Triticale in Australia

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Triticale is a mainstream crop in Australia, mostly as spring types grown for grain production and also as longer-season, dual-purpose types grown for fodder use as hay, silage or grazing followed by grain production. The grain is primarily used as stock feed, with a low level of triticale use in food products. Most of the grain is used domestically although small amounts are exported. Triticale improvement programmes continue to release a steady stream of cultivars. Improvement in grain yield coupled with rust resistance remains the general aim of breeders, with resistance to cereal cyst nematode, improved quality and agronomic characteristics also being selected for in breeding. Both locally generated germplasm and material from the International Maize and Wheat Improvement Center (CIMMYT) are used for breeding and selection purposes. Current spring-grain cultivars (2002) are: Abacus, Credit, Everest, Muir, Prime322, Tahara, Tickit and Treat. Dual-purpose cultivars are: Madonna, Maiden, Hillary, Jackie and Eleanor.

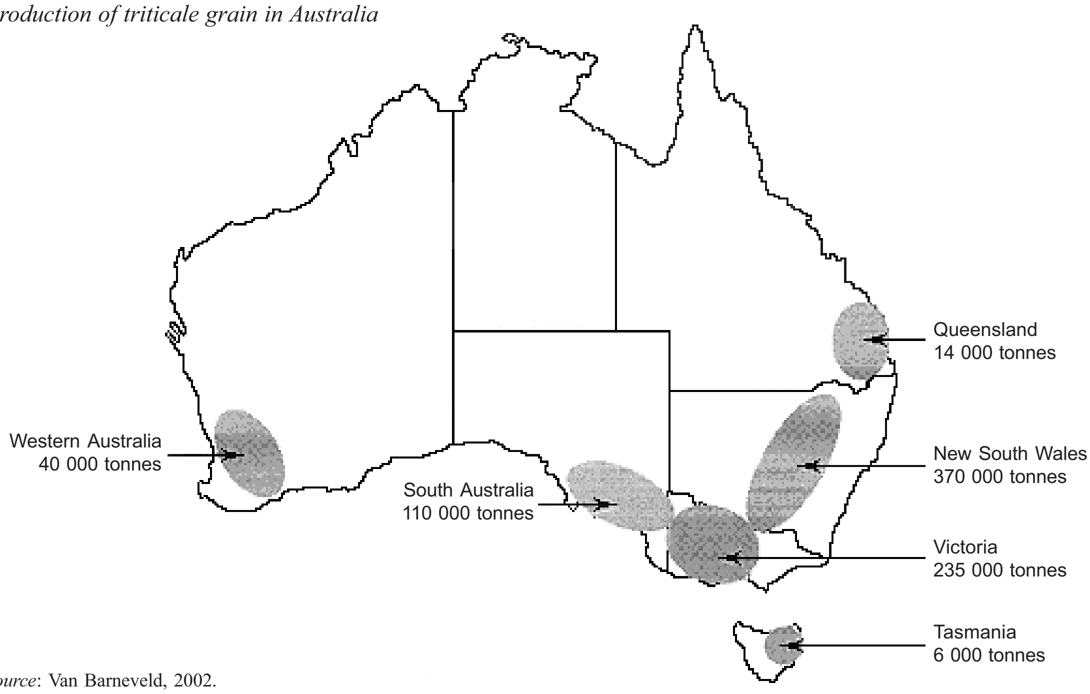
HISTORICAL BACKGROUND

Triticale was introduced into Australia in the early 1970s as experimental lines for evaluation. Breeding and selection programmes were initiated at several universities and state government departments of agriculture, and a number of varieties were released, which were mostly spring-grain lines introduced from CIMMYT. Triticale was quickly taken up as a useful crop for grain and fodder production on acid and waterlogged soils and for producing an economic and soil-conserving crop on lower rainfall, nutrient-impoverished soils. Initially, triticale was mostly used on-farm or traded locally as stock feed. It was often sought as a more easily-traded feed grain than wheat, which had to be marketed through the Australian Wheat Board. On the other hand, as triticale was not a well-known grain, and as the quantity available was limited, in some areas triticale could prove difficult to sell for a good price, which tended to limit its adoption. The first Australian cultivar was Growquick, a later-maturing line of poor-grain type most suitable for grazing use. By the mid-1980s, 11 grain cultivars had been released: Satu and Dua from the University of New England, Armidale, New South Wales; Samson, Ninghadhu and Bejon from the University of Sydney, New South Wales; Coorong, Venus and Currency from the University of Adelaide, South Australia; and Towan, Tyalla and Toort from the Victorian Department of Agriculture, Victoria. In the early 1980s, wheat stem rust races evolved in Queensland (McIntosh and Singh, 1986), which were virulent on these cultivars with the exception of Ninghadhu and Bejon. In order to reduce the likelihood of rust epidemics and further evolution of virulent races, the rust-susceptible cultivars were no longer recommended, and breeders sought to produce cultivars with full rust resistance. Ninghadhu and Bejon have now been replaced by improved cultivars. In the late 1980s, two more CIMMYT lines were released, Muir by the Western Australia Department of Agriculture and Tahara (Brouwer, 1989) by the Victorian Department of Agriculture. Tahara in particular has been a very successful cultivar, forming the mainstay of the Australian triticale industry for more than ten years. The reliability of Tahara's grain yield in all grain-growing areas, coupled with resistance to nematodes, supported a gradual increase in cropping area and production. The increasing amount of triticale produced and many years experience of good results within the stock feed industry gave users confidence in this grain, driving an increasing demand for triticale and improved prices. As more buyers in more locations have sought to buy triticale, more growers have adopted triticale in their farm operations.

CURRENT PRODUCTION

It is not possible to obtain an exact figure for current area and production, as much triticale is used on-farm rather than sold, but figures from the Australian Bureau of Statistics, Australian Bureau of Resource Economics, local district agronomists and grain-buying organizations would indicate that the production of triticale grain in 2001 was at least 800 000 tonnes. Thus triticale is a significant but minor crop compared with wheat (21 168 000 tonnes), barley (5 596 000 tonnes) and canola (1 661 000 tonnes) (O'Connel, 2002). Triticale is grown across the grain belt of Australia, with maximum grain production in New South Wales (370 000 tonnes),

FIGURE 1
Production of triticale grain in Australia



Source: Van Barneveld, 2002.

followed by the states of Victoria (235 000 tonnes), South Australia (110 000 tonnes), Western Australia (40 000 tonnes) and smaller amounts in Tasmania (6 000 tonnes) and Queensland (14 000 tonnes) (Figure 1). Within these regions, some triticale is grown for grazing, hay and silage production. The average grain yield of triticale is about 2.5 tonnes/ha, although these yields vary locally from less than 1 tonne/ha in lower rainfall areas and areas with soil problems to more than 7 tonnes/ha in higher rainfall areas with more fertile soils. Triticale is grown in areas with an annual average rainfall of about 300 mm through to at least 900 mm. Very little triticale is irrigated. Triticale for grain is generally sown in autumn (May-June) and harvested in summer (December-January). Triticale for grazing or as a green manure may be sown at other times if sufficient water is available. Triticale is commonly sown between rows of vines in vineyards where the benefits of triticale in reducing weeds and increasing organic matter in the soil are valued.

Farmers appreciate the ability of triticale to tolerate periods of drought through the growing season, and at the other extreme, its tolerance of waterlogging. Triticale grows productively on acid soils where the high availability of aluminium ions reduces the economic yield of many other crops and on alkaline soils where certain trace elements, e.g. zinc, manganese and copper, are deficient for most wheat, barley and oat cultivars. Large areas of soils with high levels of boron, which reduces yields of other cereals, are more successfully cropped with triticale. Traditionally grown in poorer conditions, triticale was treated as a 'forgiving' crop needing less care and attention. However, increasing experience of triticale's good response to fertilizer application and increasing demand for its use as animal feed have led to more triticale being grown on better soils with better management.

Many growers use triticale as a disease break in their rotations and value the benefits of triticale for its contribution to soil conservation. Thus triticale assists in maintaining soil health by the reduction of nematodes, such as *Pratylenchus neglectus* and *thornei* (root lesion nematodes) and *Heterodera avenae* (cereal cyst nematode), and a range of fungi and bacteria that build up in the soil, reducing yields when the same crop species is grown repeatedly. Other favoured characteristics of triticale are its resistances to barley yellow dwarf virus, mildew and rusts, which may cause significant yield reductions in wheat, barley and oats. The extensive root system of triticale binds sandy soils, and the fibrous stubble reduces wind and water erosion.

TRITICALE BREEDING

Breeding programmes

Triticale breeding continues to be undertaken at the University of Adelaide, University of New England and University of Sydney. Various funding sources have contributed over the years, although this has tended to be sporadic and at a lower level than that supplied for research on other crops. The Grains Research and Development Corporation (GRDC), which collects levies from crops including triticale, took on the support of triticale breeding in 1991 and continues to fund small programmes working on the improvement of spring-grain varieties at the University of Adelaide and longer-season, dual-purpose varieties at the University of Sydney. Bunge Meat Industries (Corowa, New South Wales), the largest pork producer in Australia, is supporting a programme at the University of New England. Major selection criteria are high grain yield or forage production capacity and resistance to triticale stem rust. Significant progress in grain yield, adaptability, disease resistance, grain quality and fodder production continues to be made.

Breeding spring-grain types

At the University of Adelaide, breeding material is mostly derived from crosses involving locally produced primary triticales and introduced germplasm. The cultivars Abacus, Credit, Treat and Tickit derive from a collection of octoploid and hexaploid primary triticales produced at Waite Campus 1982-1985 (Cooper and Driscoll, 1986). Further primary triticales based on locally adapted durums (*Triticum turgidum* L.) obtained from the University of Adelaide Wheat Breeding Program crossed with the Adelaide University released Bevy rye (Cooper, 1998a) are now entering the crossing programme. Primaries are top-crossed before entering the selection programme. A modified F_2 progeny method is used with reselection as necessary from F_7 onwards. Selections from F_2 plots and reselections from later generations are grown as head hills in an irrigated summer nursery. Replicated yield trials are conducted from F_5 onwards. Introduced germplasm, mostly from CIMMYT, is multiplied and assessed for suitability as parental material or direct variety releases. A total of 12 000 breeders' trial plots (plots approximately 4 m^2 in area) are sown across four major sites in South Australia and one in the southern coastal region of Western Australia. Locations have a range of soil types including deep sand, waterlogged acid and alkaline, and annual average rainfall varies from 350 to 850 mm. Selected advanced lines and check cultivars are trialled (larger plots, e.g. 15 m^2) by cooperators from state agricultural organizations in South Australia (eight sites), Victoria (five sites), New South Wales (seven sites) and Western Australia (one site). It is now common for breeders' lines to outyield Tahara, the main check variety, particularly at the higher rainfall sites. A typical year's data summary table is presented as Table 1.

Callington, Cleve and Birdwood are South Australia Breeder's sites. Greenpatch, Minnipa, Wharminda, Piednippie, Frances, Pinnaroo and Turretfield are South Australian Field Crop Evaluation Program sites. Coomalbidgup is the Western Australia breeding trial site. Rutherglen, Walpeup and Streatham are Agriculture Victoria sites. Manildra, Gerogery, Lowesdale, Temora and Mayrung are New South Wales Agriculture sites.

Although triticale stem rust has not been recorded recently in Australian triticale crops (as susceptible varieties have not been grown for some years), resistance to this disease is considered an essential requirement for a variety release. From generation F_4 onwards, all material is tested by the National Rust Control Program (NRCP) of Sydney University, Cobbitty, for resistance to triticale stem rust, and susceptible lines are discarded or re-enter the crossing programme. Generally, a high proportion of locally produced crosses are resistant, whereas the majority of CIMMYT lines are susceptible. Credit (Cooper, 1998b) was released as a rust-resistant replacement for the susceptible variety Currency. Lines put forward for replicated yield trials are tested for resistance to *Heterodera avenae* (cereal cyst nematode, CCN) by the SARDI Field Crop Pathology Laboratory. Tickit (Cooper, 2000) is CCN-resistant.

Another breeding aim is improved test weight, sought particularly because the current delivery standard for test weight for triticale, 65 kg/hl, may not be obtained by some varieties in some environments. Treat (Cooper, 1998b) has regularly produced grain up to 6 kg/hl above Tahara.

Varieties with different adaptive and plant type characteristics are sought to suit the wide range of conditions across the Australian grain belt. Breeders' trial sites tend to direct selection to a fairly narrow range of medium-season maturity, but earlier- or later-season varieties are specifically sought. Abacus (Cooper, 1992, 1994) matures a few weeks later than most grain varieties and is still proving popular. Treat matures a few days ahead of Tahara. Some longer-season (up to three weeks later maturing) and shorter-season (one week earlier maturing) candidates are being considered for release as cultivars. Whilst the tall straw of triticale is a desired characteristic in low-rainfall areas where it provides an

TABLE 1
Performance of triticale varieties at selected trial sites in Australia, 2001/02

Site	Tahara yield[a] (*tonnes/ha*)	Treat (*% Tahara*)	Credit (*% Tahara*)	Tickit (*% Tahara*)	Everest (*% Tahara*)	Muir (*% Tahara*)
Callington	2.67	103	106	104	111	106
Cleve	2.81	100	101	95	103	101
Birdwood	5.02	100	104	103	107	98
Greenpatch	4.33	96	101	95	91	96
Minnipa	2.65	95	97	95	100	96
Wharminda	1.47	107	84	105	86	100
Piednippie	2.06	86	87	104	90	95
Frances	3.41	113	119	112	109	112
Pinnaroo	3.03	84	97	94	91	85
Turretfield	4.74	110	108	110	112	110
Coomalbidgup	4.30	105	103	96	98	96
Rutherglen	6.34	104	107	109	109	108
Walpeup	3.62	98	98	93	100	-
Streatham	4.56	130	124	112	118	-
Temora	2.91	103	111	107	110	92
Manildra	5.14	102	102	104	104	97
Gerogery	7.40	102	102	102	98	105
Lowesdale	3.64	100	111	114	97	95
Mayrung	7.17	94	101	103	93	99

[a]Grain yield = mean of three or four replicates, analysed by ASREML spatial analysis.

improved height for harvesting, the excessive height of triticale in high-rainfall, high-yielding environments can be a problem. Generally, selection is aimed towards height reduction. Abacus, Credit and Tickit are about 5 cm shorter than Tahara in 600 mm annual rainfall. Considerably shorter lines and those with stronger straw strength with reduced lodging in high-yielding environments are also sought. Material with reduced awns is being tested for suitability for hay production.

The University of New England programme has concentrated on using germplasm from CIMMYT, both for direct release as cultivars and for crossing purposes. Everest, a tall variety with grain of high test weight was released in 1999, and further CIMMYT selections are currently undergoing preparation for release. Prime322, which is derived from a cross between two CIMMYT lines, was released by the University of Sydney in 2001.

Breeding dual-purpose triticales

Since the early days of European settlement in Australia, oats has traditionally been the main grazing cereal crop. However, dual-purpose triticale cultivars, which have at least the equivalent dry-matter production capacity of oats combined with better tolerance of waterlogging and acid soils and better resistance to foliar diseases, are increasingly being sown instead of dual-purpose or grazing oats. Dual-purpose triticale retains its grain better than oats, and current prices for triticale exceed those of oats, encouraging its replacement with triticale.

The development of dual-purpose cultivars has been undertaken by the University of Sydney and University of New England. The aim has been to release longer-season lines with some winter habit (but not full-winter types such as those grown in Europe) that can be sown in eastern Australia in February/March (late summer/early autumn). These varieties make sufficient growth in autumn to allow winter grazing, and the stock are removed to allow the crop to recover to produce grain for a summer harvest. Releases in the 1980s included Madonna, with excellent dry-matter production in the cooler highland regions of New South Wales, and Empat, which had better grain yields but only produced good grazing in late winter. The cultivar Tiga was released in 1987 with high levels of dry-matter yield in autumn to give good early-winter grazing. More recent dual-purpose cultivars are Maiden, released in 1999 (Roake, 1999), and Jackie and Hillary, released in 2000 (Roake, 2001), all of which have high yields of dry matter and good grain recovery after grazing. Eleanor (2001) has also given excellent dry-matter yields in many regions of New South Wales. The grazing/dual-purpose triticales have been mainly used for direct grazing, but increasing interest is being shown in the production of triticale silage and hay. Jackie, which has reduced awns, is resistant to cereal cyst nematode and is earlier maturing than the other dual-purpose cultivars, is gaining popularity for hay production in South Australia.

SEED PRODUCTION AND CULTIVAR AVAILABILITY

There is no standard way of releasing triticale cultivars. The releasing institution decides on a suitable release method for each cultivar individually. In general, a cultivar bred in Australia will be released with Plant Breeders' Rights (PBR) whereby ownership is attributed to a breeder, institution hosting the work, or funding suppliers (or combination of these). A detailed description of the variety, showing its distinctness, uniformity and stability is submitted to the Plant Breeders' Rights Office. Growers must initially buy these PBR cultivars from a specific source and are not permitted to trade the seed among themselves. Some PBR varieties have a royalty payable on the seed, or payable when the crop is delivered for sale, the idea being that this royalty is returned to the owners. Credit, Prime322, Tickit and Treat are PBR protected. Abacus is now a freely traded cultivar, although it was protected by PBR for nine years. Some varieties may be simply released without PBR protection, e.g. Everest, which can be bought and sold without restriction. The releasing institution chooses a seed company who will be granted the licence to handle a particular cultivar. A cultivar generally undergoes several years of seed production to a specified standard (free of weeds and other cereals, good germinability) before farmers gain access to the cultivar. The breeder and the commercializing company usually work together on promotion of the cultivar to growers. Adoption of some cultivars in some areas has been limited by reduced availability of sowing seed.

TRITICALE USE

Triticale represents a true premium livestock grain in Australia, which unlike wheat and barley has little competition from human food markets. About 30 percent of the triticale grain in Australia is retained on-farm with the remainder being traded. The grain may be sold directly to an animal enterprise (e.g. a dairy farm or piggery), a feed-mill that processes raw materials to produce compound feeds, or to a grain-handling organization, which provides bulk storage and markets larger parcels of grain.

The nutritional value of triticale remained underrated for a long time, and triticale was usually sold at a discount to wheat and barley. As information about the nutritional value of triticale increases and users gain more experience with this grain, demand continues to increase with an associated rise in purchase price offered. Production in Australia has now reached a critical mass, with sufficient supplies reliably available for users to be willing to formulate their rations based on triticale. Triticale currently sits between milling wheat and feed barley in price.

Current Australian triticale cultivars are free of appreciable levels of anti-nutritional factors, and triticale is basically used in rations as a substitute for wheat. Growing environments have a greater influence on the nutritional value of grain samples than does the cultivar. As triticale is grown in a wide range of environments, including the poorest of growing conditions, protein content of samples can vary considerably (in a range similar to that of wheat), although energy content is fairly stable across growing environments. Triticale is valued as a palatable, highly digestible grain for feeding pigs, chickens, cattle, sheep, deer and horses and all stock generally (Van Barneveld, 2002).

Very small amounts of triticale are used for human consumption. Thus wholemeal flour and flakes (steamed and rolled grain) are available in some specialist shops. Triticale whole grains are a component of some breads produced on a large scale, and wholemeal flour is used to a small extent in bread making. Although triticale is appreciated by some people for its delicious flavour, high fibre content and ease of use in baking (Cooper, 1985), triticale is not generally well known to Australian consumers, and there has been insufficient demand for its significant use in food products.

REFERENCES

Brouwer, J.B. 1989. X *Triticosecale* (Triticale) cv. Tahara. *Austr. J. Exp. Agric.*, 29(2): 291.

Cooper, K.V. 1985. *The Australian triticale cookery book*. Adelaide, Australia, Savvas Publishing.

Cooper, K.V. 1992. 'Abacus' triticale. *Plant Var. J.*, 5(1): 17-18.

Cooper, K.V. 1994. X. *Triticosecale* (triticale) cv. Abacus. *Austr. J. Exp. Agric.*, 34: 851.

Cooper, K.V. 1998a. 'Credit' and 'Treat' triticale. *Plant Var. J.*, 11(1): 47-48.

Cooper, K.V. 1998b. 'Bevy' cereal rye. *Plant Var. J.*, 11(2): 75-76.

Cooper, K.V. 2000. 'Tickit' triticale. *Plant Var. J.*, 13(4): 63.

Cooper, K.V. & Driscoll, C.J. 1986. Primary triticales:

an important germplasm source for triticale breeding. *In* N. Darvey, ed. *Proc. Int. Triticale Symp.*, Sydney, Australia, 1986, Occasional Publications, No. 24, p. 473-477. Sydney, Australia, Australian Institute of Agricultural Science.

McIntosh, R.A. & Singh, S.J. 1986. Rusts – real and potential problems for triticale. *In* N. Darvey, ed. *Proc. Int. Triticale Symp.*, Sydney, Australia, 1986, Occasional Publications, No. 24, p. 199-207. Sydney, Australia, Australian Institute of Agricultural Science.

O'Connel, L. 2002. *Grain Yearbook 2002*, 6. Canberra, GRDC.

Roake, J. 1999. 'Maiden' triticale. *Plant Var. J.*, 12(2): 60-61.

Roake, J. 2001. 'Maiden' and 'Hillary' triticale. *Plant Var. J.*, 14(2): 72-73.

Van Barneveld, R. 2002. *Triticale. A guide to the use of triticale in livestock feeds*. Kingston, Australia, Grains Research and Development Corporation.

Triticale in Brazil

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Triticale (X *Triticosecale* Wittmack) is an important crop for the winter season in southern Brazil. It was introduced as a cultivated species for experimental purposes in Brazil in the early 1960s (Mundstock, 1983).

Since the beginning of triticale cultivation in the southernmost state of Brazil, Rio Grande do Sul, in 1982, triticale area has increased substantially. From 1987 to 1991 in southern Brazil, the area increased steadily to between 30 000 and 40 000 ha (Baier *et al.*, 1994). The main reason for such an increase in area was that the prices and uses of triticale grain and flour were the same as those for wheat. Also, the Brazilian government guaranteed acquisition of all triticale and paid the same price for triticale and wheat. In 1990, with the interruption of the Brazilian government's support for triticale and with wheat commercialization, the economy of these products changed considerably with negative consequences on their cultivation.

Because of the slightly lower production costs of triticale compared to wheat and due to its use as a component in rations for poultry and swine feed, the area cultivated with triticale has doubled since the beginning of the 1990s. Some incentive for triticale cultivation also resulted from the organization of the Second International Triticale Symposium in October of 1990 in Brazil. In addition, the marketing devoted to triticale and the support given to producers by the swine and poultry industries enhanced triticale programmes, improving, to a certain extend, its value as animal feed (Baier *et al.*, 1994).

Recent data on triticale production in Brazil show significant increases in area, production and yield (Table 1). The major state producers in 2001 were Paraná (86 545 ha), Rio Grande do Sul (21 762 ha), São Paulo (10 000 ha), Santa Catarina (9 831 ha) and Mato Grosso do Sul. The total triticale area in 2001 was approximately 130 000 ha, used mostly for animal feed, as pasture, silage or raw material for feed rations. Moreover, triticale is presently being used for human consumption, including pizza dough and several wheat flour mixtures for cookies and pastas.

Triticale yield has been quite unstable since the beginning of its cultivation in Brazil. In general, the grain yield average has ranged from 1 600 to 2 100 kg/ha in the last decade. In spite of this, the yield potential of triticale cultivars is high. Average yield obtained in research trials was higher than 6 000 kg/ha in several locations. These results are mainly due to the selection of superior genotypes, adapted to the specific environment of production, and the development of better management practices, such as the use of adequate amounts of fertilizers, crop rotation and pest and weed control, which result in better expression of the yield potential of the cultivars.

TABLE 1
Triticale grain production, average yield and area in some states of Brazil

Year	Production (*tonnes*)	Yield (*kg/ha*)	Area (*ha*)
	Rio Grande do Sul		
1992	21 518	2 145	10 034
1996	73 281	1 768	41 459
1999	34 986	1 725	20 284
2000	38 197	1 577	24 226
2001	35 745	1 643	21 762
	Santa Catarina		
1994	15 826	1 860	8 508
1996	32 688	1 543	21 189
1998	9 705	1 550	6 260
1999	11 335	2 054	5 519
2000	-	-	-
2001	9 455	961	9 831
	Paraná		
1992	64 944	1 778	36 532
1996	128 729	2 696	47 742
1999	100 191	2 153	46 528
2000	99 678	1 650	60 403
2001	184 444	2 132	86 545

Source: Embrapa Trigo.

TRITICALE PRODUCTION

In Brazil, triticale is cultivated mainly in the southern states (Figure 1). Most of these areas are cultivated with maize and soybean during the summer season and are not entirely utilized during the winter season, leaving the soil more exposed to erosion in this critical period. Spring growth-habit triticale is the main cultivated type in Brazil.

FIGURE 1
Triticale cultivation in Brazil

It is planted in autumn/winter from April to June. Winter-type triticale genotypes are used only in crosses with spring types to enlarge the genetic variability of spring triticale by introducing new genes and to generate new germplasm with a longer crop cycle that can be used as pasture.

The climate in southern Brazil during the winter is influenced substantially by the polar and tropical air masses. Such phenomena interfere with air temperature, precipitation, sunshine duration and wind thus affecting plant development. The climate of the region is considered subtropical, with rainfall well distributed during the year and varying from 1 500 to 2 000 mm in the states of Santa Catarina and Rio Grande do Sul. In the states of Mato Grosso do Sul, São Paulo and Paraná, annual precipitation ranges from 1 000 to 1 500 mm. In general, the rainy seasons are autumn and winter, affecting the amount of sunshine duration, especially in June and July, due to the increase of nebulosity. During the winter, the entire region can be exposed to frost, especially in higher elevations, and eventually the occurrence of some low-intensity snow showers. The average daily air temperature during the growing period does not limit triticale growth and development except for the possible occurrence of frost during the flowering stage, which may cause high sterility levels in flowers.

When compared to other winter cereals, triticale is less susceptible to low temperatures and water deficit. However, triticale does not resist flooded soils or excess rain during reproductive stages. In addition, one of the greatest climatic limitations to triticale production in Brazil is the occurrence of heavy rains during flowering and maturation, which induces the appearance of foliage and spike diseases, mainly scab. This fungus causes triticale yield reduction, lower grain quality and can limit its utilization for monogastric animals, such as poultry and swine, due to the synthesis of micotoxins in the grain. Since the Rio Grande do Sul and Santa Catarina states have a high frequency of heavy rains during the winter compared to other states, there is a need to develop genotypes that are less susceptible to diseases.

In the eastern coastal areas of the various states, triticale production is limited due to the undesirable condition of the soils and weather for cereal development.

In the southern part of Rio Grande do Sul, the limitation is due to the excess of soil humidity and air moisture. These areas have typical prostrate vegetation, predominantly monocots and some native dicots. The cow and sheep stock of the region have stimulated the search for triticale genotypes that are better adapted to soils with a high risk of flooding and also genotypes with a high potential for use as pasture in the production system of the region.

Favourable inherited traits from parental species, such as high yield and biomass potential, disease resistance, low basal temperature, drought and cold tolerance, deep root system, high-quality grain for certain uses, etc., made triticale a good winter crop for soils with lower fertility levels.

USES

Triticale flour is darker than wheat and its gluten is not as adequate for bread making as wheat; however, it is used to produce cookies, pastas and pizza dough and used in mixture with wheat flour for many other purposes. The crushed grains are used in mixtures in multigrain food and dietetic products.

Triticale is, however, mainly used in animal feed since it is produced in the winter, a period of low forage availability. Triticale is therefore transformed into meat, milk or eggs, giving producers the possibility to add value to their farm production.

Grain consumption for feed in Brazil has been based on maize (97 percent). The large distance between the main maize-producing centres, the reduced possibility for expansion of growing areas near the sources of demand and the yearly oscillation of price have induced the producers to seek alternative sources of energy and protein for feed. Triticale is grown during the winter season, while maize is a summer crop and is harvested in a period when historically the price of maize is high. This has permitted triticale to become a profitable alternative for farmers that have maize as a feed base. In addition, triticale has 3 to 4 percent more crude protein concentration than maize grain, which allows the farmer to reduce other protein sources, such as soybean meal in feed formulation, assisting in the reduction of animal production costs.

According to Baier *et al.* (1994), triticale received decisive support from the swine and poultry industries in Brazil in 1991. In that year, technicians from the industry were responsible for conducting and supervising dozens of on-farm demonstration plots, thus promoting triticale cultivation.

On small farms, triticale is used especially for direct feeding as green forage or as silage of young or mature plants, moist or dry grains, and hay. The nutritional quality of the silage is a function of the raw material. Whole-plant silage, using plants close to maturity, in general gives high protein and energy yield, but low digestibility of the silage. On the other hand, when young plants are used for silage, yield is low but the silage has a high protein content and better digestibility. To obtain high-quality silage, it is important that plants be chopped into pieces no larger than 1 cm long and the silage pile be tight and well closed and compacted. Since early-stage plants present lower levels of dry matter (15 to 20 percent) than recommended for silage (30 to 35 percent), it is necessary that plants be dried out in the field, which is not easy because of the low evaporation pressure usually observed during that period. Such conditions may extend triticale presence in the field, increasing the risk of plant decomposition (Lima *et al.*, 2001).

Grain silage possesses good digestibility and high energy and protein concentrations making such silage desirable for swine and cow feed. Grain silage is made when grains have about 65 to 70 percent dry matter. Grains are ground to facilitate compaction and fermentation (Lima *et al.*, 2001).

If the purpose of triticale production is direct feeding as pasture or soil coverage, the sowing can be done just after the soybean harvest in late March to May with genotypes having a longer life cycle. Despite the early sowing date, triticale has good tolerance to low temperature compared to other winter cereals. This characteristic gives triticale an advantage because it provides good-quality pasture during the winter period of June and July when limited forage is available in the field.

Work done at Embrapa (Empresa Brasileira de Pesquisa Agropecuária) Suínos e Aves, located in Concórdia (Santa Catarina), shows that triticale grain can economically substitute maize grain and soybean bran in the formulation of rations for swine (EMBRAPA, 1991). Other advantages of triticale, including high protein levels and good digestibility, make triticale a recommended alternative to feed young animals, but the low fat and energy levels give some disadvantage to triticale for terminal feed. Some anti-nutritional factors present in rye and in old triticale varieties were not detected in the Brazilian cultivars (Baier *et al.*, 1994).

It has been observed that the substitution of maize and wheat with triticale in rations for poultry and swine allows for a reduction in the amount of soybean bran in the diet due to the high levels of lysine found in triticale.

However, the low energy levels, in general, lead to an undesirable conversion in some cases.

The high lysine levels, high digestibility of crude protein, high phosphorus content and good mineral balance make triticale especially suitable for poultry and swine feed. In a study presented by Zanotto, Guidoni and Lima (1997), it was observed that during the animal life cycle, the substitution of maize with triticale led to a reduction in ration consumption and weight gain, except when diets constituted 75 percent maize substitution. The results were similar to diets in which maize was the major grain component. However, no difference was detected when animal feed conversion was studied. Considering the characteristics of animal carcass, bacon thickness and meat yield of swine, no difference was observed when comparing animals fed with triticale and animals fed with maize as the major energetic component. On the other hand, loin depth was larger at 25 to 50 percent substitution levels, and with 50 percent substitution level, the highest carcass yield was achieved. In general, it can be concluded that triticale can be used as much as 75 percent in substitution for maize in swine diets (from early growing to termination). The optimum economic level of substitution will depend on the price of each ration component and the market price for swine.

Wheat substitution with triticale in diets (0, 50 and 100 percent) for poultry resulted in proportionally lower performance in animals fed with increasing triticale proportion. This negative effect can be corrected with the addition of fat to increase energy levels in the diet. In the same way, supplementation of 0.5 percent of DL-methionine in diets containing triticale promoted weight gain in poultry when compared to poultry fed without an amino acid supplement (Brum *et al.*, 2000).

The use of triticale grain with low crude protein content requires attention with respect to amino acid content in diets. In some cases, it is necessary to add synthetic amino acids, such as methionine, lysine and threonine. The negative effect of the use of triticale with low crude protein content in substitution for other grains in diets for laying hens can be alleviated with the addition of crude protein in the diet, with no alteration to egg production (Lima *et al.*, 2001).

According to Brum *et al.* (2000), it is possible to substitute 75 percent of maize in diets using triticale without affecting the performance of poultry, weight gain, ration consumption and feed conversion.

CROP IMPROVEMENT

The major challenges for triticale breeding in Brazil are increasing grain yield potential, disease resistance, reducing sprouting, increasing nutritional value and improving adaptation to acid soils.

There are five institutions that have been working with triticale in Brazil: Brazilian Agricultural Research Corporation (Embrapa) at the National Wheat Research Center (Embrapa Trigo), Instituto Agronômico do Paraná (IAPAR), Fundação Centro de Experimentação e Pesquisa (FUNDACEP FECOTRIGO), Cooperativa Central Agropecuária de Desenvolvimento Tecnológico e Econômico Ltda. (COODETEC) and Instituto Agronômico de São Paulo (IAC). These institutions have triticale breeding programmes, basing their major germplasm variability sources on germplasm received from the International Maize and Wheat Improvement Center (CIMMYT) through the following nurseries: International Triticale Yield Nursery (ITYN), International Triticale Screening Nursery (ITSN), Facultative Winter Triticale (FWTCL) and some F_3 populations available at CIMMYT (Mexico).

At Embrapa Trigo, the triticale genetic breeding programme is focussed on obtaining triticales with specific characteristics for adaptation to local climates and on increasing genetic variability (Baier and Nedel, 1986). Rye, grown in Brazil for more than a century, has genetic characteristics that can be transferred to new varieties to promote adaptation. Natural selection may have contributed to the accumulation of favourable genes. Darvey (1986) suggests that the genetic base for today's triticales in the world is narrow and should be increased. This can also be applied to Brazilian varieties since all recommended cultivars came from a cooperation programme with CIMMYT.

Crosses of hexaploid triticale with octoploid triticale, rye or wheat are followed by back-crosses with hexaploid triticale to guarantee better efficiency and to restrict genetic variability. In back-crosses, pollen from F_1 plants is used due to its balanced number of chromosomes, which confers more viability (Varughese, Barker and Saari, 1987).

Resistance to *Gibberella* and foliage fungus must be improved and existing resistance to other diseases maintained. Two methods are used to evaluate *Gibberella* and to select genotypes: (i) inoculation of *Gibberella* into the spike in the field (Baier *et al.*, 1994); and (ii) a natural *Gibberella* nursery, with spore distribution and wetting of spikes from the heading stage onwards. *Gibberella* incidence, severity and number of grains with *Gibberella* symptoms are evaluated to detect initial infection resistance, subsequent colonization and expressed

TABLE 2
Most common varieties, pedigree, origin and commercial seed availability of triticale in Brazil, 2000-2002

Genotype[a]	Pedigree	Origin/Brazilian partner	Availability (*tonnes*)		
			2000	2001	2002
BRS 148	Yogui/Tatu	CIMMYT/Embrapa Trigo	76	1 247	1 398
BRS 203	LT-1/Rhino	CIMMYT/Embrapa Trigo	0	176	603
CEP 22-Botucaraí	BGL/CIN//IRA/BGL	CIMMYT/FUNDACEP	0	0	0
CEP 23-Tatu	BGL/3/MTZTCL/Wheat //BGL/4/Nutria	CIMMYT/FUNDACEP	944	262	77
CEP 28-Guará	Daman (Tatu4/ARD1)	CIMMYT/FUNDACEP	386	408	187
EMBRAPA 18	Tapir/Yogui//2*MUS	CIMMYT/Embrapa Trigo	1 222	1 377	331
EMBRAPA 53	LT1117.82/Civet//Tatu	CIMMYT/Embrapa Trigo	3 398	5 840	1 534
IAC 1 Juanillo	DRIRA//KISS/ARM	CIMMYT/IAC	-	-	-
IAC 2 Tarasca	TEJON/BGL	CIMMYT/IAC	-	-	-
IAC 3 Banteng	BANTENG "S"	CIMMYT/IAC	-	-	-
IAC 4	Tatu4/ARD1	CIMMYT/IAC	-	-	-
IAPAR 23-Arapoti	CIN/CNO//BGL/3/Merino	CIMMYT/IAPAR	2 741	3 440	1 202
IPR 111	ANOAS 5/STIER 13	CIMMYT/IAPAR	0	0	0
IAPAR 54-OCEPAR 4	URON	CIMMYT/IAPAR-OCEPAR	16	199	23
TRITICALE BR 1	M2A/CML	CIMMYT/Embrapa Trigo	0	0	0
TRITICALE BR 4	BGL/CIN//MUS	CIMMYT/Embrapa Trigo	672	707	48
Total	-	-	9 455	13 656	5 403

[a]Acronyms identify the Brazilian institution for genotype selection and/or recommendation: BR, BRS, EMBRAPA = Embrapa Trigo, Passo Fundo, Rio Grande do Sul; CEP = Fundação Centro de Experimentação e Pesquisa (FUNDACEP), Cruz Alta, Rio Grande do Sul; IAC = Instituto Agronômico de São Paulo, Campinas, São Paulo; IAPAR = Instituto Agronômico do Paraná, Londrina e Ponta Grossa, Paraná; OCEPAR = Cooperativa Central Agropecuária de Desenvolvimento Tecnológico e Econômico Ltda. (COODETEC), Cascavel, Paraná.

resistance in the grain (Lima and Fernandes, 2002).

Yield is evaluated simultaneously in high- and low-fertility soils to obtain genotypes that combine hardiness and high yield potential characteristics. The selection in low-fertility soils is carried out at sites that allow the identification of plants with tolerance to high aluminium concentration, low phosphorus availability and low nitrogen content. Soil liming is a common practice in Brazil, but aluminium-tolerant plants usually present a more vigorous and deeper root system. The efficiency of phosphorus and nitrogen uptake and utilization is a very important characteristic to seek in triticale breeding programmes in Brazil due to the existence of low-fertility soils and taking into consideration economic factors.

Before the promulgation of the law concerning cultivar protection in Brazil, all institutions involved in triticale breeding conducted Brazilian Triticale Trials in a cooperative way. The best genotypes of each institution were evaluated in a network of trials. Since the year 2000, trials are exclusive to each institution. With this new system, the number of environments tested has diminished, and the evaluation for adaptation is restricted to the testing area of each institution. It is possible that in the future more local cultivars will be available with specificity to certain environments rather than more broadly adapted genotypes.

Presently, there are 15 genotypes recommended in Brazil. In general, the ones that are more productive with broad adaptation and acceptance in the market are those that have more seed available for large-scale production (Table 2). Some of them do not have seed available for farmers except for the amount of seed required by law.

Seed production and certification follow international standards. In addition, each state has some extra specifications that increase quality, health and purity standards. Seeds are divided into classes: (i) genetic seed, which is produced and maintained by breeders; (ii) basic seed, which is an institutional responsibility; and (iii) registered, certified and inspected seed, which results from multiplication and is commercially distributed to farmers.

Some farmers chose to reduce production costs by using their own farm-saved seed. These seeds are normally produced without the rigorous control used during seed production, such as quality, purity and health. This practice makes it very difficult to standardize plant type and does not take advantage of the new and more productive genotypes developed by breeders.

REFERENCES

Baier, A.C. & Nedel, J.L. 1986. Triticale in Brazil. *In* N. Darvey, ed. *Proc. Int. Triticale Symp.*, Sydney, Australia, 1986, Occasional Publications, No. 24, p. 270-282. Sydney, Australia, Australian Institute of Agricultural Science.

Baier, A.C., Nedel, J.L., Reis, E.M. & Wiethölter, S. 1994. *Triticale: cultivo e aproveitamento*. Passo Fundo, Brazil, Embrapa-CNPT.

Brum, P.A.R. de, Zanotto, D.L., Guidoni, A.L., Rosa, P.S., Lima, G.J.M.M. & Viola, E.S. 2000. Triticale em dietas para frangos de corte. *Pesquisa Agropecuária Brasileira*, 35: 229-239.

Darvey, N.L. 1986. Strategies for the production and utilization of triticale germplasm. *In* N. Darvey, ed. *Proc. Int. Triticale Symp.*, Sydney, Australia, 1986, Occasional Publications, No. 24, p. 458-564. Sydney, Australia, Australian Institute of Agricultural Science.

EMBRAPA. 1991. *Centro Nacional de Pesquisa de Suínos e Aves. Tabela de composição química e valores energéticos de alimentos para suínos e aves*. Concórdia, Brazil, Embrapa-CNPSA.

Lima, M.I.P.M. & Fernandes, J.M.C. 2002. Avaliação da resistência à giberela de genótipos de cereais de inverno. *Fitopatologia Brasileira*, 27: 104.

Lima, G.J.M.M., Viola, E.S., Kratz, L.R. & Bermudes, V.L. 2001. Triticale na alimentação animal. In *Embrapa-CNPSA. Circular Técnica, 29*. Concórdia, Brazil, Embrapa-CNPSA.

Mundstock, C.M. 1983. *Cultivo dos cereais de estação fria: trigo, cevada, aveia, centeio, alpiste e triticale*. Porto Alegre, Brazil, NBS.

Varughese, G., Barker, T. & Saari, E. 1987. *Triticale*. Mexico, DF, CIMMYT.

Zanotto, D.L., Guidoni, A.L. & Lima, G.J.M.M. 1997. Triticale em dietas de suínos na fase de terminação. In *Reunião Anual da Sociedade Brasileira de Zootecnia*, Anais SBZ 34, p. 155-157. Juiz de Fora, Brazil, SBZ.

Production of triticale on the Canadian Prairies

D.F. Salmon

In 1953, the University of Manitoba, Winnipeg, began the first Canadian triticale (X *Triticosecale* Wittmack) breeding programme. Early breeding efforts concentrated on developing a high-yielding, drought-tolerant human food crop species suitable for marginal wheat-producing areas. In contrast, more recent programmes concentrate on developing improved animal feed and fodder varieties for production under a number of diverse environmental conditions. In recent years, triticale has seen a rebirth in interest from farmers in western Canada as a means of crop diversification. As a consequence, since 1990 triticale production has risen from approximately 10 000 ha to 100 000 ha.

In western Canada, all triticale varieties both public and private have been released after rigorous cooperative testing under the auspices of the Prairie Regional Recommending Committee on Grain (PRRCG). The PRRCG meets on an annual basis and forwards recommendations for registration to the Variety Registration Office of the Canadian Food Inspection Agency (CFIA). Since the registration of the first Canadian spring triticale variety Rosner (1969), a total of only 18 spring and winter varieties have been evaluated in western Canada and subsequently released (Table 1, Table 2). This process of registration is currently under review.

Triticale, unlike the major cereal crops such as barley and several classes of wheat, is not controlled by a marketing board system, such as the Canadian Wheat Board. Most of the production is utilized within the country for forage and as a feed crop as well as for some other minor-use industries. Limited amounts are exported to mills in the United States of America and for reproduction for grain and forage use.

SPRING TRITICALE

Performance

Under dryland conditions, spring triticales are a valuable alternative to feed barley and oats. Spring triticale has a 5 to 19 percent yield advantage (Table 3) over the high-yielding Canadian Prairie Spring wheat (CPS). This advantage is most apparent in areas with longer growing seasons (Figure 1), such as the brown soil zones of Alberta, Saskatchewan and Manitoba, due to the late maturity (Table 4) of most varieties (Salmon *et al.*, 2001).

Cultural practices

While the test weights and weight per 1 000 kernels of the various Canadian classes of wheat are very similar within classes, this is not true for triticale. In general, a spring triticale has a 1 000 kernel weight that is 20 percent greater than a Canadian Western Hard Red Spring wheat (CWRS) or just slightly greater than the CPS class. It is suggested that farmers not familiar with setting their seeding equipment for triticale use a minimum of 110 kg/ha of seed. This on average comes very close to the recommended plant population of 310 plants/m^2, which compensates for the fact that the spring triticales commonly grown on the prairies are not aggressive tiller producers.

The cultural techniques for growing spring triticale in any one production zone are generally very similar to those used for spring wheat. Consequently, the fertilization, seedbed preparation, seeding depth and seeding methods used for wheat are acceptable for triticale. The major difference between wheat, as well as other common cereal crops, and triticale is the fact that few pesticides are registered for use on triticale. However, it is common for producers to use chemicals that are suitable for use on wheat and rye.

WINTER TRITICALE

Performance

Winter triticales are best adapted to the brown and black soil zones of the prairies where there is adequate snow cover (15 cm) throughout the winter or snow trapping through the use of minimum tillage. Winter triticale performs very similarly to spring triticale but has the major advantage of three-week earlier maturity compared to its spring counterpart. Varieties such as Pika, and to a lesser extent Bobcat, are similar in winter hardiness to the best of the Canadian Western Hard Red Winter wheats and 10 to 20 percent higher yielding (Table 5). To date, the winter triticale varieties have not reached the level of hardiness found in winter rye (Table 6).

TABLE 1
Old and current spring triticale varieties, 1969-1999

Variety	Year	Institution[a]	Status
Rosner	1969	University of Manitoba	Deregistered
Welsh	1977	University of Manitoba	Deregistered
Carman	1980	University of Manitoba	Deregistered
OAC Triwell	1980	Ontario Agriculture College	Deregistered
Wapiti	1987	FCDC, AAFRD, Alberta	Registered
OAC Trillium	1988	Ontario Agriculture College	Deregistered
Frank	1988	Agriculture and Agri-Food Canada	Registered
Banjo	1991	University of Manitoba	Registered
AC Copia	1993	Agriculture and Agri-Food Canada	Registered
AC Alta	1994	Agriculture and Agri-Food Canada	Registered
AC Certa	1995	Agriculture and Agri-Food Canada	Registered
Pronghorn	1996	FCDC, AAFRD, Alberta	Registered
Sandro	1998	Swiss Fed. of Agric. Res.	Registered
AC Ultima	1999	Agriculture and Agri-Food Canada	Registered

[a]FCDC = Field Crop Development Centre; AAFRD = Alberta Agriculture, Food and Rural Development.

TABLE 2
Old and current winter triticale varieties, 1980-1999

Variety	Year	Institution	Status
OAC Wintri	1980	Ontario Agriculture College	Deregistered
OAC Decade	1984	Ontario Agriculture College	Deregistered
Pika	1990	Alberta Agriculture, Food and Rural Development	Registered
Bobcat	1999	Alberta Agriculture, Food and Rural Development	Registered

TABLE 3
Grain yield of spring triticale compared to Canadian Prairie Spring wheat (CPS), 1995-2000[a]

Variety	Soil zone				
	Black (%)			Brown (%)	Irrigation (%)
	Manitoba	Saskatchewan	Alberta		
Pronghorn	136	112	119	110	114
AC Alta	135	106	119	105	121
AC Ultima[b]	140	120	120	107	115
CPS wheat	100	100	100	100	100

[a]Data based on Prairie Regional Recommending Committee on Grain (PRRCG) and provincial adaptation trials.
[b]Limited number of station years compared to other varieties.

TABLE 4
Days to maturity of spring triticale compared to Canadian Prairie Spring wheat (CPS), 1995-2000[a]

Variety	Soil zone				
	Black (*days*)			Brown (*days*)	Irrigation (*days*)
	Manitoba	Saskatchewan	Alberta		
Pronghorn	97	107	123	109	102
AC Alta	103	111	132	114	105
AC Ultima	97	-	126	109	102
CPS Wheat	95	104	116	104	98

[a]Data based on Prairie Regional Recommending Committee on Grain (PRRCG) and provincial adaptation trials.

FIGURE 1
Soil zones of the Canadian Prairies

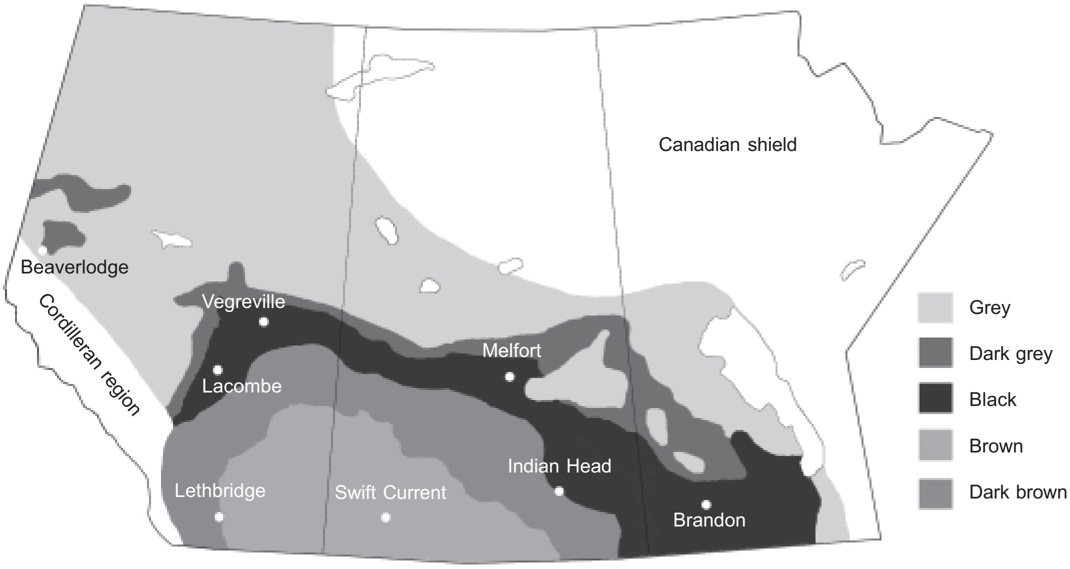


TABLE 5
Relative yield of winter triticale and rye compared to winter wheat CDC Osprey, 1995-2000[a]

Variety	Soil zone	
	Black (%)	Brown (%)
Bobcat	118	119
Pika	104	137
Musketeer[b]	100	105
CDC Opsrey	100	100

[a]Data based on Prairie Regional Recommending Committee on Grain (PRRCG) and provincial adaptation trials.
[b]Rye.

TABLE 6
Winter survival of winter triticale, rye and winter wheat CDC Osprey, 1995-2000[a]

Variety	Soil zone	
	Black (%)	Brown (%)
Bobcat	86	85
Pika	91	88
Musketeer[b]	90	91
CDC Osprey	84	80

[a]Data based on Prairie Regional Recommending Committee on Grain (PRRCG) and provincial adaptation trials.
[b]Rye.

Cultural practices

Planting densities in principle are the same for winter triticale as for spring triticale. However, since there is usually some winterkill during an average year, producers are encouraged to use at least 320 to 330 seeds/m^2. The recommended planting date for winter triticale is between the last week of August and the first ten days of September across the prairies (Jedel and Salmon, 1994). To ensure rapid emergence and adequate crown development, winter triticale as well as winter wheat is planted at a depth no greater than 2.5 cm.

The fertility requirements for winter wheat and triticale are quite similar. The development of modern minimum-tillage equipment with the capability of placing the fertilizer in bands near the seed has allowed for the placement of both the nitrogen and phosphate at seeding rather than broadcasting the nitrogen in the spring.

ABIOTIC AND BIOTIC STRESSES

The major abiotic stresses for spring and winter triticale are primarily those related to climate conditions. The relative short growing season restricts the production of spring triticale, and the severe winters impact on the production of winter triticale. Although there are significant saline as well as acid soils in parts of the prairies, these are not as serious a problem as in most other production areas around the world.

In a similar fashion, triticale has as yet not been impacted by severe biotic stresses. This is likely due to the fact that the crop has only recently reached a significant level of production. To date, triticale varieties have only low to moderate levels of wheat leaf diseases and few insect pests. The germplasm from the International Maize and Wheat Improvement Center (CIMMYT) used in most programmes has maintained excellent levels of leaf and stem rust resistance. The increasing levels of scab are expected to be a major concern in the near future.

UTILIZATION

Forage and fodder

Triticale provides an excellent alternative to and complements the production of barley silage. This is of significant importance in areas that have large populations of animals in feedlot situations. Heavy applications of animal manure and continuous cropping with barley have resulted in significant problems and a build-up of disease problems in the production fields. Spring triticale yields (Table 7) at least equal to and in many cases greater than conventional barley varieties and CPS wheat. Khorasani *et al.* (1997), studying the chemical composition of oat, barley, triticale and alfalfa, indicated that triticale was similar to barley for silage quality. This coupled with good lodging resistance and resistance to barley diseases has made triticale an important part of many large-scale silage operations.

Although winter triticale is used for the production of an early silage crop, it has had significant impact as a spring-seeded, long-season annual grazing crop. Spring-seeded (early May) winter triticale can be rotationally grazed beginning in late June until late November in years with adequate autumn moisture. This provides livestock producers with an inexpensive means of extending the grazing season and reducing the use of expensive conserved feed.

Livestock feed

Unlike in many other countries worldwide, the use of triticale as a feed grain has been somewhat limited. This has been due to the large quantities of feed barley and in many years downgraded spring wheat. However, work conducted by Jaikaran *et al.* (1998), which indicated that triticale fed to hogs resulted in growth and carcass quality similar to hulless barley and maize, has stimulated some interest in the utilization of triticale grain as a feed stock.

TABLE 7
Silage yields (dry matter) of spring triticale and Canadian Prairie Spring wheat (CPS) compared to Cascade spring oat, 1995-2000[a]

Variety	Stage	
	Anthesis (%)	Dough (%)
Pronghorn	114	109
AC Alta	113	103
AC Ultima	119	107
CPS wheat	96	81
Cascade[b]	100	100

[a]Data provided by the Field Crop Development Centre, Alberta Agriculture, Food and Rural Development, Lacombe, Alberta.
[b]Oat.

VARIETY IMPROVEMENT

Variety improvement in Canada has been mainly based on publicly funded programmes. To a large extent, the involvement of the private sector has been restricted to the marketing of varieties and products. The two current programmes at Agriculture and Agri-Food Canada (AAFC), Swift Current, Saskatchewan (spring), and at the Field Crop Development Centre (FCDC), Alberta Agriculture, Food and Rural Development (AAFRD), Lacombe, Alberta (spring and winter), are the principle players in variety development and improvement.

REFERENCES

Jaikaran, S., Robertson, W.M., Salmon, D.F., Aherne, F.X. & Hickling, D. 1998. Comparison of live performance of market pigs fed triticale, maize or hulless barley based diets. *In* P. Juskiw, ed. *Proc. 4th Int. Triticale Symp.*, Red Deer, Alberta, Canada, 26-31 July 1998, p. 185-195. International Triticale Association.

Jedel, P.E. & Salmon, D.F. 1994. Date and rate of seeding of winter cereals in central Alberta. *Can. J. Plant Sci.*, 74: 447-453.

Khorasani, G.R., Jedel, P.E., Helm, J.H. & Kennelly, J.J. 1997. Influence of stage of maturity on yield components and chemical composition of cereal grain silages. *Can. J. Anim. Sci.*, 77: 259-267.

Salmon, D.F., Hartman, M., Schoff, T., Juskiw, P.E. & Baron, V.S. 2001. *Triticale*. Alberta Agriculture, Food and Rural Development Agdex 118/20. April 2001.

Triticale developments in China

S. Yuanshu, W. Zengyuan

RESEARCH AND DEVELOPMENT OF TRITICALE

Triticale research in China started in the 1950s. The first varieties were initially tested across the country in 1970 and first released in 1976 (Wenkui, 1981). Triticale was mainly used as a food crop. Because of its resistance to diseases and good adaptation to harsh environments, triticale was planted mainly in high elevation and cold mountain areas in southwestern and northwestern China. More recently, with the new adjustment in agricultural structure, triticale began to be used as a fodder crop (Yuanshu, Yun and Zengyuan, 1996). Its production potential, particularly the biological yield and quality, was fully developed allowing it to become a dominant fodder crop around the country. Triticale planting area expanded to the Huang-huai-hai plain, south of the lower areas of the Yangtze River, and northeast to the mountain areas. In 2002, the area planted to triticale exceeded 300 000 ha and will increase in the coming years. A significant increase in area sown to triticale was noticed in 1980. The changes in triticale area in China from 1975 to 2003 are shown in Figure 1. The development of triticale in China experienced five phases (Yuanshu, 2002), which are described below.

Testing phase (1970-1975)

Triticale tests began in China in 1970. The yields of the first triticale varieties tested in mountain areas were higher than those of other crops. Compared to wheat, triticale yield increases varied from 9 to 23 percent. Multilocation tests of triticale varieties were carried out in the mountain regions of Guizhou province with an altitude of 1 700 to 2 600 m during the period 1972-1975. The yield tests showed that in eight out of ten locations triticale varieties were higher yielding than those of check crops including wheat and rye. The mean yield of triticale varieties tested was 2.5 tonnes/ha, representing a 41 to142 percent and 31 to 98 percent increase over wheat and rye, respectively. Among tested genotypes, Triticale No.2 and No.3 were the highest yielding. Their high grain yield of 1.5 tonnes/ha was mainly due to their high cold, disease and stress resistance. Wheat, in general, has very low yields in these regions due to its sensitivity to frost and hail. Therefore, the farmers in high elevation and cold mountain areas prefer to plant triticale. This resulted in a substantial increase of triticale area, which reached 733 ha in 1976.

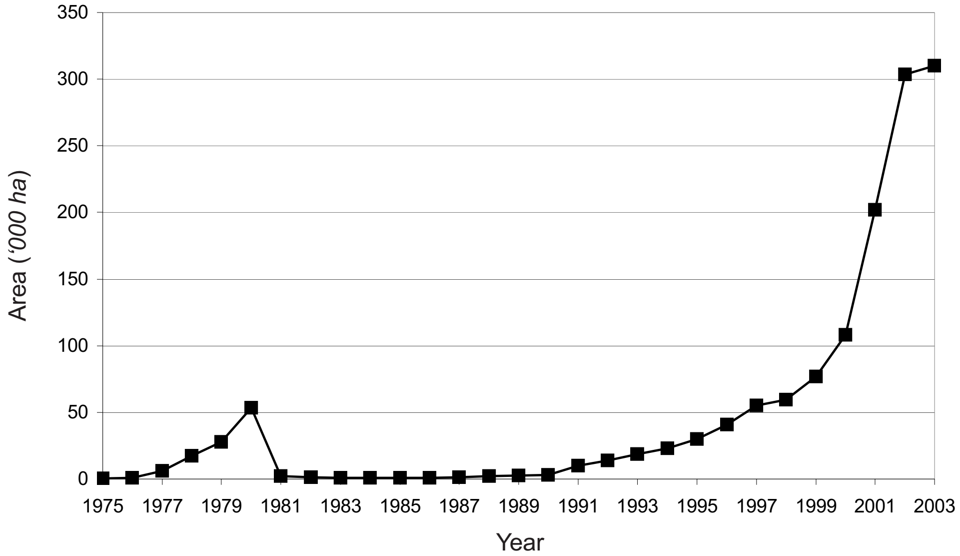
Expanding phase (1976-1980)

The first national meeting on triticale demonstration was held in Guizhou in June 1976. Scientific researchers and farmer delegates from 15 provinces attended the meeting. They visited the triticale fields and surveyed the crop growth state planted at different elevations, sowing date and cropping patterns; and they measured the triticale yields on site. The results showed that triticale mean yield was 3.5 tonnes/ha, which was 30, 40 and 50 percent higher than wheat, rye and oats yields, respectively. Following much promotion at the national level, the development of triticale was enhanced resulting in an extensive expansion of this crop around the country, and its area increased rapidly. Due to its cold resistance, good adaptation to poor soils, resistance to disease, good quality and its contribution to solve the urgent problem of food needs, octoploid triticale was quickly adopted in the Wumeng, Liang, Qinling, Dabian, Funiu, Liupan and Yin mountains. The triticale area recorded in 1977 at 5 866 ha suddenly increased substantially to reach 53 333 ha in 1980.

Decreasing phase (1980-1985)

Octoploid Triticale No.2 and No.3, which were developed by the Institute of Crop Breeding and Cultivation, Chinese Academy of Agricultural Sciences (CAAS), were the first group of varieties grown for demonstration around the country (Wenkui and Yurui, 1993). Their diverse characters, such as grain plumpness, plant height, maturity and cold resistance, were not fully satisfying, although they showed high seed fertility. These varieties could not perform well in some new areas with varying ecological environments. As a result, seeds were shrivelled, and therefore grain price was low in some areas. Hence, triticale area decreased dramatically from 53 333 ha in 1980 to 2 000 ha in 1981, and it stabilized at 866 ha in 1985. The rapid decrease in triticale area was similar to its initial increase during the expanding phase.

FIGURE 1
Change of triticale area in China, 1975-2003



Restoring phase (1986-1990)

Based on their findings, researchers found that triticale development and adoption was basically dictated by the adaptation of the varieties. For Triticale No.2 and No.3, which were the first-ever varieties released around the country, the agronomic characteristics were not generally satisfying, and the varieties were not adapted to various ecological environments. Therefore, researchers began to adjust their triticale breeding goals from selection for food crop uses only to food, fodder and food-fodder dual-crop types. Special attention was paid to varieties adapted to specific areas. Recurrent selection techniques were applied in addition to normal family selection. As a result, various variety types, such as octoploid, hexaploid and substituted lines, were selected (Yuanshu and Chongyi, 1986). The new varieties generated were better adapted to various ecological environments. Jingsong No.8, Jingsong No.49, Qianzhong No.1 and Qianzhong No.2 adapted well to the Wumeng mountain area, whereas Zhongqin No.1 and Zhongqin No.2 were adapted to the Qinling mountain area. Triticale No.81-14 and Zhongxin No.1881 were better adapted to Inner Mongolia. This enhanced triticale adoption since it became better adapted to local ecological environments and could meet the market requirements of most regions. Therefore, triticale area began to increase again and reached 3 400 ha in 1990.

Development phase based on market requirements (1991-present)

In recent years, the agricultural structures in China have changed. The food-economic cropping system is being substituted with a food-economic-fodder cropping system because fodder crops are insufficient in the country while food and economic crop production is sufficient. Triticale is promising as a high-output potential crop for food and fodder that can be planted either in winter or spring due to its fast vegetative growth, high biological output and good nutritive quality. Therefore, triticale has been given another chance for production around the country. Recently, newly developed varieties have been bred for different desirable traits following adjustments in breeding objectives. These cultivars include: fodder types Zhongsi No.237 and Zhongsi No.1890; food-fodder types Zhongxin No.830 and Zhongxin No.1881; and food types Jinsong No.49, Qianzhong No.3 and Xinjiang Triticale No.1. The fresh-matter yield of the newly developed fodder-type variety is about 37.7 to 45 tonnes/ha, while dry-matter yield is about 10 tonnes/ha. Grain yield of the food-type variety is about 3 to 4 tonnes/ha. High biological yield and good adaptation of the new varieties have resulted in a significant increase in area of triticale in the country, reaching 10 066 ha in 1991, 108 000 ha in 2000 and 303 333 ha in 2002, a substantial increase compared to triticale areas in 1991. Most triticale is used for animal feed (Table 1).

TABLE 1
Total area grown to triticale food and fodder in China, 1975-2002

Type	1975		1980		1985		1990		1995		2000		2002	
	Area (*ha*)	Type (*%*)	Area (*ha*)	Type (*%*)	Area (*ha*)	Type (*%*)	Area (*ha*)	Type (*%*)	Area (*ha*)	Type (*%*)	Area (*ha*)	Type (*%*)	Area (*ha*)	Type (*%*)
Food	467	100	53 333	100	866	100	10 000	99.3	29 000	96.7	12 000	11.1	12 666	4.3
Fodder	0	0	0	0	0	0	66	0.7	1 000	3.3	96 000	88.9	290 667	95.7
Total	467	100	53 333	100	866	100	10 066	100	30 000	100	108 000	100	303 333	100

DISTRIBUTION AND PRODUCTION AREAS OF TRITICALE

In the early stages of triticale development, triticale was mainly planted in the cold mountain areas in southwestern and northwestern China, where the environmental and production conditions are difficult and where low temperature, poor soil and bad economic conditions prevail. Triticale normally performs well and produces satisfactory yield in these areas due its cold and other stress resistance. Therefore, farmers in these areas planted triticale extensively. With the adjustments in agricultural structure in China in the 1990s, triticale began to be used as a fodder crop and showed high potential. Recently, triticale has expanded to the Huang-huai-hai plain, south of the lower areas of the Yangtze River, and to northeastern China. At present, triticale is becoming a dominant crop in the country.

Triticale in southwestern and northwestern China

The topography and climate in high elevation and cold mountainous areas in southwestern and northwestern China are very complex. Farmers in these regions have adopted specific crops and different cropping systems. In order to promote triticale in these areas, it is very important to demonstrate the technical and environmental feasibility and the economic viability of the cropping system based on local conditions.

Areas with one crop per year

These regions include the following areas: Yin mountain, with an elevation of 800 to 1 000 m and fall sowing; Liupan mountain, with an elevation of 1 000 m; Funiu mountain, with an elevation of 800 to 1 000 m; Qinling mountain, with an elevation of 1 000 to 2 500 m; Daba mountain, with an elevation of above 1 000 m; Liang mountain, with an elevation of 2 000 to 2 300 m; and Wumeng mountain, with an elevation of 2 400 to 3 000 m. The similarities between these areas are high elevation, low temperature and a harsh climate. The annual mean temperature is about 2° to 8°C, and the frost-free period is about 150 days. Crop yields with a long growth period in these areas are 3 to 4 tonnes/ha. Triticale is generally planted between the end of August and early October and harvested in July except for the spring-sowing area. The growth period of the crops in these areas is between 270 and 320 days.

The environmental and climatic conditions in these areas are difficult, often affecting crop yield because of drought, late frost, or acid or poor soil. Triticale often resists or avoids these stresses and those caused by diseases, particularly scab. Therefore, the yield of triticale in these areas is much higher than other crops, averaging about 1.5 to 2 tonnes/ha, allowing triticale to become a promising crop with high and stable yield for this region.

Areas with two crops per year

These areas are characterized by an elevation of 800 to 2 000 m, an average temperature of 12° to 16°C and a frost-free period of 200 to 250 days. The average temperature in these areas usually increases gradually with a decrease in elevation. Based on average temperatures, this region can be divided into areas with a mean temperature above 14°C (successive cropping area) and areas with a mean temperature below 14°C (intercropping area).

The successive cropping area has high solar radiation where triticale shows a longer growth period compared to wheat. However, there is enough time for other crops, such as maize and sweet potato, to reach high yields when grown after triticale.

The intercropping area includes the transitional region between areas with one crop per year and areas with two crops per year. The characteristics of this area are cold climate, mean temperature between 10° and 14°C and a cropping system with two crops per year. Triticale is normally intercropped with high-yield crops, particularly potato and maize.

Areas with three crops per two years

These areas with three crops per two years are the transitional areas located between areas with one crop and two crops per year. These areas have an elevation of 2 000 to 2 400 m. Normally, triticale could not be planted because of cold climate and delayed harvest. However, in this region triticale fits easily in the following cropping sequences: triticale-fall buckwheat-potato, triticale-fall potato-early buckwheat, or triticale-soybean-potato.

Triticale cultivation in the Huang-huai-hai plain and southern lowlands

Successive cropping in the Huang-huai-hai plain

The Huang-huai-hai plain is the largest production area for winter triticale. The accumulated sunshine hours per year are between 2 000 and 2 800 hours, and average temperature is 11° to 15°C, with an accumulated temperature above 10°C (base temperature) of 3 600° to 4 800°C d. It has a frost-free period of 170 to 240 days. The major cropping system is two crops per year. Soils both upland and lowland are fertile with excellent irrigation facilities. Although some areas north of the Yellow River receive less rainfall, most of the fields could be irrigated giving high yields. Therefore, the Huang-huai-hai plain is the main production area for food and cotton in China. The most dominant cropping systems include triticale-maize, triticale-rice and triticale-cotton.

Multiple cropping in the southern lowlands

These areas have much more solar radiation than the Huang-huai-hai plain. The accumulated temperature above 10°C is about 4 600° to 5 600°C d, and the number of frost-free days is 230. Therefore, the main crops cultivated in this area are wheat, maize, rice, peanut and soybean. Because of high rainfall during the growing period and the irrigation facilities available, crop yields are always high. These areas are, therefore, the main production source for food and oil crops in China. Since triticale has shown high yield, good quality, resistance to scab and it can be planted in winter, it has become a new dominant crop in this area.

UTILIZATION PATTERNS OF TRITICALE

Triticale end-uses have been changing with the increase of triticale adoption in China. Before 1995, it was mainly used as a food crop in high elevation and cold mountain areas. With social improvements and adjustments in the agricultural structure, triticale breeding objectives have shifted from single use for food type to multiple uses including fodder, food-fodder and dual-purpose types.

Before 1990, almost all triticale was used for food. After 1990, the use of triticale began to change from food to fodder. As a result, fodder triticale started to expand significantly in the following years. The area of fodder triticale in 1995 was only 3.3 percent; it then increased to 88.9 percent in 2000 and reached 95.7 percent in 2002. The trend of agricultural structure adjustment is reflected by the change in triticale area and uses. Subsequently, triticale areas began to expand to the Huang-huai-hai plain, Tianjin and Tangshan. On-farm demonstration results show that triticale will expand to the lowlands in southern China and to the northeastern and northwestern areas of China.

NEWLY RELEASED TRITICALE VARIETIES

From 1976 to 1993, triticale was mainly used as a food crop to resolve food problems for farmers in high elevation and cold mountain areas in southwestern and northwestern China. In recent years, fodder triticale has developed quickly in China, which has promoted the development of animal husbandry. The major triticale varieties with a large planting area in China are described in Table 2.

TRITICALE RESEARCH INSTITUTIONS

The national and regional research institutions working on triticale in China are: the Institute of Crop Breeding and Cultivation, CAAS; Crop Research Institute of Guizhou Academy of Agricultural Sciences; Agricultural College of Xinjiang Shihezi University; and the Northeast Agricultural University. A national triticale research network coordinated by the Institute of Crop Breeding and Cultivation, CAAS, was formed in the 1970s in order to improve triticale breeding efficiency, shorten the time for variety development and promote triticale. The major tasks of the triticale research network are described below.

Development of new varieties

Triticale is a new crop that lacks genetic diversity. To breed improved varieties different in their genetic construction was the first target of the network. The Chinese Academy of Agricultural Sciences was the first institution in China to start working on triticale. The long experience in triticale breeding by CAAS has allowed this institute to create and accumulate more triticale breeding material than other institutions. Therefore CAAS offered the breeding materials and breeding technology to the network members to help them establish efficient breeding programmes. Following selection within this material, new varieties adapted to different ecological

TABLE 2

Cultivar names, year and institution of release, and main agronomic characteristics of triticale

Cultivar	Year and institution of release[a]	Main characteristics
Triticale No.2	1976; CAAS	Octoploid; adapted but no winter hardiness; average tillering; 1 000 kernel weight = 40 g; 80% seed fertility; average plumpness; 16.1% protein content; resistant to powdery mildew and rusts; medium resistant to scab; used for food
Triticale No.3	1976; CAAS	Octoploid; adapted but no winter hardiness; height 140 cm; medium tillering and maturity; 1 000 kernel weight = 45 g; 80% seed fertility; 16.3% protein content; resistant to powdery mildew and rusts; medium resistant to scab; used for food
Zhongla No.1	1985; CAAS	Octoploid; spring habit; height 125 cm; medium tillering and maturity; 1 000 kernel weight = 30 g; 80% seed fertility; average plumpness; 16.9% protein content; resistant to powdery mildew and rusts; medium resistant to virus diseases; used for food
Zhongxin No.1881	1988; CAAS	Hexaploid; spring habit; height 140 cm; medium tillering and maturity; 1 000 kernel weight = 35 g; 80% seed fertility; average plumpness; 16.9% protein content; resistant to powdery mildew and rusts; medium resistant to virus diseases; used for food and fodder
Zhongqin No.1 and No.2	1991; CAAS	Hexaploid; winter hardy; height 130 cm; medium tillering and early maturity; 1 000 kernel weight = 35 g; 86-87% seed fertility; average plumpness; 16.9% protein content; resistant to powdery mildew and rusts; used for food
Zhongsi No.1890	1992; CAAS	Hexaploid; winter hardy; height 150-170 cm; medium tillering and maturity; 1 000 kernel weight = 38 g; 88% seed fertility; 15.8% protein content; resistant to powdery mildew and rusts; used for fodder
Zhongxin No.830	1993; CAAS	Hexaploid; adapted but no winter hardiness; height 140-160 cm; medium tillering and maturity; 1 000 kernel weight = 45 g; 89% seed fertility; average plumpness; 15.4% protein content; resistant to powdery mildew and rusts; used for food and fodder
Jinsong No.49	1995; CAAS	Octoploid; adapted but no winter hardiness; height 122 cm; medium tillering and early maturity; 1 000 kernel weight = 42 g; 85% seed fertility; average plumpness; resistant to powdery mildew and rusts; medium resistant to scab; used for food
Qianzhong No.3	1998; CAAS	Octoploid; adapted but no winter hardiness; height 105 cm; medium tillering and maturity; 1 000 kernel weight = 41 g; 80% seed fertility; average plumpness; resistant to powdery mildew and rusts; medium resistant to scab; used for food
Zhongsi No.237	1998; CAAS	Hexaploid; winter hardy; height 150-170 cm; medium tillering and maturity; 1 000 kernel weight = 45 g; 89% seed fertility; 15.9% protein content; resistant to powdery mildew and rusts; used for fodder

[a]CAAS = Chinese Academy of Agricultural Sciences.

zones were developed and released by the triticale network in a short time. These included: Zhongla No.1 adapted to the eastern area of Inner Mongolia; Zhongqin No.1 and No.2 targetted for the Qinling mountain area; Qianzhong No.2 and No.3 for the Giuzhou province; Xinjiang No.1 for the Xinjiang Uygur autonomous region; and Zhongxin No.830, Zhongxin No.1881, Zhongsi No.1890 and Zhongsi No.237 with wide adaptation around the country (Table 2).

Improvement of breeding methodologies

Through a collaborative research effort among the network members, the breeding efficiency of triticale was enhanced greatly. In addition, the Chinese Academy of Agricultural Sciences (CAAS) successfully transferred the dominant male sterile gene (*MS2*) from wheat into triticale allowing triticale to be used as a cross-pollinated crop. A set of recurrent selection cycles has accelerated the improvement of triticale characteristics. As a result, time for developing triticale varieties was shortened and breeding efficiency was improved.

Varietal testing in various regions

Since its creation, the national triticale network has organized four rounds of varietal tests including both winter triticale varieties and spring triticale varieties. More than 20 varieties adapted to different ecological environments have been approved for promotion and growth around the country by both state and provincial committees. The newly released varieties have helped substantially the promotion and expansion of triticale in China.

Development of new triticale products

Triticale was initially used to make steamed bread, pancakes and noodles by farmers in the mountain areas. In recent years, triticale has been extensively used as fresh fodder, silage and hay in the Huang-huai-hai plain. Recently, triticale has also been used to make beer, alcohol and other drinks. The straw of triticale has been used to weave and to make dry flowers. The extension and development of triticale has promoted the comprehensive utilization of this crop.

REFERENCES

Wenkui, B. 1981. *Octoploid triticale breeding and its management*. Guiyang, China, Guizhou People Press.

Wenkui, B. & Yurui, Y. 1993. Octoploid triticale in China. *Adv. Sci. China Bio.*, 3: 55-76.

Yuanshu, S. 2002. *Triticale genetic breeding and utilization in China*. Hangzhou, China, Zhejiang Science & Technology Press.

Yuanshu, S. & Chongyi, W. 1986. Triticale breeding in China. *In* N. Darvey, ed. *Proc. Int. Triticale Symp.*, Sydney, Australia, 1986, Occasional Publications, No. 24, p. 50-59. Sydney, Australia, Australian Institute of Agricultural Science.

Yuanshu, S., Yun, X. & Zengyuan, W. 1996. Triticale as forage in China. *In* H. Guedes-Pinto, N. Darvey & V.P. Carnide, eds. *Triticale: today and tomorrow*, p. 309-329. Dordrecht, Netherlands, Kluwer Academic Press.

Triticale in France

A. Bouguennec, M. Bernard, L. Jestin, M. Trottet, P. Lonnet

The production of triticale began in France in the early 1980s. It was mainly grown in two areas where animal breeding was dominant. These regions are: (i) Massif Central, a semi-mountainous region in the centre of France where frost resistance is important; and (ii) Bretagne and Pays de Loire, regions in western France with some hydromorphic soils and very high disease pressure.

The cultivation of triticale has expanded to other regions of France as shown in Figure 1 (ITCF, 2000). From the beginning, the area of triticale has increased continuously, reaching around 266 000 ha in 2002 (SEDIS, 2002a). Figure 2 shows the evolution of triticale and rye area from 1980 to 2001. Triticale still remains a secondary cereal compared to bread wheat with an area between 4.5 and 5 million ha for the same period[1]. However, triticale tends to replace rye in its traditional production area, i.e. in soils where wheat is not adapted and performs poorly. Triticale also has been replacing winter barley in western France.

The average yields of the main cereal species cultivated in France are shown in Table 1. The highest average yield was obtained for bread wheat, but it should be noted that triticale is mainly grown in marginal areas compared to wheat, which is usually grown on the best soils.

The French imports and exports of triticale are insignificant. The handling of triticale was about 4.5 million tonnes in 1998 (about one-third of the total production) (ITCF, 2000). However, there is a small local market in western France.

TRITICALE PRODUCTION AND MANAGEMENT

The soil and climate conditions are very different in the two regions, Massif Central and Bretagne, where triticale is mostly grown (Figure 1). Therefore, specific adaptation is required for cultivars to be released. In the Massif Central, triticale is mainly grown in semi-mountainous conditions (altitude 800 to 1 200 m). This requires early sowing (i.e. late September to early October). The varieties must be winter hardy, with good frost resistance. They should not be too early-heading in order to avoid late frost causing sterility. However, they should not be too late in order to be harvested before September. The main disease in this area is Septoria nodorum blotch.

In western France, the mild and rainy winters and springs favour the development of diseases. Therefore, the triticale cultivars released must be resistant to diseases, such as Septoria nodorum blotch, scab, leaf rust, stripe rust and eyespot, which are the most damaging pathogens in this region. In some parts of this region, good adaptation to hydromorphic soils and rainy weather is necessary. In such areas, the yield potential of triticale is greater than that of barley. In addition, the varieties with better resistance to pre-harvest sprouting are appreciated in this area. It is also very important to have varieties resistant to lodging.

Over the last few years, triticale area has also increased in some intensive cereal cultivation areas because it is more tolerant to take-all disease compared to wheat when grown in ‘cereal after cereal’ crop rotation. Until recently, triticale has been resistant to powdery mildew, but since 2000 some varieties have become very susceptible to this disease in France.

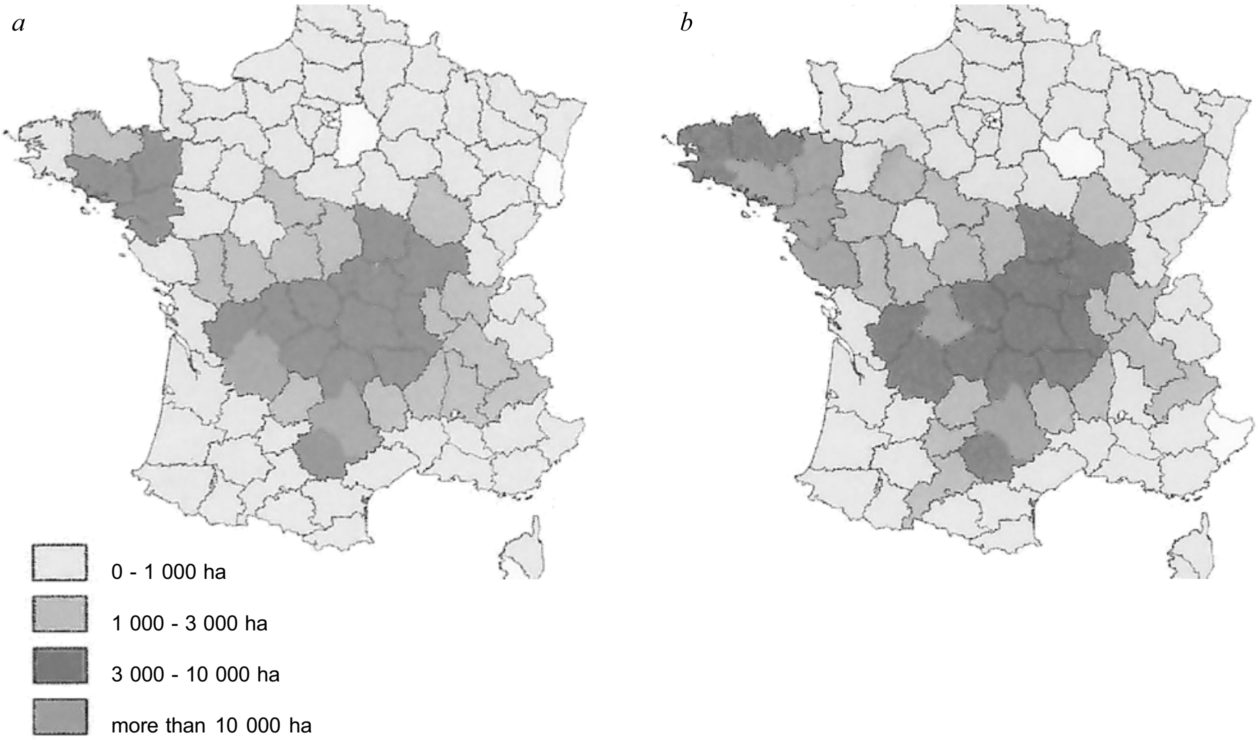
Another problem, due to an insect named Geomyza, which causes the death of plants during spring, appeared recently mainly in western and northern France. Triticale seems to be more frequently attacked than wheat by this insect. The weather conditions (cold period in spring) seem to play an important role. A difference in growth habit (more prostrate leaves at the time of hatching) may make triticale more attractive than wheat to the insects looking for a place to lay their eggs.

TRITICALE USES

Triticale in France is mainly used for animal feeding. Most triticale production is consumed directly on the farm for animal feeding, mainly for cattle. With a protein content between that of wheat and rye and more lysine than wheat, triticale can be used as well as wheat for cattle, pigs, poultry, rabbits and lambs. The low availability of triticale on the grain market is probably limiting its use by the

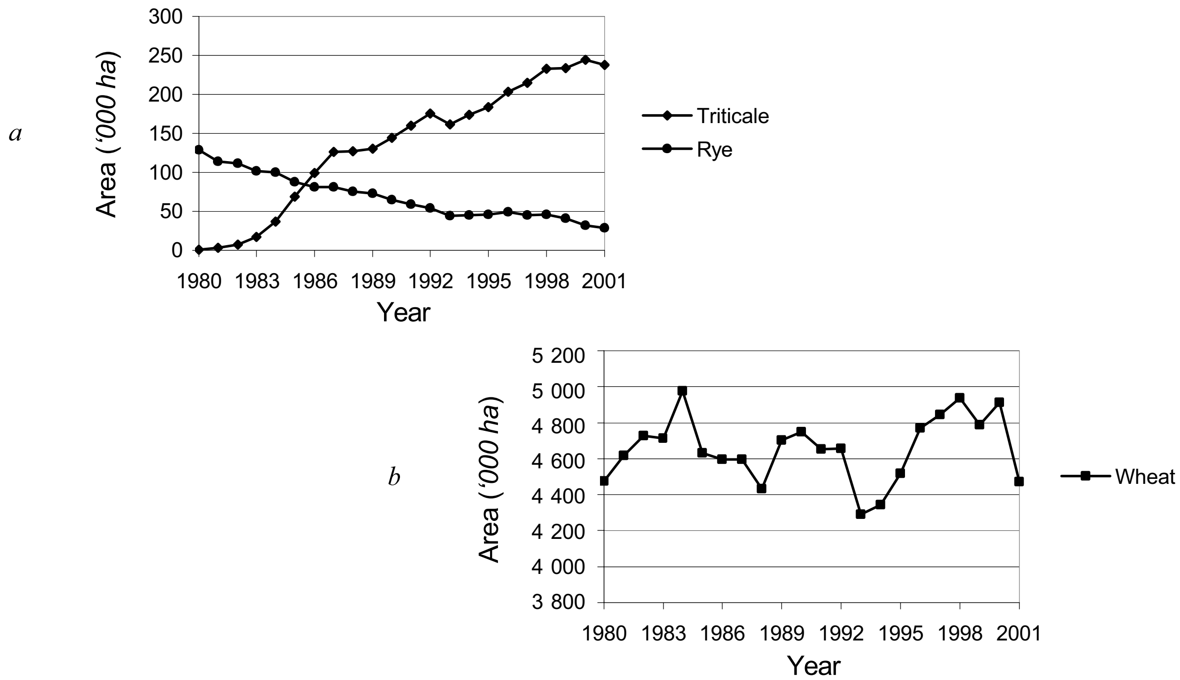
[1]Data from Statistique Agricole Annuelle and the Central Service of Statistical Surveys and Studies (French Ministry of Agriculture).

FIGURE 1
Evolution of triticale cultivation areas in France, 1989 (a) and 1997 (b)



Source: ITCF.

FIGURE 2
Area of triticale and rye (a) and wheat (b) in France, 1980-2001



Source: Data from Statistique Agricole Annuelle and the Central Service of Statistical Surveys and Studies (French Ministry of Agriculture).

TABLE 1
Average yield for main cereal species in France, 2000

Cereal species	Average yield (*tonnes/ha*)
Bread wheat	7.26
Winter barley	6.62
Triticale	5.17
Spring barley	5.67
Durum wheat	4.96
Rye	4.61

Source: SEDIS, 2002b.

feed processing industry in France. The development of this use depends mainly on the increase in area of this crop. This will be achieved only when the income provided by triticale is at least as high as that from wheat crops. New high-yielding varieties will be the key to taking up this challenge. The farmers who use straw for animal litter also appreciate the higher straw production of triticale compared to wheat. The use of triticale as forage, silage or for dual purpose is not very widespread in France.

Some companies have tried to develop the use of triticale for human food, in particular through bread making. It has been shown that, using special bread-making methods, quite valuable bread can be made with pure triticale flour. However, this use has remained very limited until now. As an anecdote, the authors can also report the use of triticale as a support for the mycelia multiplication of Paris mushrooms (ITCF, 2000).

TRITICALE IMPROVEMENT

During the period 1983-2001, 61 varieties were released (Table 2). More than half (34) were developed by French breeders. Some foreign companies also have subsidiaries working on triticale in France, such as Lochow-Petkus (Germany) or Svalöf-Weibull (Sweden). Other varieties from foreign countries were also released in France, mainly from Poland (seven varieties), but also from Switzerland (four varieties including two hybrids and five co-obtentions with French breeding companies), Germany (seven varieties) and the United Kingdom of Great Britain and Northern Ireland (two varieties). HybriTech and Dupont-Hybrinova have released three F_1 hybrid varieties of triticale (Kador and Clint from HybriTech in 1998 and 1999 and Hyno-trical from Hybrinova in 2001). However, these hybrid varieties have never been marketed because the hybridization chemical agents (Genesis and Croisor, respectively) used to produce these hybrids only have a provisional approval for wheat but not for triticale. The utilization rate of certified seed for triticale in France is 71 percent (in 1999), higher than wheat (59 percent) (SEDIS, 2002c). The evolution in time of seed multiplication area for the most cultivated varieties is reported in Figure 3.

The first triticale varieties registered in France were very tall, which made them susceptible to lodging. They were also difficult to thresh and their grain was shrivelled. Hence, breeders focussed on these traits, and modern varieties are improved for these characters. The triticale cultivar Clercal was tall, difficult to thresh and rather susceptible to pre-harvest sprouting. Lasko, the winter triticale cultivar, was also tall, but more resistant to frost and easier to thresh. Newton was even taller, but had higher productivity. Trimaran had combined higher productivity, resistance to lodging and easy threshing, which explains its widespread use. Most varieties available now are easy to thresh and many are resistant to lodging, such as Indian, Kortego, Tricolor, Galtjo, Trimaran, Ampiac and Carnac. Ampiac is one of the shortest varieties. However, triticale varieties grown in France, except for Tridel, Zeus and Rotégo, are still not very resistant to pre-harvest sprouting. Disease resistance has also been improved in triticale. Many varieties have a good level of resistance to eyespot coming from rye, but the problem of the stability of resistance has to be considered as well. The average resistance to scab in triticale is higher than in wheat, and most of the varieties have a good level of resistance to rusts. With these characters, triticale has been adopted in low-input farming, especially in areas where a low use of fungicides is common. For this reason, the interest in triticale from organic farming groups is increasing.

Due to the prevailing use of triticale in animal feeding, quality traits, such as protein content, viscosity related to arabinoxylans and phytase activity, now also have to be considered in breeding programmes (Genthon, 1997; Bouguennec *et al.*, 1998; Bouguennec, Oury and Jestin, 2000).

ROLE OF PRIVATE AND PUBLIC INSTITUTIONS IN TRITICALE IMPROVEMENT

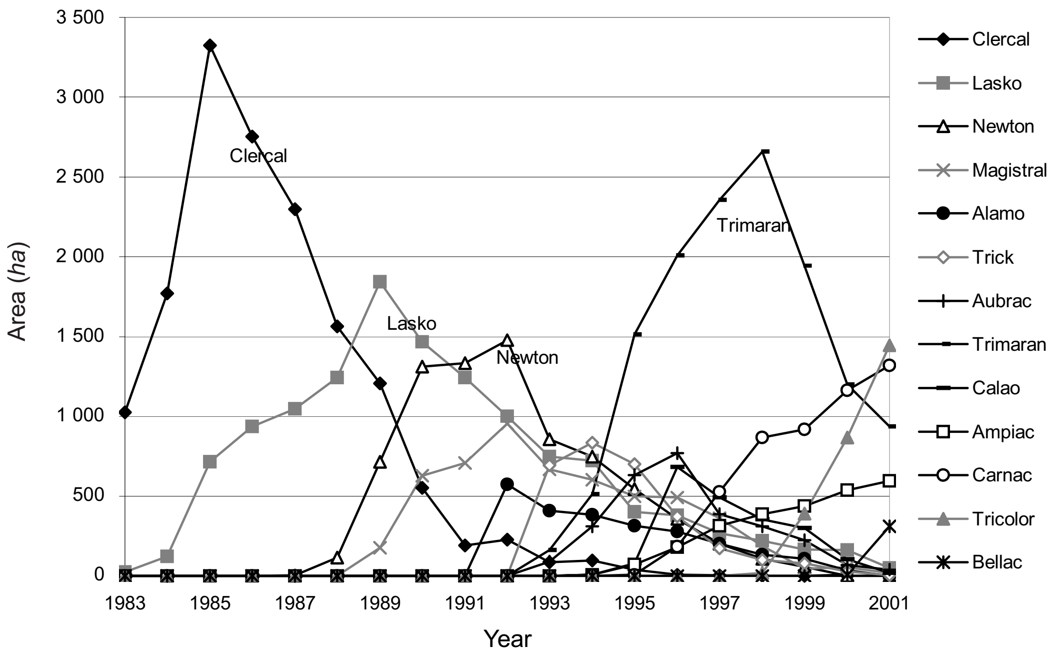
The National Institute for Agricultural Research (INRA) was the first institution to start working on triticale in France. In 1983, this institute registered the first French variety Clercal in the French official catalogue of cultivated varieties. After a few years, the increase in triticale area incited some private breeding companies to initiate a triticale breeding programme. The attraction of

TABLE 2
Triticale varieties released in France, 1983-2001

Variety	Year of release	Breeder and country
Clercal	1983	National Institute for Agricultural Research (INRA), France
Lasko	1983	Dankow-Laski, Poland
Newton	1987	Plant Breeding Institute Cambridge, United Kingdom of Great Britain and Northern Ireland
Dagro	1988 (struck off)	Poznan PB, Poland
Magistral	1988	National Institute for Agricultural Research (INRA), France
Gaétan	1989	Station de Changins, Switzerland / Orsem, France
Torpédo	1989	Serasem, France
Central	1990 (struck off)	National Institute for Agricultural Research (INRA), France
Domital	1990 (struck off)	National Institute for Agricultural Research (INRA), France
Alamo	1991	Poznan PB, Poland
Spatial	1991 (struck off)	C.C. Benoist, France
Trick	1991	Serasem, France
Aubrac	1992	RAGT, France
Trimaran	1992	Desprez, France
Tropic	1992 (struck off)	Serasem, France
Colossal	1993	National Institute for Agricultural Research (INRA), France
Formulin	1993	Orsem, France / Station de Changins, Switzerland
Graal	1993 (struck off)	C.C. Benoist, France
Olympus	1993	Semundo, United Kingdom of Great Britain and Northern Ireland
Brio	1994	DuPont-Hybrinova, France / Station de Changins, Switzerland
Calao	1994	National Institute for Agricultural Research (INRA), France
Ego	1994	Svalöf-Weibull, Sweden
Orbital	1994 (struck off)	C.C. Benoist, France
Ampiac	1995	RAGT, France
Falko	1995	Svalöf-Weibull, Sweden
Galtjo	1995	Svalöf-Weibull, Sweden
Mostral	1995	National Institute for Agricultural Research (INRA), France
Origo	1995	Svalöf-Weibull, Sweden
Carnac	1996	RAGT, France
Indiana	1996	DuPont-Hybrinova, France / Station de Changins, Switzerland
Arc-en-ciel	1997	Lemaire-Deffontaines, France
Chrono	1997	Danko Roslin, Poland
Disco	1997	Danko Roslin, Poland
Tridel	1997	Station de Changins, Switzerland
Vision	1997	Lochow-Petkus, Germany
Zeus	1997	RAGT, France
Capital	1998	National Institute for Agricultural Research (INRA), France
Imola	1998	DuPont-Hybrinova, France / Station de Changins, Switzerland
Janus	1998	Nordsaat Saatzucht, Germany
Orell	1998 (struck off)	Sudwestsaat, Germany
Rotégo	1998	Svalöf-Weibull, Sweden
Triathlon	1998	Florimond-Desprez, France
Trinidad	1998	Dr Hege, Germany
Kador	1998	Station de Changins, Switzerland
Tricolor	1998	Florimond-Desprez, France
Clint	1999	Station de Changins, Switzerland
Lamberto	1999	Danko Roslin, Poland
Lupus	1999	Nordsaat Saatzucht, Germany
Partout	1999	Dr Hege, Germany
Bellac	2000	RAGT, France
Kortego	2000	Svalöf-Weibull BV, Netherlands
Magnat	2000	Danko Roslin, Poland
Osorno	2001	Lochow-Petkus, Germany
Timbo	2001	Station de Changins, Switzerland
Auriac	2001	RAGT, France
Bienvenu	2001	Lemaire-Deffontaines, France
Cedro	2001	Svalöf-Weibull BV, Netherlands
Hyno-trical	2001	Dupont-Hybrinova, France
Passo	2001	Saaten Union recherché, France
Triade	2001	Florimond-Desprez, France
Trouvère	2001	Serasem, France

Source: Catalogue officiel des espèces et variétés, GNIS (1996-1998-2001) and Bulletin des variétés, GEVES (from 1986 to 1999).

FIGURE 3
Seed production area for official control of triticale varieties, 1983-2001



Source: SEDIS, 2002d.

TABLE 3
French public and private research institutions and their main triticale cultivar releases

Breeder	Year and name of first variety released[a]	Other varieties released (up to 2001)[a]
INRA[b]	1983, Clercal	Magistral, Central, Domital, Colossal, **Calao**, Mostral, Capital
RAGT (R2n)	1992, Aubrac	**Ampiac**, **Carnac**, Zeus, **Bellac**, Auriac
Florimond-Desprez	1992, **Trimaran**	Triathlon, **Tricolor**, Triade
C.C. Benoist	1993, Graal	Orbital, Spatial
Serasem	1989, Torpédo	**Trick**, Tropic, Trouvère
Lemaire-Deffontaines	1997, Arc-en-ciel	Bienvenu

[a]Varieties used as a control, i.e. the three varieties with the largest seed production area within a year, are indicated in bold.
[b]INRA = National Institute for Agricultural Research. This is a public institute.
Source: Catalogue officiel des espèces et variétés, GNIS (1996-1998-2001) and Bulletin des variétés, GEVES (from 1986 to 1999).

this new species was accentuated because triticale growers have a tendency to use more commercial seed than wheat growers. The main private companies that have a triticale breeding programme are presented in Table 3. In 1996, the five most important companies working on triticale (Table 3) merged their efforts in an economical interest group named GIE triticale in order to improve the breeding efforts on triticale. A joint programme has been developed with INRA for increasing genetic diversity of triticale (Bouguennec *et al.*, 1998). The National Institute for Agricultural Research produces new primary triticales (mainly octoploids from bread wheat and rye and some hexaploids from durum wheat and rye), crosses them with adapted triticale and the offsprings are advanced to the F_5 generation. The F_5 families are then evaluated by all partners, including INRA and GIE triticale, in order to find some interesting parental lines or even varieties.

CONCLUDING REMARKS

The pioneering work of INRA to develop triticale in France has been successful. Now, triticale is a 'traditional' crop in two regions of France, and private breeding companies play a major part in the development of new varieties. The narrow genetic basis of triticale, especially for the R genome from rye, is now enlarging thanks to cooperative work between private and public institutions. The first lines derived from this work are very promising. This will certainly induce the exploitation of primary triticale and advance new improved varieties, which will enhance the extension of triticale in France. Increasing area will perhaps provide greater availability of triticale grain for industries and consequently increase triticale use in France.

REFERENCES

Bouguennec, A., Oury, F.X. & Jestin, L. 2000. Viscosity related to arabinoxylans in triticale – genetic and environmental variation in France. *Vorträge für Pflanzenzüchtung*, 49: 161-169.

Bouguennec, A., Lonnet, P., Nys, Y., Genthon, C., Carre, B., Trottet, M., Lecomte, C. & Jestin, L. 1998. Developing genetic diversity of hexaploid triticale adapted in Europe. *In* P. Juskiw, ed. *Proc. 4th Int. Triticale Symp.*, Red Deer, Alberta, Canada, 26-31 July 1998, p. 22-29. International Triticale Association.

Genthon, C. 1997. *Caractérisation de l'activité phytasique et de la viscosité de variétés européennes de triticale pour une adaptation à l'alimentation avicole*. Rennes, France, D.E.A. Université Rennes I, Ecole Nationale Supérieure Agronomique de Rennes. 17 pp.

ITCF. 2000. Triticale, du débouché à la culture. *Perspectives Agricoles*, No. 256.

SEDIS. 2002a. *Semences et Progrès*, No. 112.

SEDIS. 2002b. *Semences et Progrès*, No. 110.

SEDIS. 2002c. *Semences et Progrès*, No. 111.

SEDIS. 2002d. *Semences et Progrès* (from 1990 to 2001).

Triticale in Germany

G. Oettler

The first fertile wheat x rye hybrid worldwide was produced by the German plant breeder Rimpau in 1888. He crossed a *Triticum aestivum* with rye and by spontaneous doubling of the chromosomes obtained a fertile triticale. Until the 1980s, activities in Germany were mainly devoted to cytogenetic and physiological research and also to the production and study of primary triticale. Both hexaploid and octoploid primary triticale was investigated. Breeding research and applied breeding with secondary hexaploid triticale started in the mid-1980s. The genetic material to establish breeding programmes for triticale as a winter cereal crop originated mainly from Canada, France, Mexico and Poland.

Cytological instability, low fertility and shrivelled grain, which were serious defects at the beginning of triticale work, were improved by systematic breeding and are no longer a problem. The current breeding aims are very similar to those of other small-grain cereals: high grain yield, high quality, reduction in plant height, and lodging and disease resistance. Triticale still remains highly susceptible to pre-harvest sprouting. Efforts in breeding and research to improve this complex trait should have high priority in the future.

At the beginning of triticale breeding, inherent good disease resistance from rye was one of the attractive characteristics of the new cereal. With the expansion in growing area, however, the situation is gradually changing. Although triticale can still be regarded as a healthy crop, it is attacked by various diseases. The most important ones in Germany are leaf and glume blotch (*Stagonospora nodorum* only), leaf rust and stripe rust. In some areas, mildew is becoming a major constraint. In the current triticale gene pool, however, there appears to be sufficient genetic variation for resistance to most diseases for successful improvement by systematic breeding (Oettler and Schmid, 2000; Oettler and Wahle, 2001; Schinkel, 2002).

Triticale is treated as a self-pollinated crop, and the pedigree method is applied. The presently 18 registered varieties in Germany are all hexaploid types with the complete A, B and R genomes. They are nearly homozygous and homogeneous lines. The production of hybrid triticale, however, is discussed widely at present.

TABLE 1
Growing area and grain yield of winter triticale in Germany, 1988-2001

Year	Area (*'000 ha*)	Grain yield (*tonnes/ha*)
1988	20	5.0
1989	30	5.4
1990	77	5.0
1991	130	5.5
1992	175	5.1
1993	219	5.3
1994	208	5.4
1995	299	5.7
1996	364	5.8
1997	438	6.0
1998	469	6.0
1999	366	6.1
2000	499	5.6
2001	534	6.4

Research projects investigating various aspects to establish a hybrid breeding programme are under way. These include application of molecular markers to identify and establish gene pools, information on cytoplasmic male sterile (CMS) systems, identification of restorers/nonrestorers and studies on heterosis (Bauer and Renz, 2002; Burger, Oettler and Melchinger, 2002).

The first winter triticale varieties registered in 1986 were of foreign origin. In 1993, two varieties bred in Germany were released. In less than 20 years, triticale has developed into an important cereal crop in German agricultural production. The area under cultivation increased from 20 000 ha in 1988 to an estimated 562 000 ha in 2002, which corresponds to 19 percent of the winter wheat area. During that period, average grain yield increased from 5.0 tonnes/ha in 1988 to 6.4 tonnes/ha in 2001 (Table 1). For comparison, average grain yield in 2001 was 7.9 tonnes/ha for winter wheat and 6.1 tonnes/ha for winter rye. The total production of triticale amounted to 2.8 million tonnes in 2000 and 3.42 million tonnes in 2001. Certified seed of the 18 registered varieties was produced on a total of 14 704 ha in 2001. The areas of the most widely grown varieties were: Modus with 4 653 ha, Lamberto with

2 638 ha, Kitaro with 1 610 ha, Trinidad with 1 588 ha and Trimaran with 1 470 ha (Bundessortenamt, 2002; Statistisches Bundesamt, 2002).

In Germany, as in most European countries, triticale is used as a feed grain for pigs and poultry. Its balance of available amino acids fits the requirements of monogastrics. It has none of the anti-nutritional factors associated with rye (Boros, 1998; Boros, 2002).

Of the total production of triticale, nearly 95 percent is used for feeding, about 3 percent as seed, 2 percent for export and less than 1 percent for alcohol production. The official statistics do not show any use for human consumption. Of the feed grain, about two-thirds is on-farm consumption and one-third goes into commercial feed mixtures. In contrast to wheat, barley and rye, for triticale no quality criteria have been established. Grain yield has been the dominant selection criterion. Triticale and oats are the only cereals not covered by a market intervention system. The average monthly producer price in 2001 was 105 •/tonnes (bread wheat was 116 •/tonnes and bread rye was 108 •/tonnes) (Stratmann, 2002).

Triticale can be grown on a wide range of soils due to its high adaptability. It has a low input and management demand and a high growing cost efficiency. It is attractive, therefore, for intensive livestock-raising farmers with on-farm consumption, as it produces a high-quality feed on low-input systems. On the other hand, triticale is responsive to nitrogen, which makes it also suitable for areas where high amounts of manure are produced. In addition, triticale does well on less fertile soils and in drought-stressed areas. It also has potential in regions were feed barley suffers from winterkill (Banaszak and Marciniak, 2002; Green, 2002).

In Germany, triticale breeding until registration for official trials, maintenance breeding and seed production of released varieties are carried out by private companies. The presently 18 registered varieties come from eight breeding companies. Not all of these companies maintain a complete own-breeding programme. Some of them receive early or advanced generation material from cooperating breeders in other countries, which they test and put into official trials for release.

Breeding research is under the responsibility of public institutions (Plate 1). At present, two institutes are engaged in triticale activities in Germany. These are the Federal Centre for Breeding Research on Cultivated Plants, Gross Luesewitz, and the State Plant Breeding Institute, University of Hohenheim, Stuttgart-Hohenheim. Their research activities include the development of basic genetic material, segregating populations or pre-tested lines that might be interesting for the breeders. All this material is available to them under appropriate agreements.

Besides the aforementioned studies on hybrid triticale, further activities of the institutes include quantitative-genetic studies on pre-harvest sprouting, *Fusarium* and *Stagonospora nodorum* resistance and drought stress. Studies involving both primary and secondary triticale are expected to give information on the most effective use of raw amphiploids in applied breeding.

The basic and applied research of the institutes in Germany is essentially financed by the institutes' budgets. But as a result of funds being cut, they also strongly depend on money from private sources (Landessaat-zuchtanstalt, 2000; Federal Centre for Breeding Research on Cultivated Plants, 2001).

REFERENCES

Banaszak, Z. & Marciniak, K. 2002. Wide adaptation of Danko triticale varieties. *In* E. Arseniuk, ed. *Proc. 5th Int. Triticale Symp.*, Radzikow, Poland, 30 June-5 July 2002, Vol. I, p. 217-222. Radzikow, Poland, Plant Breeding and Acclimatization Institute.

Bauer, E. & Renz, B. 2002. Molecular characterization of CMS cytoplasms in winter triticale. *In* E. Arseniuk, ed. *Proc. 5th Int. Triticale Symp.*, Radzikow, Poland, 30 June-5 July 2002, Vol. II, p. 79-84. Radzikow, Poland, Plant Breeding and Acclimatization Institute.

Boros, D. 1998. Nutritive value of different forms of triticale for monogastric animals. *In* P. Juskiw, ed. *Proc. 4th Int. Triticale Symp.*, Red Deer, Alberta, Canada, 26-31 July 1998, p. 177-184. International Triticale Association.

Boros, D. 2002. Physico-chemical quality indicators suitable in selection of triticale for high nutritive value. *In* E. Arseniuk, ed. *Proc. 5th Int. Triticale Symp.*, Radzikow, Poland, 30 June-5 July 2002, Vol. I, p. 239-244. Radzikow, Poland, Plant Breeding and Acclimatization Institute.

Bundessortenamt. 2002. *Beschreibende Sortenliste Getreide, Mais, Oelfruechte, Leguminosen, Hackfruechte*. Hannover, Germany, Deutscher Landwirtschaftsverlag.

Burger, H., Oettler, G. & Melchinger, A.E. 2002. Heterosis and combining ability for grain yield and yield components in winter triticale. *In* E. Arseniuk, ed. *Proc. 5th Int. Triticale Symp.*, Radzikow, Poland, 30 June-5 July 2002, Vol. I, p. 199-204. Radzikow, Poland, Plant Breeding and Acclimatization Institute.

Federal Centre for Breeding Research on Cultivated Plants. 2001. *Annual Report*. Quedlinburg, Germany, Quedlinburg Druck (also available at http://www.bafz.de).

Green, Ch. 2002. The competitive position of triticale in Europe. *In* E. Arseniuk, ed. *Proc. 5th Int. Triticale Symp.*, Radzikow, Poland, 30 June-5 July 2002, Vol. I, p. 21-26. Radzikow, Poland, Plant Breeding and Acclimatization Institute.

Landessaatzuchtanstalt. 2000. *Taetigkeitsbericht 1999 und 2000*. Stuttgart, Germany, Universität Hohenheim, Landessaatzuchtanstalt.

Oettler, G. & Schmid, T. 2000. Genotypic variation for resistance to *Septoria nodorum* in triticale. *Plant Breed.*, 119: 487-490.

Oettler, G. & Wahle, G. 2001. Genotypic and environmental variation of resistance to head blight in triticale inoculated with *Fusarium culmorum*. *Plant Breed.*, 120: 297-300.

Schinkel, B. 2002. Triticale – still a healthy crop? *In* E. Arseniuk, ed. *Proc. 5th Int. Triticale Symp.*, Radzikow, Poland, 30 June-5 July 2002, Vol. I, p. 157-162. Radzikow, Poland, Plant Breeding and Acclimatization Institute.

Statistisches Bundesamt. 2002. *Fachserie 3: Land- und Forstwirtschaft, Fischerei. R1, R3*. Stuttgart, Germany, Metzler-Poeschel.

Stratmann, R. 2002. *ZMP-Marktbilanz Getreide, Oelsaaten, Futtermittel*. Deutschland, Europaeische Union, Weltmarkt. Bonn, Germany, ZMP Zentrale Markt- und Preisberichtstelle.

PLATE 1
Triticale breeding plot at the University of Hohenheim, State Plant Breeding Institute, Stuttgart, Germany
G. Oettler

Triticale in Hungary

L. Bona

In the last ten years (1992-2002), winter triticale has achieved outstanding progress in Central Europe. In Hungary, triticale production started in the late 1960s on sandy soil areas in the middle regions of the country, around Kecskemét where Kiss exhibited his pioneer breeding efforts on this crop. After twenty years of inactivity, triticale revival started in the early 1990s. As a result of political changes in 1990, cooperative- and state-owned lands were returned to original owners (or to their descendants), and the renewed small family farms showed a strong interest in triticale. Smallholders and new private farmers quickly discovered the profitability of triticale, particularly on dry, poor, infertile soils. Subsequently, the planting area to winter triticale has been steadily growing (Figure 1), reaching 120 000 ha in 2001.

Spring triticale, a new crop in the area, has received less attention than other crops. In 2000, two Polish-origin spring varieties were registered in Hungary and from that time onwards, farmers' interest has turned to this crop. National Variety Field Tests and recent studies (Bona *et al.*, 2002) indicate that spring triticale has a lower yield potential than winter triticale in the region.

TRITICALE PRODUCTION

The production of triticale is mainly concentrated in the following areas:

- Areas characterized by raw, sandy soils with low pH, low organic matter content and poor in macronutrients. These large areas are located in the northeastern (Nyírség) and western (Somogy) parts of Hungary.
- Areas characterized by sandy soils with a pH of 6 to 9 and low or medium organic matter content. Precipitation is usually very low in these areas (400 to 500 mm/year). These soils are rich in calcium and sodium; sometimes the B horizon is highly sodic. These areas are located in the middle of the country.
- Areas characterized by meadow 'solonetz solods' with dry and compact soils, located in middle of the country.
- Areas characterized by black Chernozem soils and meadows (appropriate for excellent wheat production). To a lesser extent, growers produce triticales on these soils for feed for the pork and poultry industries.
- Areas characterized by red or brown forest soils, located in the western part of Hungary. These are smaller, hilly areas where wheat has poor yield in terms of quantity and end-use quality traits.

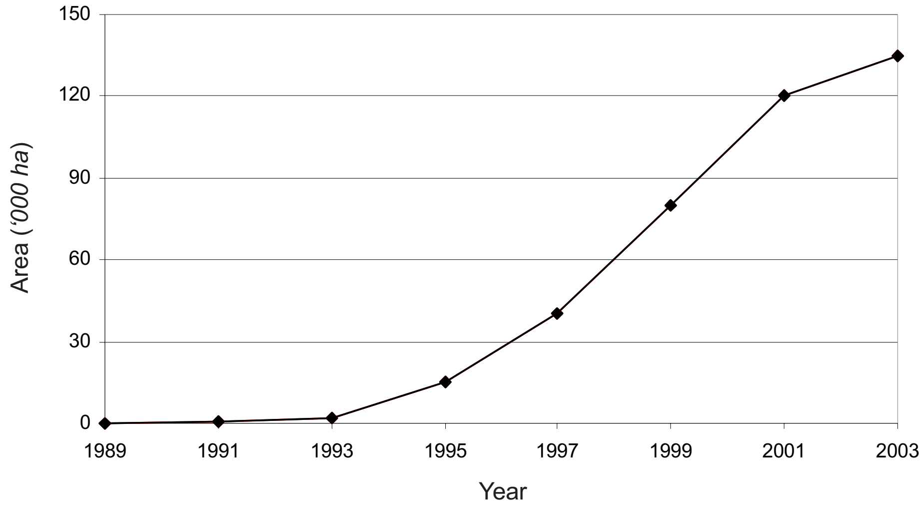
The average grain yield in the poor areas varies between 3 and 4.5 tonnes/ha. However, recent studies revealed that even in the infertile, acidic, sandy soils in northeastern Hungary triticale can produce up to 7.9 tonnes/ha yield, if properly fertilized with nitrogen, phosphorus, potassium, calcium and magnesium (Kádár, Németh and Szemes, 1999). Small-grain variety performance tests have been conducted at National Variety Field Tests proving the excellence of triticale within small-grain cereals. In a five-year period, triticale outyielded wheat and rye except in one year where it had lower yield than wheat.

In summary, on most of the areas where triticale is grown, it has an advantage over wheat in terms of yield stability. Growers appreciate the crop because it can produce satisfactory yield without using fertilizers, pesticides and intensive tillage. Today, on all of the areas previously described, smallholders as well as larger farms utilize this crop as a feed grain for livestock and obtain better results with triticale than with any other crops.

TRITICALE UTILIZATION

Most of the produced triticale grain is used by the growers as a feed grain mainly for pigs and poultry. Triticale has become an important on-farm crop in the last ten years in Hungary. However, farmers have not yet discovered how important triticale can be as an alternative forage crop (mainly as silage) for the cattle industry. One of the weaknesses of triticale is its poor market competition compared to wheat, barley or maize. Triticale has yet to achieve its appropriate market position in Europe (Green, 2002). However, there are several points that will change the present negative image of triticale. Many governments in the European Union aim to change future agriculture policies so that they are more environmentally sound. Also, throughout the world, including Central Europe, there is an extremely strong emphasis on costs and benefits. In terms of unit costs, triticale will be a more favoured crop among farmers in the region. It will be

FIGURE 1
Area planted to triticale in Hungary, 1989-2003



one of the most promising non-food, small-grain cereals for industrial production. Triticale has a prospect as a raw material for bio-fuels (ethanol), organic and industrial chemicals, paper, the building and plastic industries and the beverage (beer) industry. In addition, it may also be possible to utilize triticale as a substitute for wheat and rye for human use in baking and breakfast cereal products (Salmon, Temelli and Spence, 2002; Bona *et al.*, 2002). According Jenkins (personal communication), triticale porridge has a tremendous benefit for the human body, probably due to its high fibre content, essential amino acids and antioxidant activity. Thus, the utilization of triticale in the milling and baking industry will play a more pronounced role in future research.

CROP IMPROVEMENT, VARIETY USE AND SEED PRODUCTION

In Hungary, research on wheat x rye hybrids was started almost 50 years ago by Kiss and Rédei (1952). By the early 1960s, crossing octoploid x hexaploid triticale lines, Kiss had developed the secondary hexaploid populations T-30, T-57 and T-64. He named these populations 'secondary hexaploids' because they originated from crossings of primary hexaploids x octoploids. He released them immediately and started to initiate on-farm trials on sandy soil areas (Kiss, 1966; Kiss and Kiss, 1981). In fact, the Hungarian cultivars T-57 and T-64 were the first triticale cultivars worldwide to be released for commercial production (Zillinsky, 1985). Based on his annually repeated crossings and progeny tests, Kiss (1966) indicated that the hexaploid level should be the optimum genomic level for triticale (rather than the octoploid one). Kiss established modern triticale breeding with his secondary hexaploids, since they were as competitive on marginal soils as rye with 30 to 50 percent more protein.

Despite exceptionally successful breeding work, an adverse political-economic decision blocked the research, development and production of this crop in Hungary. In 1970, the Hungarian Ministry of Agriculture decided to terminate extensive triticale breeding in Hungary, justifying their action by the fact that Hungary was more suitable for wheat production. In 1970, Kiss's dwarf cultivar Bokolo was also patented in Germany, but no interest was shown by the Hungarian authorities. The state officials during that time made international decisions on the scientific and technological cooperation of communist countries. Based on those decisions, Kiss was forced to donate his valuable advanced materials to Polish scientists. From that time onwards, triticale breeding in Poland was enhanced substantially. Polish scientists have made tremendous efforts to improve the adaptation (mainly frost resistance) of triticale (Wolski and Tymieniecka, 1988).

In the last 10 to 15 years, Polish varieties have had significant influence on triticale production all over Europe, including Hungary. During the last decade, only Polish cultivars have been used in Hungarian triticale production areas. Cultivars Presto, Bogo, Marko,

TABLE 1
Main institutions involved in triticale research in Hungary

Institution and location	Main research activities
Agricultural Research Institute of the Hungarian Academy of Sciences, Martonvasar	Adaptation trials; variety introduction; seed production
Agricultural Research Station of the University of Debrecen, Karcag	Breeding; seed production; variety trials
Cereal Research Non-Profit Co., Szeged	Breeding; seed production; quality analysis; adaptation trials; variety introduction

Lamberto and Kitaro are the most popular varieties among Hungarian farmers.

Similarly, in Hungarian breeding programmes, Polish varieties are extensively used to improve adaptation and yield potential of triticale. Nowadays, there are three triticale research programmes in three different parts of Hungary as indicated in Table 1.

These three institutions, where research and development work on triticale is carried out, are public institutions. Breeder and foundation seed are also produced in these institutions. Nevertheless, all certified seed for the country is produced by private companies and farms. The quantity of certified seed sold in Hungary in the last three to four years has been 6 000 to 9 000 tonnes/year. It is expected that 10 000 tonnes/year of certified seed will cover future needs for the country.

REFERENCES

Bona, L., Purnhauser, L., Acs, E., Beke, B., Aniol, A., Boros, D. & Cyran, M. 2002. Yield and protein content of winter versus spring triticale genotypes. *In* E. Arseniuk, ed. *Proc. 5th Int. Triticale Symp.*, Radzikow, Poland, 30 June-5 July 2002, Vol. II, p. 433-438. Radzikow, Poland, Plant Breeding and Acclimatization Institute.

Green, Ch. 2002. The competitive position of triticale in Europe. *In* E. Arseniuk, ed. *Proc. 5th Int. Triticale Symp.*, Radzikow, Poland, 30 June-5 July 2002, Vol. I, p. 22-26. Radzikow, Poland, Plant Breeding and Acclimatization Institute.

Kádár, I., Németh, T. & Szemes, I. 1999. Fertilizer response of triticale in long-term experiment in Nyirlugos. In Hungarian with English summary. *Novenytermeles*, 48: 647-661.

Kiss, Á. 1966. Experiments with hexaploid triticale. In Hungarian with English summary. *Novenytermeles*, 15: 311-328.

Kiss, J.M. & Kiss, Á. 1981. Triticale results and problems. In Hungarian with English summary. *Novenytermeles*, 30: 275-281.

Kiss, Á. & Rédei, G. 1952. Experiments to produce wheat-rye hybrid (triticale). In Hungarian with English summary. *Novenytermeles*, 1: 67-84.

Salmon, D., Temelli, F. & Spence, S. 2002. Chemical composition of Western Canadian triticale varieties. *In* E. Arseniuk, ed. *Proc. 5th Int. Triticale Symp.*, Radzikow, Poland, 30 June-5 July 2002, Vol. II, p. 445-450. Radzikow, Poland, Plant Breeding and Acclimatization Institute.

Wolski, T. & Tymieniecka, E. 1988. Breeding for winter hardiness in the triticale programme of Poznan Plant Breeders. *Eucarpia Triticale*, 359-367.

Zillinsky, F.J. 1985. Triticale – an update on yield, adaptation, and world production. *In* R.A. Forsberg, ed. *Triticale*. Madison, WI, USA, CSSA.