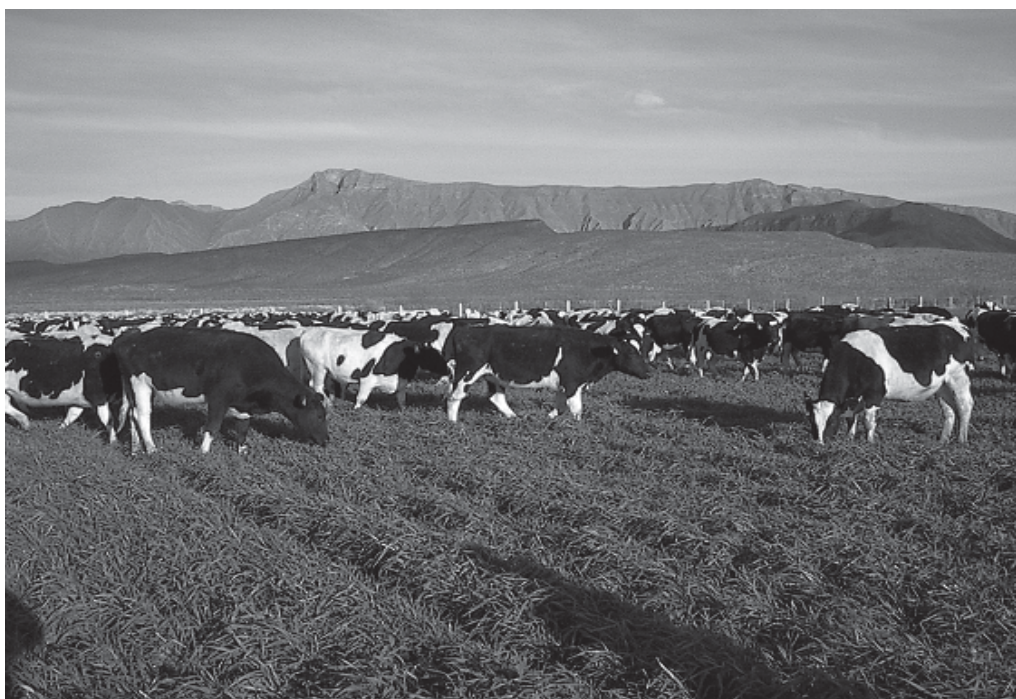
REFERENCES

- Carney, J. 1992. *Triticale production in the Central Mexican Highlands: smallholders' experiences and lessons for research*. CIMMYT Economics Papers

- No. 2. Mexico, DF, CIMMYT. 48 pp.
- Estrada, C.G., Melgarejo, B.A., Martinez, R.C., Mergoum, M. & Pfeiffer, W.H.** 1998. Yield stability in triticale and wheat cultivars in Central Valley of Mexico. In P. Juskiw, ed. *Proc. 4th Int. Triticale Symp.*, Red Deer, Alberta, Canada, 26-31 July 1998, Vol. II, p. 317. International Triticale Association.
- González Iñiguez, R.M.** 1991. Adaptation and stability of triticales Eronga 83 and Tarasca 86 in Michoacan, Mexico. In *Proc. 2nd Int. Triticale Symp.*, Passo Fundo, Rio Grande do Sul, Brazil, 1-5 Oct. 1990, p. 614. Mexico, DF, CIMMYT.
- González Iñiguez, R.M., Castrejon, C.A. & Venegas Gonzalez, E.** 1996. Evaluation of selection criteria for tolerance to *Fusarium graminearum* in triticale. In H. Guedes-Pinto, N. Darvey & V.P. Carnide, eds. *Triticale: today and tomorrow*, p. 549. Dordrecht, Netherlands, Kluwer Academic Press.
- González Iñiguez, R.M., Pfeiffer, W.H., Castrejon, C.A. & Venegas Gonzalez, E.** 1996. Characterization of Lamb-2, a new triticale variety for the highly variable moisture situation of Central Mexico. In H. Guedes-Pinto, N. Darvey & V.P. Carnide, eds. *Triticale: today and tomorrow*, p. 679. Dordrecht, Netherlands, Kluwer Academic Press.
- Hernández, S.A.** 2001. *Experiencias en el mejoramiento y difusión del triticale desde 1996 en el INIA, CIMMYT, INIFAP e ICAMEX.*
- Hernández, S.A. & Macario, R.** 2000. *El triticale, su cultivo, su potencial productivo y nutritivo en el Estado de México.* Folleto de Difusión del ICAMEX. Gobierno del Estado de México. Metepec, Mexico, SEDAGRO, ICAMEX. 20 pp.
- Hernández, S.A. & Rodríguez D., R.** 1998. *Guía para cultivar triticale de temporal en el Estado de México.* Folleto Técnico No. 4. Gobierno del Estado de México. Metepec, Mexico, SEDAGRO, ICAMEX. 8 pp.
- Hernández, S.A., Mergoum, M., Pfeiffer, W.H., Rajaram, S. & Zuloaga A., A.** 2001. Registration of Supremo-TCL 2000 triticale. *Crop. Sci.*, 41: 259.
- Hinojosa, M.B., Hede, A., Rajaram, S., Lozano del Río, J. & Valderrabano Gonzalez, A.** 2002a. Triticale: an alternative forage crop under rainfed conditions in Chihuahua, Mexico. In E. Arseniuk, ed. *Proc. 5th Int. Triticale Symp.*, Radzikow, Poland, 30 June-5 July 2002, Suppl., p. 27. Radzikow, Poland, Plant Breeding and Acclimatization Institute.
- Hinojosa, M.B., Lozano del Río, J., Hede, A. & Rajaram, S.** 2002b. Experiences and potential of triticale as a winter irrigated fodder crop in Northern Mexico. In E. Arseniuk, ed. *Proc. 5th Int. Triticale Symp.*, Radzikow, Poland, 30 June-5 July 2002, Suppl., p. 45. Radzikow, Poland, Plant Breeding and Acclimatization Institute.
- Lozano, A.J.** 1991. Studies on triticale forage production under semiarid conditions of northern Mexico. In *Proc. 2nd Int. Triticale Symp.*, Passo Fundo, Rio Grande do Sul, Brazil, 1-5 Oct. 1990, p. 264. Mexico, DF, CIMMYT.
- Lozano, A.J., Zamora, V.M., Diaz-Solis, H., Mergoum, M. & Pfeiffer, W.H.** 1998. Triticale forage production and nutritional value in the northern region of Mexico. In P. Juskiw, ed. *Proc. 4th Int. Triticale Symp.*, Red Deer, Alberta, Canada, 26-31 July 1998, Vol. II, p. 259. International Triticale Association.
- Lozano del Río, A.J.** 2002. *AN-105 Triticale. AN-31 Triticale.* Agribiotech Mexico (available at <http://www.agribiotech.com.mx>).
- Lozano del Río, A.J., Rodriguez-Herrera, S.A., Diaz-Solis, H., Fuentes Rodriguez, J.M., Fernandez-Brondo, J.M., Narvaez-Melo, J.M.F. & Zamora-Villa, V.M.** 2002a. Forage production and nutritional value of mixtures of triticale (*X Triticosecale* Wittmack) and ryegrass (*Lolium multiflorum*) in Navidad, N.L. *Técnica Pecuaria en México*, 40: 17.
- Lozano del Río, A.J., Colin Rico, M., Reyes Valdes, M.H., Pfeiffer, W.H., Mergoum, M. & Hede, A.** 2002b. Registration of TCLF-AN-31 triticale. *Crop Sci.*, 42: 214.
- Lozano del Río, A.J., Colin Rico, M., Reyes Valdes, M.H., Pfeiffer, W.H., Mergoum, M. & Hede, A.** 2002c. Registration of TCLF-AN-34 triticale. *Crop Sci.*, 42: 215.
- Macario, B.R.** 1998. *El triticale (X Triticosecale Wittmack) en la alimentación humana.* Tesis Profesional de Ingeniero Agroindustrial, Departamento de Ingeniería Agroindustrial, Universidad Autónoma Chapingo, Chapingo, Mexico.
- Mergoum, M., Pfeiffer, W.H., Peña, R.J. & Lozano, A.J.** 1999. Triticale: adaptation, end-uses and challenges. In *Jornadas Ibericas sobre triticale*, p. 26. Andalucía, Spain.
- Mergoum, M., Hernández, S.A., Pfeiffer, W.H., Rajaram, S., Zuloaga A., A., Abdalla, O. & Varughese, G.** 2001a. Registration of Milenio-TCL3 triticale. *Crop. Sci.*, 41: 272.
- Mergoum, M., Hernández, S.A., Pfeiffer, W.H.,**

- Rajaram, S., Zuloaga A., A., Abdalla, O. & Varughese, G.** 2001b. Registration of Siglo-TCL 21 triticale. *Crop. Sci.*, 41: 273.
- Pat, F.L.A. & Hernández, S.A.** 2001. *Cultivo de cereales, una alternativa para las áreas de temporal del Estado de México. Un enfoque regional de reconversión de cultivos.* Folleto de Difusión. Gobierno del Estado de México. Metepec, Mexico, SEDAGRO, ICAMEX. 64 pp.
- Sayre, K., Pfeiffer, W.H., Mergoum, M. & Cruz Miranda, J.** 1998. Triticale yield potential under full irrigation in northwest Mexico. In P. Juskiw, ed. *Proc. 4th Int. Triticale Symp.*, Red Deer, Alberta, Canada, 26-31 July 1998, Vol. II, p. 346. International Triticale Association.
- Zillinsky, F.J.** 1973. *Mejoramiento e investigación sobre triticale en el CIMMYT. Informe de Avances.* Folleto de Investigación No. 24. Mexico, DF, CIMMYT. 78 pp.

PLATE 1
Holstein heifers grazing AN-31, an intermediate-winter triticale, at Cuatrociénegas, Coahuila, Mexico
A.J. Lozano del Río



Triticale in Poland

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Research and breeding of triticale in Poland was started in the 1960s, i.e. a few years after work was undertaken in Europe and America (Shebeski, 1980; Tarkowski, 1989). The first Polish cultivar Lasko was registered in 1982 and Dagro in 1984. At that early stage, triticale research and breeding was focussed on winter types. In the 1980s, triticale in Poland developed rapidly. The crop was enthusiastically and widely accepted by farmers, and its sowing area increased each year considerably. In the 1990s, the area planted to triticale in Poland stabilized and even dropped slightly (Smagacz, 1999). The main reason for this was the limited production of triticale by state-owned farms. In the late 1990s, 600 000 ha of triticale was grown in Poland. In recent years, farmers have shown a new interest in winter triticale growing, and triticale area under commercial production increased to 734 000 ha in 2001. Winter triticale is grown mainly in the following regions: Wielkopolska, Ziemia Lubuska, Gdańsk, Pomerania, Warmia, Mazury and central Poland. In addition, triticale is grown quite extensively in the former voivodships of Czêstochowa, Skierniewice and Bia³a Podlaska (Figure 1).

The breeding successes of winter triticale have contributed to a greater interest in spring triticale. The outcome of breeding work on spring triticale was the registration of spring cultivars Jago in 1987 and Maja in 1988. However, it should be noted that originally spring triticale generated less enthusiasm than winter triticale. Nonetheless, the slow increase of spring triticale growing area resulted in 106 000 ha in 2001. Spring triticale is grown in northern, western (3.3 percent in the Zielona Góra region) and central (3.5 percent in the Mazovian voivodship) Poland and in Silesia (Figure 2). The economic importance of spring triticale is not high. It is used mainly for animal feeding. At present, five spring triticale cultivars are on the official list of varieties. They differ from each other in yield potential and agronomic characteristics. In general, yield potential and resistance to diseases, lodging and sprouting have been decisive as to whether or not a triticale cultivar can be commercially produced.

Triticale holds a strong position in Polish plant breeding (Czembor, 1999). In total, 41 winter-habit

triticale cultivars and seven spring-habit triticale cultivars have been released so far. Currently, 28 cultivars of winter habit and five cultivars of spring habit are on the official list of varieties. In addition, six winter cultivars designed for export are included in the register. It should be underlined that according to data from the Organisation for Economic Co-operation and Development (OECD) 19 triticale cultivars from Poland have been placed in the variety catalogues of 13 countries (OECD, 2001). Winter triticale cultivar Presto is registered in six countries, and winter cultivar Ugo registered under the name Modus has been grown extensively in Germany. Other well-known winter triticale cultivars with high yield potential are Tornado, Kitaro, Kazo (2000) and frost-resistant cultivar Janko (2000). Among cultivars registered in 2001, Hewo, Krakowiak and Sekundo are especially suitable for growing in southeastern Poland. The breeding of cultivars with short straw and high resistance to lodging has been successful. Bogo was the first such cultivar registered in 1993, followed by short-straw cultivars Fidelio and Woltario. Winter triticale cultivar Fidelio provided one-third of the certified seed production in Poland and is used as a reference cultivar in the United Kingdom of Great Britain and Northern Ireland. In 2002, three new winter triticale cultivars were released: Pawo and Witon (released by breeders from Malyszyn Experiment Station) and Sorento (released by breeders from Danko Plant Breeding Co.) (Wolski, 1995; Wolski *et al.*, 1998).

Apart from advantages, which have made triticale competitive with rye and wheat, there are also triticale disadvantages, such as sensitivity to grain sprouting or long growth period. Higher yielding is associated with lower protein content in grain. Spring triticale breeding was the responsibility of the Plant Breeding and Acclimatization Institute (IHAR) in Radzikow. After 2000, breeding was taken over by Strzelce Plant Breeding Company Ltd., established on the basis of former IHAR Experimental Stations.

Triticale cultivars released in Poland have wide adaptation and could be grown in all geographical regions of the country. Leaf rust (*Puccinia triticina*) and sporadically stripe rust and stem rust, *Stagonospora*

FIGURE 1

Geographical distribution of winter triticale production in Poland; percentage as compared to total cereal-sowing area

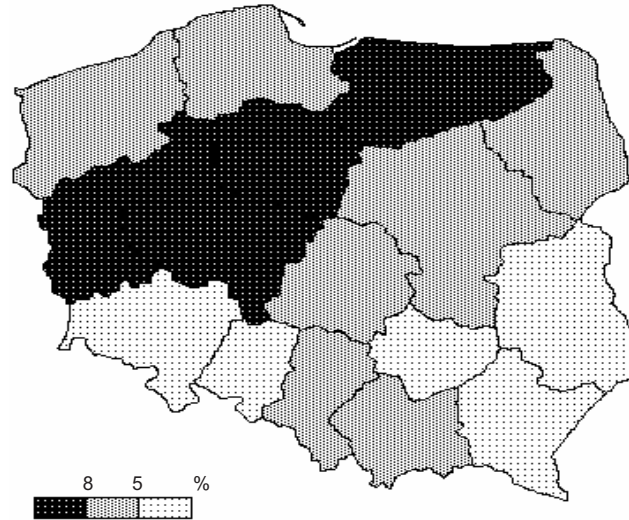
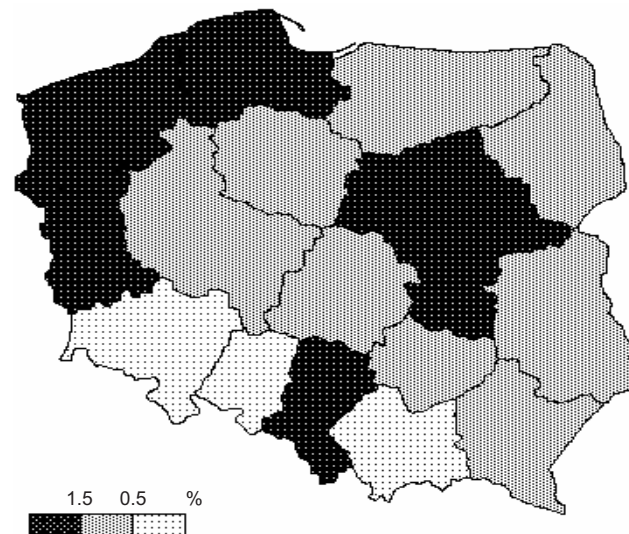


FIGURE 2

Geographical distribution of spring triticale production in Poland; percentage as compared to total cereal-sowing area



nodorum blotch, scab, *Rhynchosporium* scald, take-all (*Gaeumannomyces graminis*), foot and root rots caused by *Microdochium nivale* and *Fusarium* sp. and eyespot (*Pseudocercospora herpotrichoides*) are the main diseases that afflict triticale in Poland (Arseniuk, 1996; Arseniuk *et al.*, 1999).

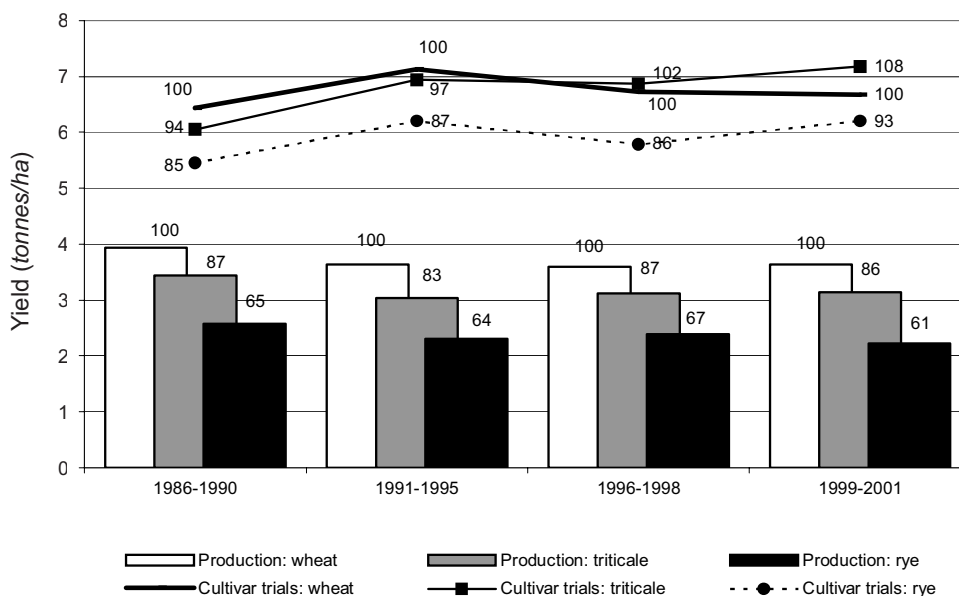
Changes in the yield of winter triticale under experimental and production conditions in relation to

winter wheat and rye are shown in Figure 3. The yield of winter triticale in experimental field tests increased over several years with an average yield over 7 tonnes/ha. Triticale appears to be the highest yielding cereal species in Poland.

The grain yields of cereals under commercial production conditions over the last decade have not changed substantially. A lack of yield increase was caused

FIGURE 3

Wheat, triticale and rye yields under commercial production and trial conditions; numbers above bars and lines are relative percentages to wheat yield



Source: Krzymuski and Oleksiak, 1997.

by factors related to cultivation technology, which was influenced by an agricultural and economic recession in Poland. This explains why the difference in cereal yields between experimental and production conditions increased. Additionally, an increasing area of wheat grown each year pushes triticale and rye to be grown in poor and marginal soils. Other factors affecting cereal yield are mineral fertilization, use of chemicals to control pests and diseases and use of new cultivars and certified seed for planting.

Finally, it should be pointed out that average triticale yields in commercial production during the 1999-2001 period represented only 43.8 percent of yields obtained in experimental trials. This relationship was much better than in rye and much less than in wheat. The problem is that the new cultivars developed by breeding companies are not directly associated with certified seed production (Oleksiak, 2000), which delays the introduction of modern cultivars into commercial production. Low demand for certified seed is a common phenomenon. In the case of triticale, however, reduction of demand for certified seed is relatively unimportant. In 2001, the area grown to triticale in Poland increased substantially. Despite this increase, the certified triticale seed used for planting constituted only 12.3 percent. It is obvious that such a

low use of certified seed resulted in a slower introduction of new cultivars into production, which undermines any progress made in plant breeding. It is worth mentioning that in large farms the use of certified triticale seed was significantly higher (Table 1). The increase in average triticale area observed in recent years is certainly encouraging. Such an increase in crop production was also accompanied by higher production inputs, such as certified seed, fertilizers and pesticides. In large production areas, the use of mineral fertilization and chemical crop protection were almost doubled compared to other areas. Triticale production using higher inputs appeared to be associated with higher grain yields that compensate the production costs (Table 1).

REFERENCES

- Arseniuk, E.** 1996. Triticale diseases – a review. *In* H. Guedes-Pinto, N. Darvey & V.P. Carnide, eds. *Triticale: today and tomorrow*, p. 499-525. Dordrecht, Netherlands, Kluwer Academic Press.
- Arseniuk, E., Foremska, E., Góral, T. & Chełkowski, J.** 1999. Fusarium head blight reactions and accumulation of deoxynivalenol (DON) and some of

TABLE 1
Relationship between triticale plantation size and the use of production means^a

Production means	Area of triticale field				
	<0.5 ha	0.5-1.0 ha	1.0-2.0 ha	2.0-5.0 ha	>5.0 ha
N (kg/ha)	43.3	53.1	58.3	68.0	81.7
P ₂ O ₅ (kg/ha)	25.0	27.0	32.4	40.2	41.6
K ₂ O (kg/ha)	21.7	28.0	34.5	44.9	52.1
NPK (kg/ha)	90.0	108.1	125.2	153.1	175.4
Herbicides	0.66	0.79	0.84	0.98	1.00
Fungicides	0.17	0.13	0.13	0.26	0.45
Certified seed (%)	31.4	27.5	31.4	35.2	51.0
Cultivar value ^b (kg/ha)	-110	-150	-140	-20	80
Sowing rate (kg/ha)	236.3	232.7	242.5	232.7	230.0
Age of a cultivar since release (year)	8.3	8.8	8.6	7.5	6.9
Soil quality (points 0-100)	49.6	52.7	48.7	47.0	44.8
Relative yield (%)	92.3	93.9	94.6	105.8	111.2
Yield (kg/ha)	3 410	3 510	3 540	3 970	4 210
Number of fields	137	345	444	318	98

^aAverage values of survey data for the period 1995-2000.

^bYield deviation from a standard.

- its derivatives in kernels of wheat, triticale and rye. *J. Phytopath.*, 147: 577-590.
- Czembor, H.J.** 1999. Achievements in cereal breeding in Poland and varietal progress. *Pamiętnik Puławski* (Polish), 114: 41-55.
- Krzymuski, J. & Oleksiak, T.** 1997. Winter triticale in field trials and in commercial production in 1986-1995. *Zesz. Nauk. AR Szczecin* (Polish), 175: 213-218.
- OECD.** 2001. *List of varieties eligible for certification* (available at <http://www.oecd.org/agr/code/seeds/>).
- Oleksiak, T.** 2000. Triticale in production – practical utilization of breeding effects. Quality of planted seed and triticale yields. *Folia Univ. Agric. Stetin. Agricultura* (Polish), 82: 199-204.
- Shebeski, L.H.** 1980. Hodowla Rootin. *Aklimatyzacja i Nasiennictwo*, 24(4): 279-285.
- Smagacz, J.** 1999. Importance of triticale under conditions of large share of cereals in the sowing structure. *Pamiętnik Puławski Z.* (Polish), 114: 325-334.
- Tarkowski, C.** 1989. *Biology of triticale* (Polish). Warszawa, PWN. 383 pp.
- Wolski, T.** 1995. Present and future in small grain breeding and seed production in Poland. *Fragmenta Agronomica*, 2(46): 52-55.
- Wolski, T., Szołkowski, A., Gryka, J. & Pojmaj, M.S.** 1998. Current status of winter triticale breeding in Danko. *Biuletyn IHAR* (Polish), 205/206: 289-297.

Triticale in Portugal

B. Maçãs

Farmers in Portugal first cultivated triticale in 1979. By the end of the 1980s, Portuguese farmers were growing an estimated area of 80 000 ha. Triticale was mostly grown for grain and used mainly for feeding. After 1992, with the new Common Agricultural Policy (CAP) reform, the area grown to triticale started to decrease due to a shift in subsidies allocated to wheat. In the 2000/01 crop season, 32 425 ha were grown to triticale and half of this area was used for forage purposes.

The main cereal-growing region in Portugal is located in the southern part of the country, which has a strong Mediterranean climate. Both climate and soil conditions are variable. Despite the good amount of rainfall, its distribution remains the main limiting factor for cereal yields. Other constraints, such as low-fertility soils, toxicity caused by Al^{+++} and Mn^{++} in acidic soils, late frosts that occur during anthesis and heat stress during grainfilling, also limit cereal production in these regions.

Planting starts after the first rains in autumn and continues until 15 December. Spring and facultative triticale types are both grown in the region. True winter types cannot be used due to vernalization requirements.

Although production of triticale on the farm scale started in the 1980s, research involving triticale in Portugal began much earlier. Victória-Pires, the founder of the National Plant Breeding Station at Elvas, pointed out in 1937, in his general guide for the establishment of a breeding programme for cereals and forages, the interest of exploiting the progenies of crosses involving the genera *Triticum* and *Secale* in order to obtain a plant with adaptation to low-fertility soils (Victória-Pires, 1939). This first work on triticale resulted in an octoploid line S. José derived from a cross between bread wheat Ardito and the rye Petkus (Villax, Mota and Ponce-Dentinho, 1954). S. José showed very poor agronomic characteristics but was successfully used in cytogenetic studies to achieve good scientific information.

In 1967, the triticale programme at Elvas received the first triticale nursery from the International Maize and Wheat Improvement Center (CIMMYT). At the beginning, all the genotypes were very poor, showing low spike fertility, tall straw, shrivelled kernels and very low yields. But the rapid progress achieved by the CIMMYT

triticale programme allowed the release of one Armadillo line, which was the first triticale actually grown in Portugal (Barradas, 1982). Following Armadillo, a second generation of varieties showing interesting characteristics was distributed to farmers. The most successful varieties were Arabian and Bacum substituted cultivars derived from the M2A line, with 2D/2R substitution, and Beagle, a complete triticale (Table 1). These varieties showed excellent results and stimulated triticale cultivation in Portugal (Bagulho *et al.*, 1996). At that time, the substitution-type varieties were extensively used by farmers due to their better threshing ability. However, the kernels were shrivelled showing low test weight. At Elvas, the breeding programme during the 1980s focussed on improving kernel characteristics, selecting for better tillering in order to increase the number of grains/m² and selecting for long-cycle germplasm. This effort resulted in the release of the variety Alter, selected in the Rhino'S' cross from CIMMYT (Table 1).

The data in Table 1 show the progress in yield potential is mainly due to increasing kernel number and 1 000 kernel weight. Harvest index still tends to be low (26 percent compared with 30 percent for durum wheat for the same period of trials), but steady improvements have been recorded, indicating that work should continue with this trait (Maçãs, Coutinho and Bagulho, 1998).

In summary, marked progress has been achieved with spring triticale varieties, with special reference to yield potential, improved test weight and yield stability, but growth cycle is still not suitable for winter grazing.

After the CAP reform in 1992, the traditional use of triticale decreased, and farmers started to demand varieties suitable for grazing and silage. Therefore, an intensive crossing programme was started at Elvas to promote the introgression of winter genes onto spring genotypes. Although CIMMYT material is still the most important source of germplasm both for field evaluation and as parental material, winter and facultative genotypes are being used extensively to enhance the diversity of the germplasm base in order to select genotypes with a longer growth cycle.

In order to maintain the intergenomic genetic balance within triticale genotypes, the crossing programme

TABLE 1
Range and mean values for grain yield, yield components, test weight and days to heading for Alter and older triticale varieties released in Portugal^a

Variety	Grain yield (kg/ha)	Number of kernels/m ²	'000 kernel weight (g)	Test weight (kg/hl)	Days to heading ^b (days)
Arabian	2 570-7 027	7 637-14 397	33.65-49.74	65.32-72.15	19-31
	4 296	-	42.15	68.60	25
Bacum	2 784-7 308	8 926-14 222	31.19-52.91	65.68-75.45	16-32
	4 686	11 088	41.86	69.32	26
Beagle	3 309-6 539	8 768-14 169	34.59-52.45	64.15-68.75	25-32
	4 435	10 218	43.14	66.58	29
Alter	3 473-10 092	9 227-20 504	35.20-59.01	70.55-79.00	22-36
	5 890	13 007	44.49	75.32	30

^aData are average over eight year trials at Elvas, Portugal.

^bDays to heading after 1 March.

TABLE 2
Forage yield and quality means for winter cutting and grain yield, straw and harvest index for regrowth of three different growth-habit triticale germplasms^a

Growth habit	Winter cutting ^b			Regrowth ^b			
	Biomass (kg/ha DM)	Protein (% DM)	Fibre (% DM)	Biomass (kg/ha DM)	Grain yield (kg/ha)	Straw (kg/ha)	Harvest index (%)
Early triticale	4 737	17.05	20.53	12 581	3 787	8 794	30
Facultative triticale	4 311	17.91	20.82	14 761	4 198	10 563	28
Winter triticale	3 678	18.18	20.01	15 718	3 854	11 864	24

^aTested at Elvas, Portugal, over three years.

^bDM = dry matter.

includes different types of crosses: three-way crosses among triticales where the first cross is spring x winter or facultative and the third parent is facultative; triticale x bread wheat x triticale; and triticale x durum wheat x triticale. The main goal is to transfer valuable traits, such as low vernalization requirement, day-length sensitivity, late flowering, short grainfilling period, high tillering and early growth for grazing in winter as well as good recovery after grazing.

The first variety released nationally with these characteristics was Fronteira, which has some vernalization requirement and hence can be classified with the facultative types. The timing of availability of green forage in winter is very important for feeding animals in the field. In southern Portugal, animals (cattle, sheep and pigs) are left free to graze all year long. With this system, there are two critical periods for livestock feeding, winter and summer (Maças, Coutinho and Dias, 1998). In winter, forage legumes and grasses, such as ryegrass, have problems due to their lack of resistance to frost. During summer, drought and high temperatures do not allow growing any crop. Thus, intensive work has been carried out to identify germplasm suitable for these

systems. The production of winter forage with good regrowth capacity is influenced by the growth habit of triticale, as shown in Table 2.

Facultative triticale types showed better performance when combining early growth with good recovery capacity after grazing. The growing point of these materials was not destroyed by the animals, assuring good regrowth after grazing. Almost all advanced genotypes were submitted to animal grazing or cut during the selection process in order to have materials that could accumulate high dry matter during winter while keeping the growing point below or at the soil level.

In Portugal, public institutions conduct all triticale breeding work. The National Plant Breeding Station at Elvas has been conducting the main programme. This programme released seven of the ten varieties that are included on the national list of released varieties. A second research programme is located at the University of Trás-os-Montes e Alto Douro in Vila Real. This programme recently released one variety under the name Douro, a variety very well adapted to the conditions in the northern part of the country.

In the future, triticale has a major role to play in

Portuguese agriculture, mainly as forage but also as a grain source. The advantages of triticale can overcome some of the difficulties imposed by the CAP policy of the European Union. In rainfed systems, there is unfortunately no viable alternative for cereals, therefore, triticale appears to be a very good crop to include in rotations with wheat. It may provide the solution to take-all (*Gaeumannomyces graminis*) diseases in wheat. In the 2001/02 crop season, in adjacent trials conducted at Elvas in a field with a very strong attack of take-all, triticale produced almost double that of bread wheat. In addition to this advantage, triticale is also efficient in using nutrients, which maybe promising for organic systems which are increasing in Portugal.

REFERENCES

- Bagulho, F., Barradas, M.T., Maças, B. & Coutinho, J.** 1996. Some remarks on triticale breeding evolution in Portugal: a) role played by the National Plant Breeding Station. In H. Guedes-Pinto, N. Darvey & V.P. Carnide, eds. *Triticale: today and tomorrow*, p. 635-641. Dordrecht, Netherlands, Kluwer Academic Press.
- Barradas, M.T.** 1982. Algumas características de quatro cultivares de triticale a propor à Lavoura. *Melhoramento*, 27: 141-159.
- Maças, B., Coutinho, J. & Bagulho, F.** 1998. Forage and pasture potential of triticale growing in marginal environments: the case of semi-arid conditions. In P. Juskiw, ed. *Proc. 4th Int. Triticale Symp.*, Red Deer, Alberta, Canada, 26-31 July 1998, p. 140-142. International Triticale Association.
- Maças, B., Coutinho, J. & Dias, A.S.** 1998. Oportunidades para aumentar o potencial produtivo do trigo da região Mediterrânica do Sul de Portugal. I. Produção de biomassa. Componentes da produção e índice de colheita. *Melhoramento*, 35: 5-18.
- Victória-Pires, D.R.** 1939. *Linha geral de um plano para melhoramento de cereais e forragem*. Lisboa, Sep. Planos de trabalho da Estação Agronómica Nacional. 27 pp.
- Villax, E., Mota, M. & Ponce-Dentinho, A.** 1954. Dois novos triticales. *Melhoramento*, 7: 29-57.

Triticale in Spain

C. Royo, D. Villegas, L.F. García del Moral

The area devoted to triticale in Spain increased sharply between 1986 and 1989 when it reached 75 500 ha (Figure 1). From 1989 onwards, triticale cultivation declined due to its replacement by other subsidized field crops, mainly durum wheat. At present, triticale covers about 32 000 ha with a total production of 75 000 tonnes, averaging 2.3 tonnes/ha (Figure 2). The export market is minor, while within the country the average price received by farmers for this grain has decreased 16 percent since 1995 to 130 €/tonne in 2000 (Figure 3).

TRITICALE CULTIVATION

In Spain, triticale is generally cultivated under rainfed conditions, mostly in the southern regions of the country: Andalusia (which accounts for about 65 percent of the area) and Extremadura (with about 20 percent). These regions have a Mediterranean climate, with an average annual precipitation of about 450 mm, usually distributed evenly throughout the growing season. Terminal drought stress is the main abiotic constraint to the crop. However, minor cultivation areas are scattered in central-eastern regions (Castilla-La Mancha, 11 percent), the Balearic Islands (3 percent) and northeastern zones (Catalonia, 1 percent). The central and northern regions have a more continental climate, with lower temperatures during winter and spring and very high temperatures and water stress during grainfilling. Rainfall is lower (200 to 300 mm) and less evenly distributed. Hail damage (Plate 1) may occur occasionally. In the wet northern region, grain damage due to sprouting (Plate 2) may occur. Biotic stresses have not limited the cultivation of triticale in the past. However, some varieties have recently become susceptible to foliar diseases, especially leaf rust.

Most of the triticale varieties cultivated in Spain are spring types that admit an alternative sowing, even during autumn. Planting is generally carried out in November. Earlier sowings are not recommended in cool areas to avoid frost damage (Plate 3) to the crop during spring or aphid infestations during autumn (Royo, 1992). The impact of a delayed sowing date and drought on grain growth and morphometry has recently been investigated (Royo *et al.*, 2000). Recommended sowing densities range between 200 and 250 kg/ha. One of the advantages

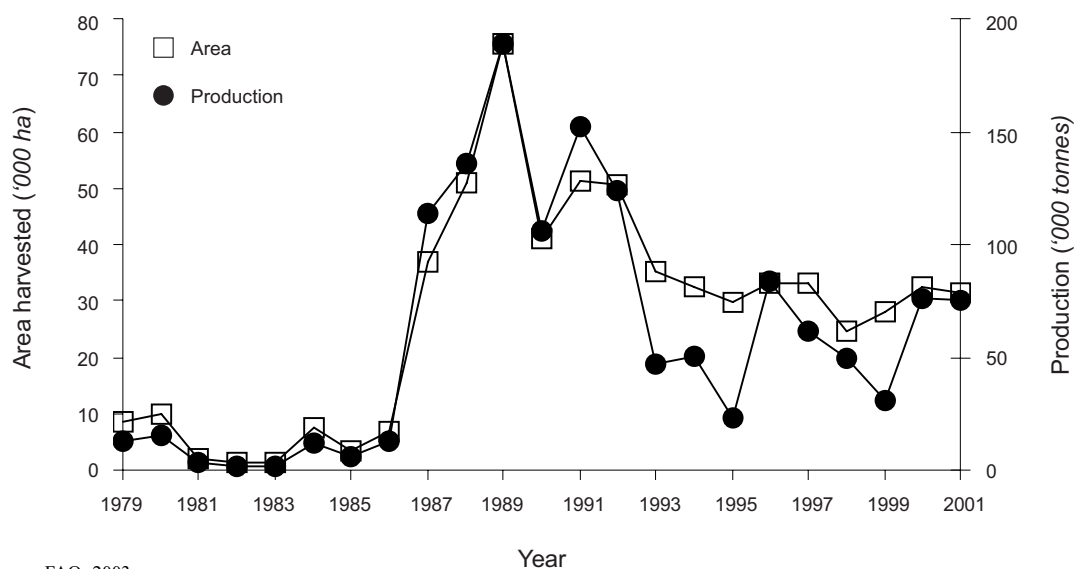
of triticale compared with barley or wheat is its early vigour, which enables a fast crop growth during the first stages of development and a rapid cover of the soil by the crop canopy. Moreover, during its vegetative growth, triticale is much less attractive to rabbits and other rodents than other small-grain cereals.

END-USES

Triticale was first introduced in Spain as a grain crop. Under the Mediterranean conditions of Spain, triticale grain can provide between 300 kg/ha of crude protein under rainfed conditions to almost 900 kg/ha under irrigation, with a content in essential amino acids (g aa/100 g protein) ranging between: 1.98 and 2.29 for lysine; 0.94 and 2.04 for methionine; 3.02 and 3.44 for phenylalanine; 4.25 and 4.52 for threonine; and 4.83 and 4.98 for leucine (García del Moral *et al.*, 1995; Fernandez-Figares *et al.*, 2000). Although most of the triticale fields have this end-use, farmers familiar with the crop are increasingly focussing on alternative and specific uses. On the other hand, marketing problems are frequent for the growers when trying to sell their triticale grain, and often when they find a purchaser, the prices received are lower than for bread wheat, but similar to those for barley or rye for feed.

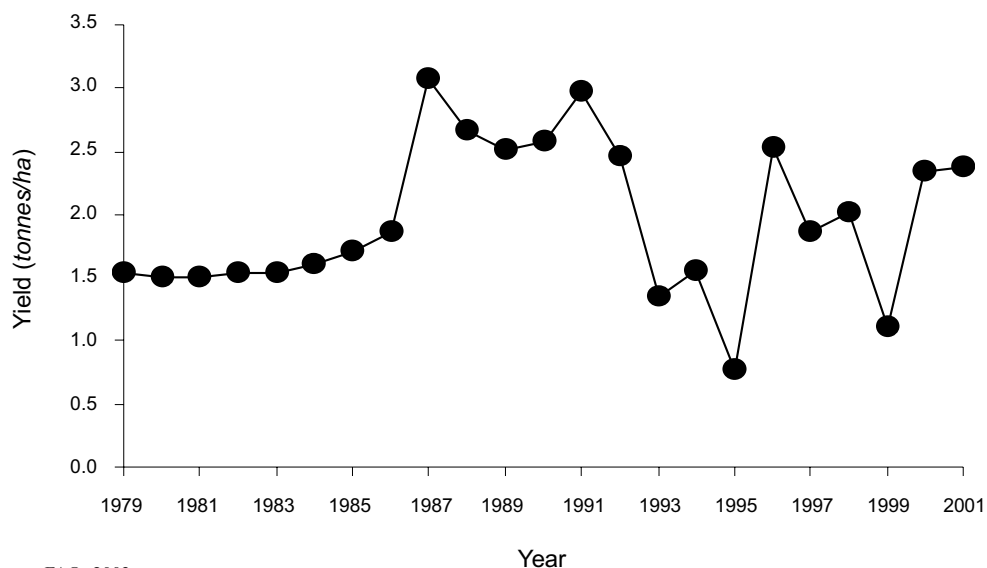
In some meadows of Extremadura and Andalusia, triticale is grown as an intercrop in ilex fields, for pig or sheep grazing, providing green forage or mature spikes. Conversely, in the cereal-producing areas of northeastern Spain, with an average rainfall during the crop season (from November to July) of 500 mm and where sheep and dairy cattle are common, triticale is grown on about 1 500 ha for silage (Plate 4) in rotation with maize. Harvesting takes place about ten days after flowering in order to have enough forage production with acceptable quality (Royo *et al.*, 1998) and to avoid significant yield reductions from delayed sowing of maize, the main crop of the rotation. This practice allows farmers to grow two crops per year. The average composition from 17 analyses of silages from different farms showed 28.8 percent dry matter, 9.4 percent crude protein, 32.6 percent crude fibre, 29.4 percent acid detergent fibre, 58.2 percent neutral detergent fibre and 6.2 percent lignin (Royo and Serra,

FIGURE 1
Evolution of the area devoted to triticale and total production in Spain, 1979-2001



Source: FAO, 2003.

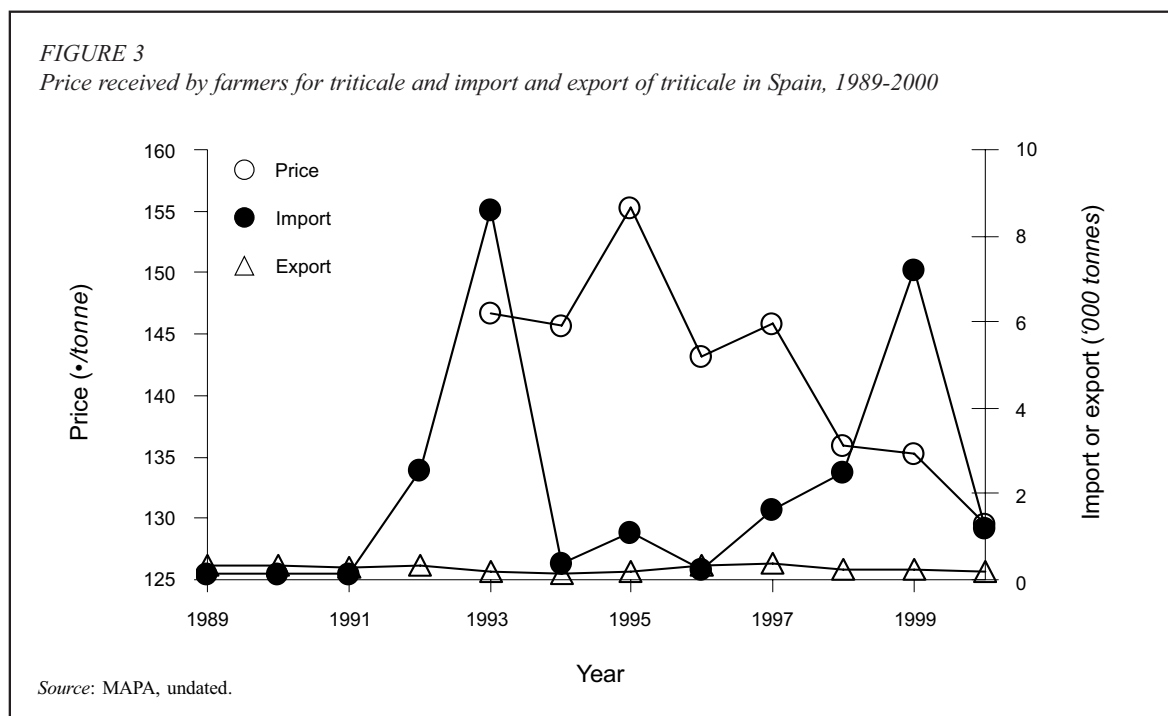
FIGURE 2
Average yield of triticale in Spain, 1979-2001



Source: FAO, 2003.

1993). Farmers agree that the advantages of triticale in rotation with maize in these areas include: (i) guaranteed forage supply during winter (triticale is grown from November to May and maize in the remaining months); (ii) higher productivity than other cereals, such as wheat

or barley; (iii) less lodging and fewer diseases than barley; (iv) earlier flowering than wheat; and (v) lower water consumption than ryegrass (Royo and Aragay, 1994). Different studies conducted in the region have concluded that when triticale is the only crop grown during the year,



forage has to be harvested at the late-milk/early-dough stage, because the low quality at this stage compared with earlier ones is offset by higher dry-matter yields.

The use of triticale for dual purpose (forage and grain production in the same crop season) has been widely investigated in Spain (Royo, 1997; Royo and Tribó, 1997). This end-use is recommended when forage is needed during winter but the main objective of the field is grain production. In several experiments throughout Spain, the crude protein in the forage varied from 29.6 to 31.2 percent (showing a trend to diminish with late cuttings), the digestible crude protein varied from 24.9 to 26.3 percent and the acid detergent fibre from 17.2 to 19.8 percent (tending to increase with late cuttings) (Royo *et al.*, 1994). Early sowing is recommended when forage and grain are to be harvested in the same cropping season. To avoid drastic grain yield reductions, forage should be cut no later than the beginning of jointing, leaving intact the apical dome (Plate 5) (Royo *et al.*, 1997). Winter triticals appear to be better adapted for forage production, but the combined output of both forage and grain makes spring types seem better suited to the Mediterranean climate and to late-autumn sowing (Royo and Parés, 1996; Royo and Romagosa, 1996).

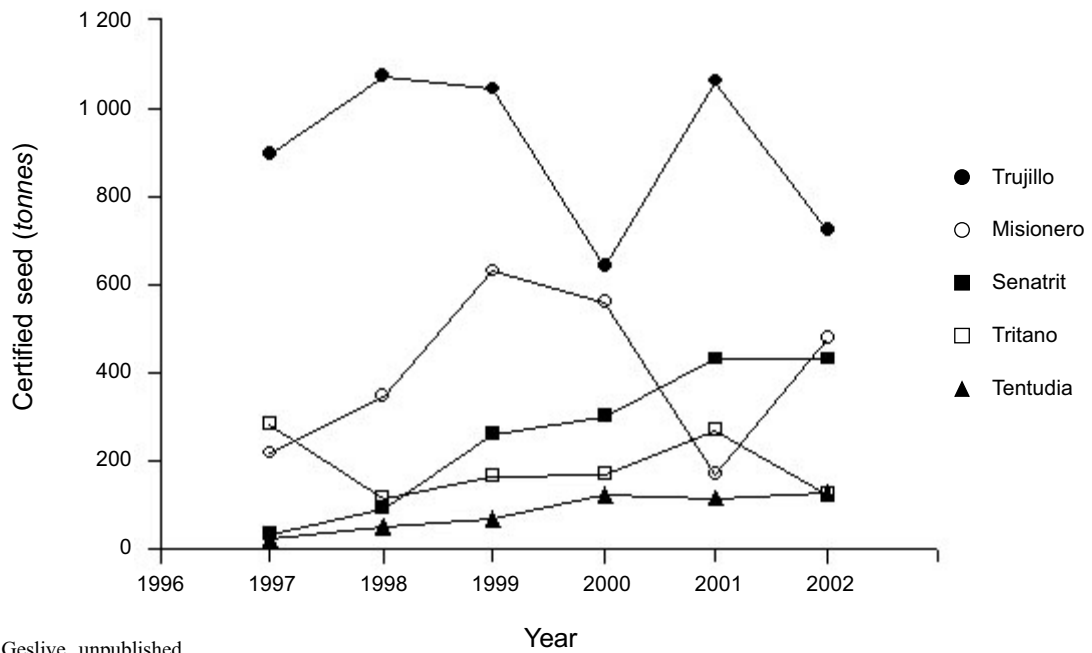
VARIETY DEVELOPMENT

In 1947, Sánchez-Monge started the first triticale breeding programme in Spain (Sánchez-Monge, 1996). He also

determined that the hexaploid ploidy level of triticale was the optimal level for vigour and productivity. Cachirulo, the first Spanish triticale variety, was developed by this programme and released for production in 1969. Since then, about 50 new varieties have been released in the country, but only a few of them have reached the farmers. Germplasm from the International Maize and Wheat Improvement Center (CIMMYT) has had a strong impact on the development of new triticale varieties in Spain. Manigero and Fascal, two substituted types (rye chromosome 2R replaced by chromosome 2D of wheat), were the most cultivated varieties in the 1980s. Afterwards, a new generation of complete types (having all seven rye chromosomes), more productive and stress tolerant, was introduced. Presently, several public and private breeding programmes continue (Plate 6), and the best performing varieties are selected for demonstration trials (Plate 7) visited by farmers during field days.

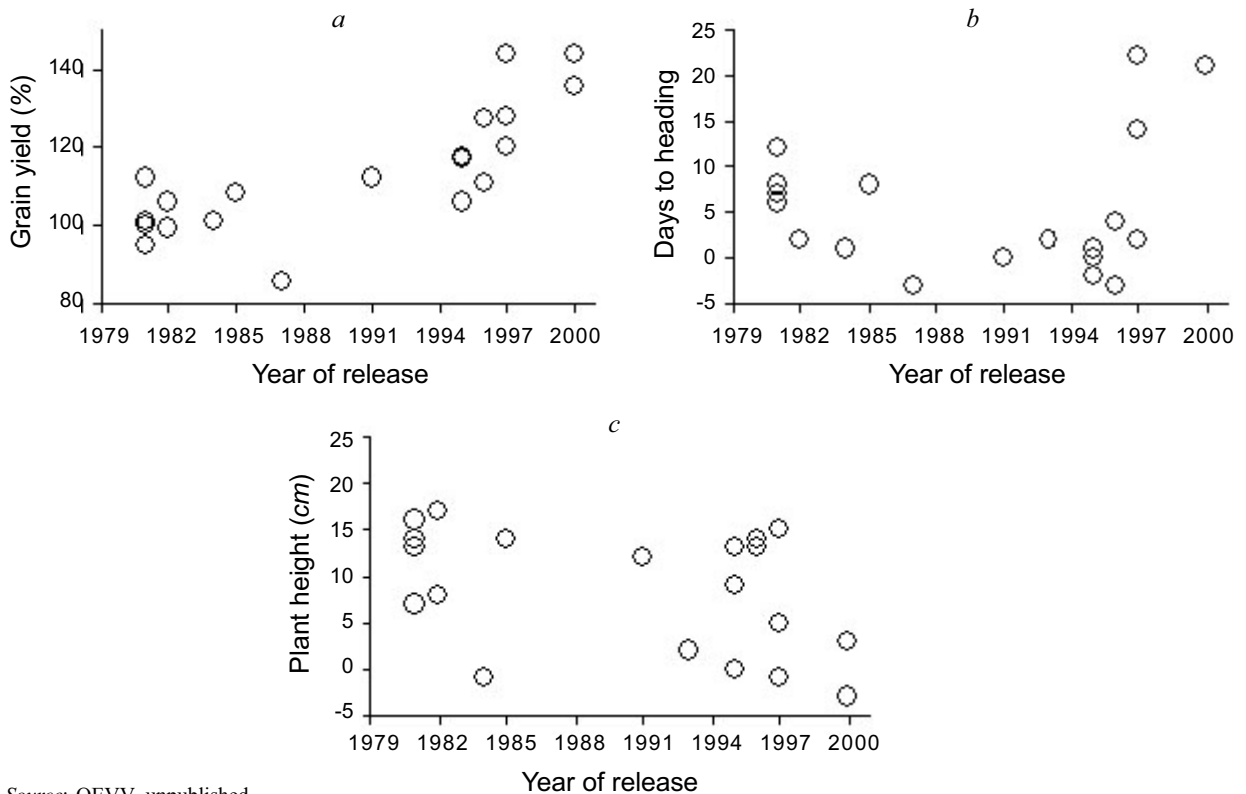
A map of the current variety structure in Spain can be determined by looking at the amount of certified seed used for each variety. The five most cultivated varieties at present are Trujillo, Misionero, Senatrit, Tritano and Tentudia (Figure 4). However, low amounts of Trijan, Galgo, Activo, Noe, Abaco, Camarma and Medellin seed were also certified in 2002. The total amount of triticale seed certified in Spain during the 2001/02 crop season was 2 553 tonnes, representing only 0.8 percent of the total certified seed of small-grain cereals.

FIGURE 4
Use of certified triticale seed in Spain, 1997-2002



Source: Geslive, unpublished.

FIGURE 5
Average yearly values for official multilocational trials of triticale genotypes released as varieties for grain yield (a), days to heading (b) and plant height (c) in relation to the check variety Manigero, 1981-2000



Source: OEVV, unpublished.

Genotype candidates to be released for cultivation must be submitted by breeders to the Oficina Española de Variedades Vegetales (OEVV), the office responsible for determining whether the candidate varieties meet the requirements to be released. The candidates are tested for two crop seasons in multilocation trials around the country. A committee evaluates annually the performance of candidates in the cooperative test network and either recommends or rejects the registration of the proposed lines. Progress in yield may be assessed by comparing the yield of the varieties released each year with the main yield of the check variety Manigero that remains stable over different crop seasons. Yield has risen mostly from 1995 onwards (Figure 5a) at an overall mean rate of 1.68 percent/year. The latest yield increases may be associated with the late-heading varieties (Figure 5b). On the other hand, recently released triticales are also shorter in height than their predecessors (Figure 5c). Important improvements have also been achieved among the released lines in 1 000 kernel weight (average gain of 2.5 percent/year), in specific grain weight (gain of 1.44 percent/year) and in protein content (gain of 1.92 percent/year).

CONCLUDING REMARKS

Triticale has a place in Spanish agriculture. However, until now its spread has been restricted by causes other than the intrinsic value of the crop. The lack of expansion of the crop, due mainly to political and commercial reasons, has compelled some Spanish institutions that traditionally conducted breeding programmes and research projects on triticale to dedicate their efforts to crops with greater market demand. Good varieties for grain production are available at present, but future efforts should concentrate on the development of triticale varieties for forage production.

REFERENCES

- FAO. 2003. *FAOSTAT, FAO statistical databases – agriculture* (available at <http://apps.fao.org>).
- Fernandez-Figares, I., Martinetto, J., Royo, C., Ramos, J.M. & García del Moral, L.F. 2000. Amino-acid composition and protein and carbohydrate accumulation in the grain of triticale grown under terminal water stress simulated by a senescing agent. *J. Cer. Sci.*, 32: 249-258.
- García del Moral, L.F., Boujenna, A., Yañez, J.A. & Ramos, J.M. 1995. Forage production, grain yield and protein content in dual-purpose triticale grown for both grain and forage. *Agron. J.*, 87: 902-908.
- Geslive. Unpublished. Madrid, Gestión de Licencias Vegetales.
- MAPA. Undated. *Anuarios de estadística agraria 1997-2002*. Madrid, Ministerio de Agricultura, Pesca y Alimentación.
- OEVV. Unpublished. Madrid, Oficina Española de Variedades Vegetales, Ministerio de Agricultura, Pesca y Alimentación.
- Royo, C. 1992. *El triticale: bases para el cultivo y aprovechamiento*. Madrid, Ed. Mundi Prensa. 96 pp.
- Royo, C. 1997. Grain yield and yield components as affected by forage removal in winter and spring triticale. *Grass Forage Sci.*, 52: 63-72.
- Royo, C. & Aragay, M. 1994. Forage yield and quality of triticale Trujillo. In *Triticale Topics*, No. 12, p. 2-4. Armidale, Australia, International Triticale Association.
- Royo, C. & Parés, D. 1996. Yield and quality of winter and spring triticales for forage and grain. *Grass Forage Sci.*, 51: 449-455.
- Royo, C. & Romagosa, I. 1996. Effect of a forage removal at the first node detectable stage on the growth of winter and spring triticale. *Grass Forage Sci.*, 51: 170-179.
- Royo, C. & Serra, J. 1993. Triticale for forage and dual-purpose in Catalonia (Spain). In *Triticale Topics*, No. 10. Armidale, Australia, International Triticale Association.
- Royo, C. & Tribó, F. 1997. Triticale and barley for grain and for dual-purpose (forage + grain) in a Mediterranean-type environment. II. Yield, yield components and quality. *Austr. J. Agric. Res.*, 48: 423-432.
- Royo, C., Insa, J.A., Boujenna, A., Ramos, J.M., Montesinos, E. & García del Moral, L.F. 1994. Yield and quality of spring triticale used for forage and grain as influenced by sowing date and cutting stage. *Field Crops Res.*, 37: 161-168.
- Royo, C., López, A., Serra, J. & Tribó, F. 1997. Effect of sowing date and cutting stage on yield and quality of irrigated barley and triticale used for forage and grain. *J. Agron. Crop Sci.*, 179: 227-234.
- Royo, C., Serra, J., Puigdomenech, A. & Aragay, M. 1998. Yield and quality of triticale cv. Trujillo and barley cv. Flika grown for different end-uses in a Mediterranean environment. *Cer. Res. Com.*, 26: 169-176.
- Royo, C., Abaza, M., Blanco, R. & García del Moral,

L.F. 2000. Triticale grain growth and morphometry as affected by drought stress, late sowing and simulated drought stress. *Austr. J. Plant Physio.*, 27(11): 1051-1059.

Sánchez-Monge, E. 1996. A retrospection on triticale. In H. Guedes-Pinto, N. Darvey & V.P. Carnide, eds. *Triticale: today and tomorrow*, p. 73-81. Dordrecht, Netherlands, Kluwer Academic Press.

PLATE 1
Damaged triticale stems after a hail storm in Lérida, Spain
C. Royo

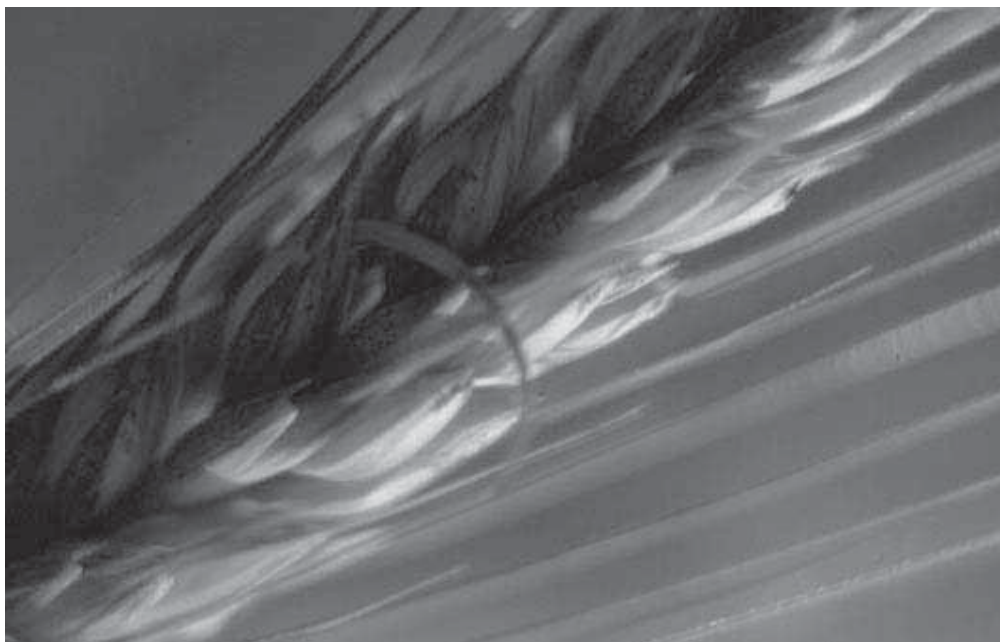
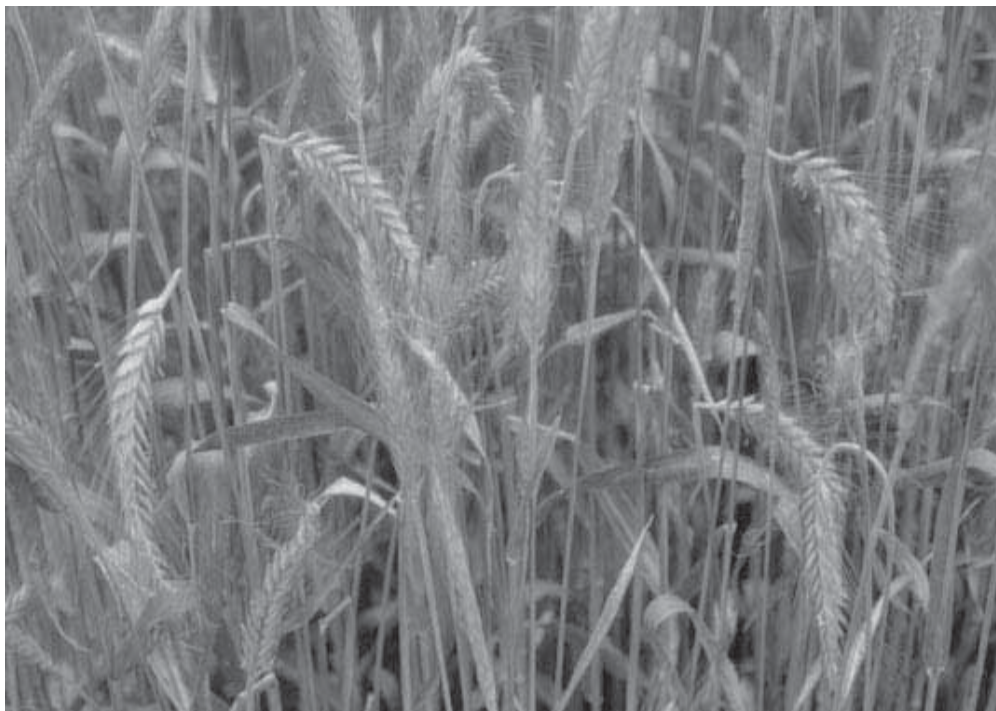


PLATE 2
Sprouting in a triticale spike due to wet conditions during grainfilling in Lérida, Spain
C. Royo

PLATE 3
Frost damage to triticale in Granada, Spain
C. Royo



PLATE 4
Triticale silo in the Alt Empordà region, Gerona, Spain
C. Royo

PLATE 5

Study conducted on the double use of triticale and barley; shorter plants have been cut and have regrown in El Palau d'Anglesola, Lérida, Spain

C. Royo



PLATE 6

F₈ lines at an IRTA triticale breeding programme in which barley rows have been used for isolation in El Palau d'Anglesola, Lérida, Spain

C. Royo

PLATE 7
Triticale and wheat variety demonstration trial at IRTA Fundación Mas Badia,
Gerona, Spain
C. Royo



Triticale in Turkey

S.A. Bađcý M. Keser, S. Taner, T. Ta° y¼rek

In Turkey, cereals are commonly grown in areas where the environmental conditions are not very suitable for these crops. Generally, in the central and southeastern Anatolia regions and in the high altitudes of other regions where a rainfed agricultural system is practiced, the possibility of growing crops other than cereals is limited. Annual average precipitation is approximately 350 mm in these regions. Because growing other crops is not economically profitable under these circumstances, compulsorily cereals are grown with low yield. The most important yield-limiting factor in these regions is a lack of water. To increase the productivity in these regions, besides using suitable varieties and growing techniques, triticale is one option for farmers, especially in areas of central and eastern Anatolia where lack of water and low temperature predominate. In these cold regions, winter-type triticale has shown comparative advantage, and recently its planting area has increased. Triticale tolerance to drought, winter and plant nutrition deficiencies is complemented by its good resistance to common cereal diseases. These advantages make triticale a good alternative to other cereals.

Triticale area in Turkey was estimated at 10 000 ha at the end of the 1990s. Nowadays, with dramatic increases, its area has reached approximately 160 000 ha, and it is becoming one of the main cereals after wheat and barley (Table 1). Since triticale is a new crop for Turkey, its end-use is not as diverse as would be expected. Current production of triticale in Turkey is used mainly in the feed industry.

CROP IMPROVEMENT

The first studies on triticale in Turkey started with several international projects at universities in the 1940s. These studies focussed on testing and evaluating triticale for quality and yield. In the 1980s, university studies taking place along the coastal areas of Turkey concentrated on spring-type germplasm that came from the International Maize and Wheat Improvement Center (CIMMYT). In this germplasm, a few lines selected had better quality and yield. Winter-facultative triticale studies started at Bahri Dađda° International Winter Cereal Research Center in Konya in the early 1990s. Triticale materials

TABLE 1
Harvested area, average yield and production of main small-grain cereals in Turkey, 2002

Cereal	Area (ha)	Yield (kg/ha)	Production (tonnes)
Wheat	9 400 000	2 128	20 000 000
Barley	3 550 000	2 085	7 400 000
Rye	135 000	1 740	235 000
Oats	150 000	1 933	290 000
Triticale ^a	160 000	2 100	336 000

^aEstimate based on seed production and Extension Services surveys. Source: FAO, 2002.

mainly from European sets and material from CIMMYT were evaluated and subjected to selection. As a result of these studies, the first triticale cultivar Tatlıcak-97 was registered in 1997. The newly released triticale, having longer spikes and more kernels per spike compared to wheat and barley, was introduced to Turkish farmers as an alternative crop in marginal areas. Farmers immediately showed great interest in triticale, and since then triticale has expanded very quickly.

Triticale improvement studies are currently being carried out at several institutes belonging to the Ministry of Agriculture – Bahri Dađda° International Agricultural Research Institute (BDUTAE) in Konya, Anatolian Agricultural Research Institute (ATAE) in Eski°ehir and Eastern Anatolia Agricultural Research Institute (DATAE) in Erzurum – and at a few universities, such as Çukurova University in Adana. The germplasm used in these research programmes is mainly from CIMMYT material. The performance of the elite material selected from this germplasm is very promising (Table 2). Agronomy studies on triticale have been conducted at various institutes and universities.

Triticale is, in general, more tolerant than wheat and barley for biotic and abiotic stresses. Breeding for marginal areas (acidic or alkali soils), micronutrient deficiencies (copper, zinc or magnesium) or toxicity (boron) and drought stress are the main objectives of most spring- and winter-triticale breeding programmes in the world. Experiments on fertilization carried out in the Konya and Sivas regions, where triticale crops are grown widely, showed that triticale requires approximately 60 to

TABLE 2
Yields of some triticale varieties in different locations in Turkey

Genotype	Rainfed			Irrigated	
	Konya	Çumra	Obruk (kg/ha)	Konya	Çumra
Tatlıcak-97	6 335	3 800	1 783	7 348	5 823
Melez-2001	5 540	2 765	1 517	6 728	5 063
BDMT 98/8 S	5 250	2 605	1 890	7 183	5 778
Mikham-2002	4 993	2 490	1 626	7 318	5 603
LSD (%5)	86.2	59.4	47.1	95.9	77.3
CV	11.0	12.5	19.7	8.9	9.0

Source: BDUTAE-Konya, Annual Report 2002.

TABLE 3
Overall effect of zinc application on plant productivity of various cereal species

Cereal species	Dry production (g/plant)		Index for zinc efficiency (%)	Difference (%)
	-Zinc	+Zinc		
Rye	0.74	0.87	85	18
Triticale	0.64	0.85	75	33
Barley	0.74	1.14	65	54
Bread wheat	0.48	0.83	58	73
Durum wheat	0.28	0.77	38	166
Oats	0.37	1.06	35	186

Source: Torun *et al.*, 1998.

TABLE 4
Effects of zinc application on triticale and other cereal varieties

Variety	+Zinc (kg/ha)	-Zinc (kg/ha)	Difference (%)	Index for zinc efficiency (%)
Gerek-79	3 100	4 460	44	70
Bezostaja	1 900	4 150	118	47
Kundur	330	2 470	648	13
Çakmak-79	170	760	347	22
Presto ^a	3 380	4 280	26	79
BDMT-19 ^a	4 000	4 240	6	94
Tokak	2 240	4 770	113	47
Erginel	1 920	4 360	127	44
Aslim	3 560	3 340	-7	107
Chekota	810	1 880	132	43
LSD (%5)	59	47	-	-

^aTriticale.

Source: Ekiz *et al.*, 1998.

70 kg/ha P₂O₅ and 60 to 90 kg/ha nitrogen (Bađcý 1999) in Konya; whereas in Sivas it was found that 70 to 80 kg/ha P₂O₅ and 120 kg/ha nitrogen (Ta°yürek *et al.*, 2001) may be needed. The main advantage of triticale in Turkey is its high tolerance to zinc (Zn) deficiency compared to wheat, barley and oats. Zinc deficiency is one of the most important yield-limiting factors in the Konya region (Bađcý 2000). The resistance index for Zn for rye, barley, bread wheat, durum wheat and oats

was 85, 65, 58, 38 and 35 percent, respectively. The resistance index for Zn for triticale was 75 percent, second only to rye, which is a very resistant crop to zinc deficiency (Table 3) (Torun *et al.*, 1998). In another study carried out on the zinc efficiency of various cereal species in Konya, it was shown again that triticale genotypes (Presto and BDMT-19) had the highest zinc resistance index after rye (Table 4) (Ekiz *et al.*, 1998).

With the increase of triticale area, wheat and rye

TABLE 5
Reactions of various cereal genotypes to common root and crown rot pathogens

Genotype	Cereal	Pathogen ^a			
		<i>Drechslera sorokiniana</i>	<i>Fusarium culmorum</i>	<i>Fusarium moniliforme</i>	<i>Rhizoctonia cerealis</i>
Bezostaja-1	Bread wheat	18.9 MR	33.3 MR	30.6 MR	18.6 MR
Haymana-79	Bread wheat	73.4 S	66.3 MS	65.0 MS	73.7 S
Gün-91	Bread wheat	38.9 MR	38.1 MR	12.6 R	41.9 MR
Dağdaş-94	Bread wheat	39.0 MR	7.9 R	17.6 MR	24.6 MR
Kınacı-97	Bread wheat	23.9 MR	11.5 R	21.0 MR	20.9 MR
Selçuklu-97	Durum wheat	22.4 MR	18.7 MR	18.0 MR	13.6 R
Erginel-90	Barley	81.0 S	40.0 MR	70.0 MS	27.2 MR
Asım-95	Rye	6.5 R	13.3 R	12.1 R	8.1 R
Tatlıcak-97	Triticale	12.1 R	14.0 R	6.9 R	10.9 R
BDMT-19	Triticale	7.7 R	9.9 R	7.7 R	6.0 R

^aR = resistant; S = susceptible; M = medium.

Source: Akta^o *et al.*, 1997.

diseases and insects could be a potential problem for triticale (El Harrak, Mergoum and Saadaoui, 1998). It has been reported that triticale is tolerant to rusts (*Puccinia* sp.), *Septoria tritici*, smuts (*Ustilago* sp. and *Urocystis* sp.), bunt (*Tilletia* sp., *Neovossia* sp.), powdery mildew (*Blumeria graminis*), take-all (*Gaeumannomyces graminis*), root rots, cereal cyst nematode (*Heterodera avenae*), Russian wheat aphid (*Diuraphis noxia*), barley yellow dwarf virus, wheat mosaic virus and barley stripe mosaic virus (Varughese, Pfeiffer and Peña, 1996). However, it has been shown that in North Africa (Mergoum, 1994) under severe infestation with Hessian fly (*Mayetiola destructor*) and dry conditions many triticale genotypes were susceptible to attacks by this insect. Similarly, in Mexico, a new race of stripe rust (*Puccinia striiformis*) that overcame the *Yr9* gene of resistance caused severe damage on more than 20 percent of CIMMYT germplasm at the Toluca CIMMYT Station during the summer of 1996 (Mergoum *et al.*, 1998). Triticale has also been reported not to have enough resistance against *Fusarium* sp., *Septoria nodorum*, *Helminthosporium* sp., eyespot (*Cercospora herpotrichoides*) and bacterial diseases (*Xanthomonas* sp. and *Pseudomonas* sp.). Developing tolerance in triticale against these diseases should be a prime objective. Triticale tolerance to ergot is greater than in rye, and in some cases, this tolerance has come about through an increase in triticale productivity.

Diseases have not been a major problem for triticale in regions where triticale is widely grown in Turkey. In disease tests, it has been seen that triticale has enough tolerance to the diseases prominent on wheat. Variety Tatlıcak-97 was more tolerant to *Fusarium culmorum*, *Drechslera sorokiniana*, *Fusarium moniliforme* and

Rhizoctonia cerealis, which are the most common pathogens of root and crown rot diseases in Konya, than other wheat and barley varieties in the same experiment (Table 5) (Akta^o *et al.*, 1997). In another study, wheat, barley and triticale lines were tested using root and crown rot pathogens, in particular *Drechslera sorokiniana*, *Fusarium culmorum* and *Fusarium avenaceum*. Tolerance/resistance percentages were 28, 7, 6 and 88 percent for lines developed for rainfed conditions, irrigated conditions, triticale lines and barley, respectively (Bađcýet al., 2001).

TRITICALE VARIETIES AND SEED PRODUCTION

Six triticale varieties have been registered in Turkey. Five of them are winter-facultative types. Tatlıcak-97, Melez-2001 and Mikham-2002 were developed by the Bahri Dađda^o International Agricultural Research Institute and Karma-2000 and Presto by the Anatolian Agricultural Research Institute (Table 6). These varieties are mostly grown in rainfed, winter-facultative, cereal-growing areas. The most widely grown triticale variety in Turkey is Tatlıcak-97. Although it is grown across the country, Tatlıcak-97 is widely cultivated in the Konya, Sivas, Tokat, Afyon, Aydın, Bolu, Aksaray, Sinop, Tekirdađ and Kars regions. Tacettinbey, developed by the College of Agriculture at Çukurova University, is a spring type. This variety is recommended for the coastal regions of the country, especially the Mediterranean zones.

Seed production in Turkey has been the responsibility of the institutions that develop the variety and the State Farms (Table 7). Each institute has the responsibility of producing breeder and basic seed and giving the seed to State Farms, which produce certified seed.

TABLE 6
Triticale varieties released in Turkey and some of their characteristics

Variety	Registration (year)	Growth habit	Yield (kg/ha)	'000 kernel weight (g)	Test weight (kg/hl)	Protein (%)
Tatlıcak-97	1997	Winter	3 560	36-39	75	12-14
Melez-2001	2001	Winter	3 350	36	68	11-12
Karma-2000	2000	Winter	3 350	33-43	74-78	10-12
Presto	2000	Winter	3 340	22-23	76	11-12
Mikham-2002	2002	Winter	5 930	38-39	73-74	12
Tacettinbey	1999	Spring	7 150	40-46	73-75	11-13

Source: Anonymous, 1999, 2000, 2001, 2002.

TABLE 7
Seed production of triticale varieties, 2001-2002

Variety	2001 (tonnes)	2002 (tonnes)	Institute or State Farm ^a
Tatlıcak-97	255	377	BDUTAE, TİM
Melez-2001	-	10	BDUTAE
Mikham-2002	-	2	BDUTAE
Karma-2000	-	10	ATAE
Presto	-	11	ATAE
Tacettinbey	50	50	ÇÜZF
Total	305	460	

^aBDUTAE = Bahri Dağdağ International Agricultural Research Institute; TİM = State Farm; ATAЕ = Anatolian Agricultural Research Institute, ÇÜZF = College of Agriculture, Çukurova University.

TRITICALE USE

Triticale is used for different purposes, in particular for feed as grain, hay and silage. Although triticale is grown as a silage crop by farmers, it is also planted in mixture with other forage crops. Triticale is used as grain especially for poultry. Triticale can be used in rations as a protein resource replacing other cereals (Belaid, 1994). In rations where triticale replaced maize, it was reported that increasing the triticale ratio positively affected egg productivity up to 40 percent (Table 8) (Azman *et al.*, 1997).

Triticale flour can also be used to replace soft wheat flour in mixture in breads, cakes or cookies. In a study

involving different mixture ratios of Tatlıcak-97 triticale and Gerek-79 bread wheat with Bezostaja-1 (1:1), total protein, raw ash amount, amylase activity, Zeleny sedimentation value, Alveogram resistance and energy increased, but gluten index and falling number value decreased (Table 9) (Elgün, Türker and Bađcý, 1996). In some regions of Turkey, up to 30 percent triticale flour is used in mixture with wheat flour for bread making. In addition, triticale is used in some villages to make flat bread.

CONCLUDING REMARKS

Although triticale is a new crop for Turkish farmers, it has been well accepted, and its dissemination is much faster than a new wheat or barley cultivar. Triticale growing area is rapidly increasing in the Anatolia plateau where cereal production (wheat in particular) is limited by some biotic and abiotic factors. Triticale has resistance/tolerance to most known stresses in the Anatolia region. Because of the low nutritional value of rye and the low yield of oats, triticale has been spreading rapidly in areas where wheat yield is limited. Creating new opportunities for triticale by developing new triticale cultivars that meet farmer and consumer preferences and needs, triticale production will continue to increase. Triticale, with all of its advantages, promises to be a real alternative crop for Turkish farmers.

TABLE 8
Effects on egg productivity of adding triticale to feed rations

Ration ^a	Egg productivity (%)	Egg weight (g)	Feed consumption (g)
% 0 triticale	63.22 ± 4.02	60.71 ± 0.69	98.46 ± 1.56
% 10 triticale	64.78 ± 3.01	59.54 ± 0.98	94.91 ± 4.04
% 20 triticale	65.13 ± 3.24	59.16 ± 0.69	98.45 ± 1.06
% 40 triticale	69.04 ± 3.40	59.30 ± 0.79	97.03 ± 3.46

^aControl ration includes 62 percent maize.

Source: Azman *et al.*, 1997.

TABLE 9
Effects on some quality traits of triticale flour in mixture^a

Mixture Bez : (Grk+Ttl)	Moisture (%)	Total protein (%)	Raw ash (%)	Zeleny sed. (ml)	Wet gluten (%)	Gluten index (%)	Falling number (sn)
100 : (100 + 00)	14.5	9.4c	0.50e	24.1c	30.5	57.9a	428a
100 : (75 + 25)	14.5	9.8bc	0.51d	25.9bc	30.9	51.2ab	413ab
100 : (50 + 50)	14.5	10.1abc	0.52c	27.5ab	31.6	48.0b	405ab
100 : (25 + 75)	14.5	10.5ab	0.53b	28.2ab	31.8	50.3ab	394b
100 : (00 + 100)	14.5	10.9a	0.54a	29.7a	32.0	46.6b	369c
LSD	-	0.88*	**	4.03**	ns	8.74*	23.8*
Bezostaja-1	15.6	10.0	0.54	30.4	33.0	59.3	566
Gerek-79	13.6	8.8	0.46	22.0	29.0	47.4	392
Tatlıcak-97	13.3	11.7	0.55	26.5	31.6	31.7	321

^aSignificant at p<0.05 represented by *; significant at p<0.01 represented by **; ns = non-significant. Numbers with different letters are significantly different.

Source: Elgün, Türker and Bađcý, 1996.

REFERENCES

- Akta^o, H., Kýnacý, E., Yýldýrým, A.F., Sayýn, L. & Kural, A. 1997. *Konya Yöresinde Hububatta Sorun Olan Kök ve Kökbođazy Çürüklüdü Etmenlerinin Saptanması ve Çözüm Yollarýnýn Ara'týrýlması*. TOGTAG-1254 No'lu Proje. Kasým 1997, Ankara.
- Anonymous. 1999, 2000, 2001, 2002. *Variety catalogs*. Ankara, Seed Registration and Certification Center, Ministry of Agriculture and Rural Affairs.
- Azman, M.A., Co'kun, B., Tekik, H. & Aral, S. 1997. Tritikalenin yumurta tavuđu rasyonlarında kullanýlabilirliði. *Hayvancýlık Ara'týrma Dergisi*, 7(1): 11-14.
- Bađcý, S.A. 1999. Konya ve benzeri yöreler için BD.MÝKHAM tarafýndan geli'tirilen hububat çe'itleri ve özellikleri. In *Orta Anadolu'da Hububat Tarýnýnýn Sorunları ve Çözüm Yollarý Sempozyumu*, 8-11 Haziran 1999, Konya, Turkey, p. 100-107.
- Bađcý, S.A. 2000. *Konya 'artlarında çinko uygulamasýnýn farklı tahýl türlerinde verim ve verim unsurları ve kalite üzerine etkileri*. Konya, Turkey, Selçuk Üniversitesi, Fen Bilimleri Enstitüsü.
- Bađcý S.A., Hekimhan, H., Mergoum, M., Akta^o, H., Taner, S., Tulukçu, E. & Ekiz, H. 2001. Kök ve kök bođazy çürüklüdü etmenlerinin bazı tahýl genotiplerinin verimleri üzerine etkileri ve dayanýklılık kaynaklarınýn tespiti. Türkiye 4. In *Tarla Bitkileri Kongresi*, 17-21 Eylül 2001, Tekirdađ, Turkey, p. 115-120.
- Belaid, A. 1994. *Nutritive and economic value of triticale as feed grain for poultry*. CIMMYT Economics Working Paper 94-01. Mexico, DF, CIMMYT.
- Ekiz, H., Bađcý S.A., Kýral, A.S., Eker, S., Gültekin, Ý., Alkan, A. & Çakmak, Ý 1998. Effects of zinc fertilization and irrigation on grain yield and zinc concentration of various cereals grown in zinc-deficient calcareous soils. *J. Plant Nutri.*, 21: 2245-2256.
- Elgün, A., Türker, S. & Bađcý S.A. 1996. Paçal yapýmýnda tritikalenin yumu'ak buđday yerine Kullanýlması. *Un Mamülleri Dünyası*, 4-10.
- El Harrak, A., Mergoum, M. & Saadaoui, E. 1998. Major foliar diseases of triticale in Morocco. In E. Duveiller, H.J. Dubin, J. Reeves & A. McNab, eds. *Helminthosporium Blights of Wheat: Spot Blotch and Tan Spot. Proc. Int. Workshop*, CIMMYT, El Batan, Mexico, 9-14 Feb. 1997, p. 150-156. Mexico, DF, CIMMYT.
- FAO. 2002. *FAOSTAT, FAO statistical databases – agriculture* (available at <http://apps.fao.org>).
- Mergoum, M. 1994. Performance and adaptation of triticale to Moroccan environments. In *Proc. 3rd Int. Triticale Symp.*, Lisbon, 14-17 June 1994, Vol. Abstr., p. G10.
- Mergoum, M., Pfeiffer, W.H., Rajaram, S. & Peña, R.J. 1998. Triticale at CIMMYT: improvement and adaptation. In P. Juskiw, ed. *Proc. 4th Int. Triticale Symp.*, Red Deer, Alberta, Canada, 26-31 July 1998, p. 58-64. International Triticale Association.
- Ta'yürek, T., Demir, M., enol, M. & Gökmen, S. 2001. Sivas yöresinde tritikalenin azotlu ve fosforlu gübre isteði. In *Toprak ve Su Kaynakları Ara'týrma Yýllyđý 2000*. Köy Hizmetleri Genel Müdürlüdü yayýnları No. 117.
- Torun, B., Çakmak, Ö., Özbek, H. & Çakmak, Ý 1998.

Çinko eksikliði ko°ullarında yeti°tirilen deði°ik tahıl türlerinin ve çe°itlerinin çinko eksikliðine kar°ý duyarlılıđın belirlenmesi. In *I. Ulusal Çinko Kongresi*, 12-16 Mayıs 1997, Eski°ehir, Turkey, p. 363-369.

Varughese, G., Pfeiffer, W.H. & Peña, R.J. 1996. Triticale: a successful alternative crop. Reprinted from *Cer. Foods World*, 41(6/7).

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