Food uses of triticale

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Rapid increases in world population demand concomitant increases in food production, particularly of cereal grains, the main source of nutrients for both humans and animals. However, further increases in cereal production must occur while preserving the environment and natural resources. Therefore, production increases must come mainly from enhancing the yield potential of new crops and not from expanding the global cultivated area. Triticale (X *Triticosecale* Wittmack), the product of wheat and rye hybridization, has demonstrated high yield potential even under marginal growing conditions and could be a very attractive alternative for raising cereal production globally. Unfortunately, recent estimates (FAO, 2003) indicate that the area sown to triticale worldwide is approximately 3 million ha, slightly higher than a decade ago. Despite the high productivity of triticale, global production is increasing slowly, and the crop has not yet become well established in local or world markets. The main reason for the lower-than-expected production is that triticale, a good source of protein and energy (Hill, 1991), is used mainly for animal feed but very little for human consumption.

Triticale could become a major crop if, in addition to its use as a feed grain, it were cultivated on a large commercial scale for human consumption. This chapter presents an overview of the potential food uses of triticale and of the grain and non-grain factors associated with utilizing triticale as a food grain. The aim is to stimulate scientists and other professionals to address issues that may help increase triticale production significantly, thereby contributing to raise the global food supply.

FOOD-PROCESSING CHARACTERISTICS OF TRITICALE

The physical characteristics and proximate chemical composition of triticale grain are in general intermediate between its two parent species (Table 1). Triticale's properties for milling and baking, the two main uses of its parent species, have been examined widely. Its potential utilization in malting and brewing has also been studied. Triticale characteristics related to milling, baking and malting are described in this section.

Grain milling

Triticale can be milled into flour using standard wheat or rye flour-milling procedures (Kolkunova *et al.*, 1983; Weipert, 1986). However, the wheat milling process is more suitable for obtaining maximum triticale flour extraction rates, mainly because rye flour milling precludes the use of smooth rolls (smooth rolls tend to flake rye middlings due to their high pentosan content) thus reducing flour extraction rates. Early triticale lines tended to produce low flour yields due to long grains with a deep crease and incomplete plumpness, which made it difficult to obtain high extraction rates of low-ash flours. More recent triticales possessing improved grain shape and plumpness have flour yields equal or closer to those of wheat (Amaya, Peña and Varughese, 1986; Macri, Balance and Larter, 1986a; Ullah, Bajwa and Anjum, 1986; Saxena *et al*., 1992). At low ash content, semi-hard and soft triticales show higher flour extraction rates than do hard triticales, which in this sense resemble durum wheat more than bread wheat (Amaya, Peña and Varughese, 1986; Saxena *et al*., 1992).

One way to improve the milling performance of triticale is to mill wheat-triticale grain blends, as suggested by Peña and Amaya (1992). These authors found that blending wheat and triticale grains in a 75:25 ratio prior to milling produces flour yields equal to those of wheat milled alone (Table 2). Although blending wheat and triticale may not be desirable when there is no shortage of wheat, it may be acceptable in countries aiming to reduce wheat imports. The milling quality of triticale should not be a constraint when it is used to produce wholemeal and high-ash flour baking products.

Bread making

Whole and refined triticale flours have been evaluated for their suitability in the preparation of baking products, such as different types of bread, oriental noodles and soft-wheat type products.

Leavened bread

Some studies (Lorenz, 1972; Kolkunova *et al*., 1983; Weipert, 1986) have shown that triticale and rye present few quality differences in relation to their baking

TABLE 1
Proximate composition of triticale, wheat and rye (dry basis)

Cereal	Protein (%)[a]	Starch (%)	Crude fibre (%)	Ether extract (%)	Free sugars (%)	Ash (%)	Reference[b]
Spring triticale	10.3-15.6	57-65	3.1-4.5	1.5-2.4	3.7-5.2	1.4-2.0	1, 2, 3
Winter triticale	10.2-13.5	53-63	2.3-3.0	1.1-1.9	4.3-7.6	1.8-2.9	4
Spring wheat	9.3-16.8	61-66	2.8-3.9	1.9-2.2	2.6-3.0	1.3-2.0	1, 2, 3
Winter wheat	11.0-12.8	58-62	3.0-3.1	1.6-1.7	2.6-3.3	1.7-1.8	4
Spring rye	13.0-14.3	54.5	2.6	1.8	5.0	2.1	1, 2

[a]Nx 5.7.
[b]1 = Bushuk and Larter, 1980; 2 = Peña and Bates, 1982; 3 = Johnson and Eason, 1988; 4 = Heger and Eggum, 1991. Data used in value ranges for spring triticale, spring wheat and spring rye were pulled out from one or more of the references indicated.

properties for preparing white-rye type and wheat-rye mixed breads. Triticale is acceptable for making rye bread because gluten protein-related factors, which are deficient in triticale, are not as critical as polysaccharides (starch and pentosans) and soluble proteins for rye flour dough and rye bread characteristics. Also, rye bread may be made from triticale flours with high levels of alpha-amylase activity, which is suppressed by acidic conditions prevailing during lactic fermentation used to produce this type of bread (Kolkunova *et al*., 1983; Weipert, 1986). Triticale flour may replace wheat or rye flour in the production of breads such as the American mixed wheat-rye bread, in which organic acids increase protein solubilization and, consequently, dough viscosity. Light rye bread can be made by blending wheat flour with triticale in a 60:85 ratio (Drew and Seibel, 1976). Alternatively, triticale may also be used to produce European rye-wheat or wheat-rye mixed breads (Ceglinska and Wolski, 1991; Háp and Pelikán, 1995; Sowa *et al*., 1995).

Triticale flours produce weak doughs due to low gluten content, inferior gluten strength and high levels of alpha-amylase activity (Macri, Balance and Larter, 1986a; Amaya and Peña, 1991). Weak dough is unsuitable for the manufacture of wheat-type leavened breads requiring medium-strong to strong dough properties, particularly pan-type breads and breads produced under high work-input conditions, as occurs in large baking plants and highly mechanized bakeries. Nonetheless, there is bread-making quality variability in triticale, and some triticale lines have been found to possess medium dough-strength character, acceptable for producing popular breads in Eastern Europe (Sowa *et al*., 1995; Sowa, Peña and Bushuk, 1998; Gryka, 1998; Täht *et al*., 1998; Tsvetkov and Stoeva, 2003).

Dense and flat breads

Some triticales can produce bread of acceptable quality under certain special bread-making conditions, such as low mixing speed and reduced fermentation times (Lorenz and Welsh, 1977; Amaya and Skovmand, 1985; Rakowska and Haber, 1991). This is particularly true for breads with dense crumb or flat-type breads prepared at home or in small bakeries where baking conditions are adjusted according to the quality attributes of the flour. Indian chapattis made with 100 percent triticale were found to be acceptable, except for their reddish colour (Sadiq, Saleem and Mohammad, 1985). However, the development of new triticale lines with white or amber grain colour (Sadiq, 1990; Naeem and Darvey, 1998) should overcome the undesirable reddish tint of triticale chapattis.

Wheat-triticale flour blends

The use of triticale in bread making seems more feasible in wheat-triticale flour blends; leavened breads with very acceptable quality attributes can be prepared with wheat-triticale flour blends containing up to 40 percent triticale. It has been shown that combining strong wheat flour and triticale flour with the best possible baking quality to prepare wheat-triticale flour blends containing 30 to 50 percent triticale may produce breads of a quality similar to, or even better than, that of 100 percent wheat breads (Lorenz and Ross, 1986; Bakhshi *et al*., 1989; Peña and Amaya, 1992; Naeem *et al*., 2002). Wheat-triticale wholemeal blends containing up to 50 percent triticale have been found to produce acceptable chapattis (Chawla and Kapoor, 1983; Ullah, Bajwa and Anjum, 1986).

Oriental noodles

Flour noodles, widely consumed in East Asia, are a staple food in northern China. Triticale flour has been evaluated

TABLE 2
Milling yields and ash content of wheat, triticale and wheat-triticale (75:25) grain blends[a]

Sample	Shorts (%)	Bran (%)	Flour (%)	Ash (%)
Wheat				
Hard	8.64	12.72	74.55	0.48
Semi-hard	10.02	14.33	71.69	0.42
Triticale				
Semi-hard	13.90	17.07	64.70	0.55
Soft	11.92	16.42	67.53	0.53
Grain blends[b]				
HW-SHTL	8.15	13.32	74.06	0.47
HW-STL	8.21	15.29	72.26	0.51
SHW-SHTL	9.83	13.74	71.94	0.46
SHW-STL	8.12	13.94	74.88	0.48

[a]Milling data for all samples and ash contents of grain blends adapted from Peña and Amaya, 1992.
[b]HW = hard wheat; SHW = semi-hard wheat; SHTL = semi-hard triticale; STL = soft triticale.

TABLE 3
Some physical and chemical characteristics of barley and triticale malts

Cereal and sample	Malt		Diastatic power	Amylase	
	Loss (%)	Extract (%)	(°)	β (*maltose equiv.*)	α (*20° units*)
Barley					
Dickson	8.0	76.6	115	361	30.4
Piroline	8.9	77.6	98	308	26.6
Hembar	7.8	71.6	68	222	15.3
Triticale					
6T204	9.7	78.8	253	804	62.9
6T208	9.3	75.1	252	822	58.2
6T209	11.2	77.9	231	704	66.0
6450-3-1	14.4	78.8	180	517	61.6
Rosner	10.2	82.4	140	422	45.6
6714	8.7	80.4	184	806	42.8
6804	8.7	80.8	173	558	44.7
6437-6	12.4	82.6	137	469	25.2
6450	12.3	81.9	161	483	50.8

Source: Adapted from Pomeranz, Burkhart and Moon, 1970.

for the manufacture of oriental noodles. Lorenz, Dildaver and Lough (1972) compared triticale flour with all-purpose flour in the preparation of regular and egg noodles. Dry regular noodles prepared with both flours were brittle, while egg noodles were hard. Thus, the cooking properties of triticale noodles were inferior to those of wheat noodles. Differences in the cooking quality of wheat and triticale flours decreased when egg was added, but no significant differences in noodle flavour were found. Lorenz, Dildaver and Lough (1972) concluded that triticale flour is suitable for the manufacture of both regular and egg noodles. In another study, Shin, Bae and Pack (1980) compared three locally grown winter wheats with introduced spring triticales in the preparation of Korean noodles. They found noodle-making quality differences among wheats and among triticales. Two of the three triticale lines tested produced Korean noodles of satisfactory quality. The main deficiency found in some triticale flours was the high (for noodle making) flour ash content, which imparts an undesirable greyish colour to the noodles. Modern triticales, particularly those with white or amber plump grain, should yield refined flour suitable for noodle making.

Soft-wheat type products

Triticales with soft grain texture are in general suitable for the manufacture of soft wheat flour-based baking products because the weak gluten properties that characterize triticale are favourable for the processing and quality of soft-wheat type products. Triticale flour has been found suitable for the production of layer cakes (Kissell and Lorenz, 1976; Lorenz and Ross, 1986). Optimal triticale flour performance in layer-cake making is achieved when straight-run flour is rebolted, pin-milled and chlorinated. The cookie-making quality of triticale is generally acceptable, but can be further improved by adding lecithin to the formula (Lorenz and Ross, 1986; Bakhshi *et al*., 1989; Leon, Rubiolo and Anon, 1996).

High-fibre extruded snacks

A formula containing 20 to 40 percent oat bran and wheat and triticale flours was extruded using a twin-screw to produce high-fibre snack bars that were comparable in most attributes with snack bars currently on the market but had significantly higher fibre content (Onwulata *et al*., 2000). Thus triticale is suitable for making nutritious health-food bars.

Malting and brewing

The ease with which triticale produces high levels of alpha-amylase activity has its positive side, as it allows triticale to perform well in malting and brewing. In general, triticale has larger malt losses but higher malt extracts, higher diastatic power and higher alpha- and beta-amylase activity than barley (Table 3) (Pomeranz, Burkhart and Moon, 1970). Gupta, Singh and Bains

(1985) additionally found that both duration of germination and level of steeping moisture significantly influenced malt losses; the largest malt losses and highest enzymatic (amylase and protease) activity were achieved when 42 percent steeping moisture (instead of 38 percent) and four to six days germination in the presence of gibberellic acid were used. One disadvantage of triticale malt is that it produces worts with high nitrogen content and high proteolytic activity, both of which promote dark colour, instability and haziness in beer (Pomeranz, Burkhart and Moon, 1970; Gupta, Singh and Bains, 1985; Lersrutaiyotin, Shigenaga and Utsunomiya, 1991). Lersrutaiyotin and Shigenaga (1991) found that among triticales used in their study, winter types had better malting quality than spring types, and complete triticales had better malting quality and lower total nitrogen content than substituted triticales. Pomeranz, Burkhart and Moon (1970) found that triticale beers were in general darker than barley beers; six of ten triticale beers had satisfactory clarity stability and seven showed satisfactory gas stability. The taste of triticale beer was acceptable.

Although there is malting quality variability in triticale, Holmes (1989) has indicated that it would be difficult to breed for this trait because there is no methodology available for rapid and simultaneous screening for both protein solubilization and carbohydrate modification.

FACTORS AFFECTING TRITICALE AS A FOOD GRAIN

The use of triticale as food is rather limited due to grain and non-grain factors. Although the poor processing quality of triticale is directly related to grain composition, it is also true that very little effort has been invested in breeding triticale for food uses. Non-grain factors, such as region-specific consumer preferences, competitiveness with other grains and economic and marketing issues, also affect triticale food use by limiting the supply of grain. These issues are briefly discussed in this section.

Grain factors

Considering milling and baking, the two main uses of its parent species, the grain factors that most affect processing quality and end-product characteristics of triticale are: grain size, shape and texture; flour-milling potential; enzymatic activity (particularly alpha-amylase); and protein (particularly gluten) and polysaccharide (particularly pentosan) composition. Although starch plays a major role in some baking products, it is not considered a problem for the food utilization of triticale, whose properties are basically the same as those of wheat and rye.

Physical characteristics

Triticale resembles wheat more than rye in terms of grain size, shape and colour. However, triticale grain is usually larger and longer than wheat grain. The grain of early triticales had a wrinkled appearance that ranged from slight to severe. Triticales developed in the late 1960s to the mid-1970s almost invariably produced shrivelled grains; however, this defect was gradually corrected after breeders started to apply selection pressure for plump grain. Today improved triticale cultivars have from plump to slightly shrivelled grain. Grain colour is generally red, but lines with more attractive colour (white and amber) have been developed (Sadiq, 1990; Naeem and Darvey, 1998). White and amber grain colour may be adequate for the production of flat breads, such as Indian chapattis, and baked products requiring white or amber grains.

Chemical composition

The chemical composition of triticale grain is essential for determining its potential end-uses. The nutritional aspects of grain composition are perhaps most important for feed uses of triticale, but the functionality of its grain components is critical for the manufacture of food products (particularly processed foods).

The proximate chemical composition of triticale grain is closer to that of wheat than rye, except for free sugar content, which is higher than that of wheat and closer to that of rye (Table 1). The wheat-like composition of triticale is most likely due to the fact that it received two genomes from wheat and only one from rye.

Amino acids

One of the traits that initially made triticale attractive as a crop was its good protein nutritional value, particularly its high (for a cereal) lysine content, the main limiting amino acid in cereal grains (Kies and Fox, 1970; Villegas, McDonald and Gilles, 1970). The high lysine levels found in the high-protein, shrivelled grain of early triticales have also been found in the plumper grain of more recent cultivars that nonetheless show lower protein contents (Johnson and Eason 1988; Mossé, Huet and Baudet, 1988; Heger and Eggum, 1991). Actually, lysine content has generally been found to be higher when protein content is low (Table 4) (Mossé, Huet and Baudet, 1988).

Proteins

Triticale's protein content is 10.0 to 16.0 percent

TABLE 4
Amino acid composition of triticale, wheat and rye varieties

Amino acid	Triticale[a]					Wheat[a]			Rye
	Dua	Towan	UH 116	Lasko	Lasko	Caton	Caton	Selekta	Petkus II
					(*g/16 g N*)				
Protein (Nx 5.7)	11.1	12.9	12.2	9.7	13.4	8.6	13.2	13.7	8.3
Gly	-	-	-	4.4	4.2	4.4	4.0	-	5.7
Ala	-	-	-	4.3	3.8	3.9	3.6	-	4.3
Val	4.7	4.6	4.4	4.9	4.6	4.6	4.4	3.6	4.7
Leu	6.6	6.4	6.0	6.4	6.4	6.8	7.0	6.5	6.4
Ile	3.6	3.6	3.3	3.9	3.7	3.5	3.7	3.4	3.8
Ser	-	-	-	4.5	4.5	4.8	5.4	-	2.9
Thr	3.4	3.3	3.0	3.5	3.2	3.2	3.2	2.8	2.8
Tyr	3.1	3.0	2.9	2.9	3.2	3.1	3.3	3.4	2.1
Phe	4.5	4.6	3.9	4.4	4.6	4.4	4.8	4.8	3.3
Trp	-	-	-	1.2	1.2	1.2	1.1	-	-
Pro	-	-	-	9.0	10.2	9.3	10.2	-	9.8
Met	1.7	1.7	1.8	1.9	1.6	1.8	1.5	1.9	-
Cys/2	2.5	2.6	2.6	2.7	2.6	2.6	2.6	1.9	-
Lys	3.4	3.1	3.2	4.0	3.4	3.4	2.7	2.8	3.8
His	2.3	2.3	2.5	2.3	2.2	2.4	2.3	2.5	2.7
Arg	5.3	5.1	4.5	5.5	5.0	5.2	5.0	4.7	5.0
Asp	-	-	-	6.8	5.9	5.5	5.0	-	7.3
Glu	-	-	-	25.2	26.8	25.9	30.6	-	22.7

[a]Varughese, Pfeiffer and Peña, 1996.

(Table 1), and its NaCl-soluble protein (albumins plus globulins) content is higher than that of wheat. The proportion of storage proteins (NaCl-insoluble) is lower in triticale than in wheat (Table 5).

Storage proteins interact to form gluten in wheat. Gluten quantity and quality are responsible for dough viscoelastic properties, which enable the production of a large variety of leavened and unleavened breads. The storage protein (NaCl-insoluble) content of triticale is considerably lower than that of wheat, and only part of it forms gluten (Table 5). In triticale, the portion of storage protein that does not form wheat-like gluten was inherited from rye. These differences in the amount and composition of storage proteins are the main factors responsible for the inferior bread-making quality of triticale as compared to wheat. Triticale bread-making dough shows deficient viscoelasticity and poor handling properties, and yields breads with low loaf volumes and compact crumb.

Triticale shows genetic variability for gluten content and gluten quality (Macri, Balance and Larter, 1986a; Peña and Balance, 1987; Peña *et al.*, 1991; Peña, Mergoum and Pfeiffer, 1998). Table 6 shows the variability in gluten content and bread-making quality characteristics of two sets of triticale lines of contrasting bread-making quality. As shown in Table 6, there is bread-making quality variability at similar gluten content; therefore, in addition to gluten quantity, gluten quality is a major factor influencing the bread-making quality of triticale.

The highest gluten content in triticale is still 20 to 30 percent below that of wheat (Table 5), a situation that is difficult to improve substantially with the present gene

TABLE 5
Protein solubility in 0.5M NaCl and gluten protein content of wheat, triticale and rye flours

Flour	NaCl-soluble (%)	NaCl-insoluble (%)	Gluten protein in flour protein (%)	Difference[a] (%)
Wheat	17.7	78.2	78.5	-0.3
Triticale (S)[b]	32.4	65.6	50.5	15.1
Triticale (C)[b]	32.5	64.2	46.4	17.8
Rye	36.7	63.0	-	-

[a]Difference is NaCl-insoluble minus gluten protein.
[b]S = substituted; C = complete. Data correspond to the mean of eight different lines in each case.
Source: Peña, 1996.

TABLE 6
Bread-making quality-related characteristics of spring hexaploid triticale groups possessing poor and good bread-making quality[a]

Bread-making quality group	Flour protein (%)	Dry gluten (%)	Flour SDSS[b] (ml)	Mixograph DDT[c] (min)	Bread loaf volume (ml)
Poor (n=46)[d]					
Mean	9.7a	6.3a	6.4a	1.5a	394a
Range	8.7-11.2	3.5-8.1	4.0-9.5	0.7-2.7	320-435
Good (n=46)[e]					
Mean	9.8a	6.2a	10.0b	2.5b	595b
Range	9.0-10.7	3.8-7.6	8.0-13.0	1.4-4.2	520-820

[a]Values within each column followed by the same letter are not significantly different (á = 0.05).
[b]SDSS = SDS-sedimentation volume (gluten strength-related parameter).
[c]DDT = dough development time.
[d]Poor bread-making quality = loaf volume < 440 ml.
[e]Good bread-making quality = loaf volume > 520 ml.
Source: Peña, Mergoum and Pfeiffer, 1998.

pool of triticale. However, further improvements in gluten quantity and quality through chromosome transformation seem feasible. Lukaszewski and Curtis (1992) induced translocations in triticale genotypes involving bread wheat chromosome 1DL, which carries genes encoding for high molecular weight subunits of glutenin that contribute greatly to bread-making quality, and triticale group 1 chromosomes. Quality evaluations of triticales carrying the 1DL gene pool (particularly the 1R.1D translocation) indicate that gluten quality in triticale can be further improved (Lukaszewski, 1998).

Enzymes: alpha-amylase activity

Mature, sound cereal grains are characterized by very low levels of enzymatic activity. Upon wetting, cereal grains tend to germinate (sprout), promoting an increase in enzymatic activity, which in turn hydrolyses starch and other grain components to sustain the development of a new plant. Greater than normal levels of enzymatic activity in sprouted grain may promote fungal development during storage or may have deleterious effects on the food-processing characteristics of cereals. Some triticales show high levels of alpha-amylase activity even in the absence of visual sprouting or spike wetting (Peña and Balance, 1987; Mares and Oettler, 1991; Trethowan *et al.*, 1993; Trethowan, Peña and Pfeiffer, 1994). Grain sprouting thus has important sanitation and economic implications.

Triticale has a tendency to sprout pre-harvest and to produce high levels of alpha-amylase activity (AAA). Pre-harvest sprouting is probably the most important grain-related factor that limits the food use of triticale. Particularly in bread making, it significantly alters the functional properties of starch and of the baking dough in which the starch is contained. The products of hydrolysis (sugars and gums) may also negatively alter end-use quality. Triticale exhibits large genetic variability for AAA and pre-harvest tolerance (Oettler and Mares, 1991; Trethowan, Peña and Pfeiffer, 1994), which has allowed breeders to select for low AAA.

From a different perspective, the tendency for triticale to produce high AAA could be advantageous in the production of triticale malt, which is used as an additive in the food industry, or in brewing. In the latter case, triticale malt has been found acceptable in relation to amylolytic activity and wort yields, but slightly high in proteolytic activity. This results in high levels of solubilized protein, which could cause problems during fermentation and storage (protein precipitation) and in the colour (dark) of the beer (Gupta, Singh and Bains, 1985; Holmes, 1989).

Enzymes: proteolytic activity

The proteolytic activity of triticale tends to be higher than that of wheat and, in some cases, even than that of rye (Madl and Tsen, 1974; Macri, Balance and Larter, 1986b). Madl and Tsen (1974) observed that the proteolytic activity of triticale varies greatly depending on genotype and/or growing location. From their bread-making results, Madl and Tsen (1973) and Macri, Balance and Larter (1986a) concluded that moderately high proteolytic activity would not be detrimental to bread-making quality, given that triticale flour had acceptable dough strength character.

Pentosans

Pentosans (arabinose plus xylose) are cell wall polysaccharides that play a major role in determining the viscous properties of rye flour dough required to produce good-quality rye bread. Pentosan content in rye flour determines dough yield, stability and volume, and partially influences bread-loaf volume and crumb texture. Proteins are important in rye flour dough but not to the same extent as in wheat flour dough (Drew and Seibel, 1976). Saini and Henry (1989) found that triticale had total and soluble pentosan contents similar to or slightly higher than those of wheat and much lower than those of rye (Table 7). In a different study, Fengler and Marquardt (1988) found that the flour soluble pentosan content and viscosity of water extracts were practically the same in wheat and triticale but significantly lower than those of rye (Table 7). Therefore, in the production of rye bread, triticale doughs would have inferior viscosity properties and baking quality as compared to doughs made with 100 percent rye flour.

TABLE 7
Pentosan content in grain and flour of triticale, wheat and rye

Cereal	Grain[a]		Flour[b]		
	Total (%)	Soluble (%)	Soluble (%)	Ash (%)	Viscosity (*water extract*)[c]
Triticale	7.60	1.82	0.05	0.70	1.39
Wheat	6.60	2.16	0.05	0.46	1.31
Rye	12.20	3.89	2.40	0.97	3.15

[a]Saini and Henry, 1989.
[b]Fengler and Marquardt, 1988.
[c]Values relative to water.

Flour and dough functional properties

Viscosity and other pasting properties of flour-water slurries depend greatly on starch properties. Although triticale's starch properties are similar to those of its parents, due to higher-than-normal levels of enzymatically (alpha-amylase) damaged starch, the paste viscosity of triticale flour-water slurries is often low compared to that of wheat (Lorenz, 1972; Weipert, 1986).

The rheological properties of triticale flour doughs have been extensively examined and compared with those of wheat and rye doughs. Studies using the Farinograph and the Mixograph (Lorenz *et al*., 1972; Lorenz and Welsh, 1977; Macri, Balance and Larter, 1986a; Rakowska and Haber, 1991) have shown that triticale flour doughs generally have lower water absorption, shorter dough development times and less mixing tolerance than wheat flour doughs. Studies using the Extensigraph and the Alveograph (Macri, Balance and Larter, 1986a; Weipert, 1986) have shown that triticale flours have dough strength values usually lower than those of wheat. Weipert (1986) indicated that triticale farinograms and extensigrams are more similar to those of rye than to those of wheat. On the other hand, Macri, Balance and Larter (1986a) and Peña, Mergoum and Pfeiffer (1998) have shown there is wide variability within triticale for dough strength-related properties; in some cases triticale doughs are more similar to weak to medium-strong wheat doughs than to rye doughs. It seems that there are rye-like and wheat-like triticale types.

Gluten protein content and gluten quality are the main factors affecting the viscoelastic properties of wheat flour doughs. Macri, Balance and Larter (1986a) and Peña and Balance (1987) showed that the same concepts apply to triticale; the weak dough character of triticale is influenced primarily by its low gluten protein content and by differences in the quality of its gluten-forming protein. At a more basic molecular level, differential quality (gluten strength-related parameters) effects have been associated with variations in high and low molecular weight glutenin subunit compositions (Ciaffi *et al*., 1991; Peña *et al*., 1991; Peña, Mergoum and Pfeiffer, 1998) and with the presence of secalins (rye proteins) in a triticale background (Ciaffi *et al*., 1991). In relation to quality effects, the above studies separately indicated that the high molecular weight subunit 13+16 and the low molecular weight subunit LMW-2, both controlled by genes located in the long and short arms, respectively, of chromosome 1B, should be superior to their counterparts 13+19 and LMW-1.

Recent studies on the diversity of glutenin and secalin of triticale cultivars grown in Europe have found large allelic diversity in glutenin and secalin proteins in winter and in spring triticales (Amiour *et al*., 2002a, 2002b). Examining the relationship between individual alleles and their combinations and gluten properties should allow us to determine which glutenin (and secalin) combinations are more desirable for improving gluten and dough viscoelasticity properties beyond what can be obtained with current triticale cultivars.

Non-grain factors

To avoid food-processing problems caused by grain compositional factors, triticale can partially replace wheat and/or rye flours in the preparation of baking products. In major triticale-producing countries, diverse baking

TABLE 8
Food uses of triticale in some major triticale-producing countries

Country	Product	Proportion of triticale flour (%)	Result[a]	Reference
Australia, New Zealand	Breads, cookies, biscuits	100, blend	+	Cooper, 1985, 1986; Lorenz and Ross, 1986; Naeem *et al.*, 2002
Brazil	Variety breads	40-100	+	Baier and Nedel, 1986
Germany	Leavened bread	40	+	Saurer, 1985
Poland	Rye-type bread	100	+	Rakowska and Haber, 1991; Sowa, Peña and Bushuk, 1998
Russian Federation	Rye-type bread	100, blend	+	Kolkunova *et al.*, 1983
United States of America	Layer cake	100, blend	+	Kissell and Lorenz, 1976

[a]Denotes positive experience with triticale as food.

products have been prepared successfully with triticale alone or by blending it with wheat and rye flours (Table 8). However, the food use of triticale remains very limited for reasons related to grain compositional factors (as previously discussed) and such non-grain factors as: (i) breeding issues; (ii) the fact that triticale is regarded as a feed grain and not promoted as a food crop; and (iii) marketing and processing difficulties. Some of these factors apply globally; others are region- or population-specific.

Breeding for quality

Breeding for grain size, shape and plumpness is highly desirable in order to achieve high test weight and acceptable flour-milling properties. Breeding for pre-harvest sprouting tolerance is necessary to maintain low, desirable levels of enzymatic activity and, consequently, good processing quality. Breeding for medium-hard to hard grain and for white grain colour would favour using triticale in wholemeal flat bread production as well as in noodle making. Finally, improving gluten strength by combining gluten proteins already present in triticale or incorporating alien gluten proteins would further increase the acceptability of triticale for bread production. Breeding triticale for malting quality has also proved feasible.

Although there are many issues to address in breeding triticale for food uses, formal triticale quality improvement seems not to occur (except in Australia) in breeding programmes. Possible reasons for this are:

- The perception that there is no need to improve triticale as a food grain because the local supply of traditional food grains is sufficient.
- Triticale quality improvement is desirable, but sources for quality improvement are not available.
- Triticale food quality improvement is desirable, but the required resources are not available.

In the latter two cases, it would be very useful to form international quality nurseries that group triticale lines according to their potential food use and an international network to help exchange and distribute triticale germplasm targetted for food uses.

Acceptability as a food grain

Despite agronomic and quality suitability, a new food grain for the preparation of traditional foods is not always well received. For example, Algeria imports large amounts of wheat for bread production. In an attempt to reduce wheat imports, triticale was tested and found suitable for bread making if used in wheat-triticale blends (70-30); however, it could not be utilized because people were not yet prepared to accept the use of cereals other than wheat in bread making (Benbelkacem, 1987). Another factor influencing the adoption of triticale is how well it competes with other cereals; for example, barley is a better cash crop than triticale in Algeria (Benbelkacem, 1987) and oat is better in central Mexico (Carney, 1990). Finally, acceptability may be limited due to socio-political factors. For instance, in some parts of Europe triticale is officially recognized as a feed grain not suitable for food uses (A. Kratigger, personal communication, 1995).

Promotion as a food crop

Promotion could play a very important role in gaining acceptance for triticale. Once non-grain problems have been solved, the lack of promotion becomes the main factor limiting the use of triticale as a food grain. The type of promotion required will vary according to the targetted area, population, or sector. Smallholders need to be shown that triticale has a role to play in sustainable farming systems as a low-input cereal and/or dual-purpose crop (food and feed) that fits local crop rotations. Among consumers looking for nutritious foods, it should be promoted as a good source of energy, lysine and dietary fibre. At the end-use level, triticale should be promoted as good for making local, cereal-based foods and new, non-conventional foods (snacks and breakfast cereal), and also as a raw material in the food industry (starch production and malted triticale).

Marketing and food processing

A reliable grain supply is a prerequisite for establishing a triticale market, but farmers often claim that they require a well-established market before they set up production. Marketing is also difficult due to the lack of official grading factors and price for triticale. In addition, disappointing results have sometimes been obtained from milling, baking and malting tests conducted at the industrial level in which triticale has received the same treatment as wheat or barley. This is not appropriate, but has occurred because the industry has little experience in processing triticale. However, when certain feasible modifications have been made, satisfactory results have been obtained. In these cases, the unwillingness of food processors to make these changes has become the limiting factor.

UTILIZATION

Although triticale is now commercially grown on approximately 3 million ha, there is little published information on its commercial utilization. Studies on the potential food and feed utilization of triticale in the last 25 years are numerous, however.

Although in many cases triticale has proven suitable as a food grain (Table 8), its food use has not reached the commercial level. Given its generally inferior wheat-like bread-making quality, triticale flour is not considered suitable for bread making, particularly if wheat flour is available. In a few cases, when wheat has been in short supply, triticale has been used, particularly by small landholders, alone or blended with wheat, for the manufacture of local home-made breads, for example, sweet breads in the highlands of central Mexico (Carney 1990), local breads in southern Brazil (Baier and Nedel, 1986) and chapattis in northern India (Biggs, 1982). Small amounts of rolled triticale ('flakes'), wholemeal flour, wholemeal speciality breads and other health foods have been marketed in Australia (Cooper, 1986).

In summary, several grain and non-grain factors have caused triticale to fail as a commercial food grain. The global wheat surplus, lack of year-to-year consistency in triticale grain supply and possibly in grain quality (as related to year-to-year variations in environmental conditions promoting grain sprouting and/or year-to-year differences in crop management affecting grain plumpness and grain protein content), absence of official triticale grading systems and lack of proper promotion are other factors that do not allow the formation of the farmer-industry-consumer chain necessary for triticale to become established as a commercial food grain.

CONCLUDING REMARKS

The utilization of triticale as a food grain is influenced by grain and non-grain factors. Despite important grain compositional problems, triticale can be used as a food grain, mainly as a replacement of wheat and rye flour in proportions that will depend on the type of baking product. Further improvements, particularly in grain plumpness, grain colour (white or amber) and gluten quantity and quality, are expected to make triticale more attractive as a food grain. As has been suggested (N. Darvey, personal communication, 1996), global networking among breeding programmes willing to improve triticale quality could play a determining role in germplasm exchange and in accelerating triticale quality breeding. However, no action has been taken so far. This may be due to the economic problems facing breeding programmes all over the world. Thus non-grain factors, which are diverse, complex, and in many cases region- and population-specific, may limit the food use of triticale more than grain-related factors.

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Triticale as animal feed

R. Myer, A.J. Lozano del Río

Triticale has been produced for many years. Advances in plant breeding have made triticale a viable crop in many parts of the world. Much of the production is as triticale grain, but triticale is also grown as a forage crop and as a dual-purpose crop (both forage and grain). The grain is primarily used for feeding pigs, but it can be and is fed to poultry and ruminant animals, such as cattle and sheep. As forage, the crop can be and is grazed by cattle and sheep, or harvested for silage or hay. Triticale also produces an abundant amount of straw.

Early on, interest in triticale as a feed grain was generated because of its higher protein concentration and better amino acid balance as compared to other feed grains such as maize. Production problems, including variable yield, pre-harvest sprouting and light-weight, shrivelled kernels, and nutrition problems, such as low energy density, variable composition and low palatability, have detracted interest (NRC, 1989; Myer, Combs and Barnett, 1990; Hill, 1991; Varughese, Pfeiffer and Peña, 1996; Boros, 2002). Plant breeders over the last 30 years, however, have greatly improved the crop. Modern triticale grain varieties are high yielding, and yield grain is plumper and has a heavier test weight than the older varieties. Plant breeders also have and are developing varieties specifically for forage and for dual purposes.

TRITICALE AS A FEED GRAIN

The increase in grain plumpness of modern triticale varieties has resulted in grain of higher starch content and thus more energy dense than was typical of the older, shrivel-seeded, light-weight varieties (NRC, 1989; Varughese, Pfeiffer and Peña, 1996; Boros, 2002). The increase in starch content, however, has resulted in grain with a lower protein concentration than the older varieties (NRC, 1989; Myer, Combs and Barnett, 1990; Varughese, Pfeiffer and Peña, 1996; Boros, 2002; Van Barneveld, 2002). Protein content and quality, nevertheless, are still greater than most other cereal feed grains (NRC, 1989; Myer, Combs and Barnett, 1990; Varughese, Pfeiffer and Peña, 1996; Boros, 2002; Van Barneveld, 2002). Of its two parents, modern triticale grain resembles wheat more than rye in regards to grain morphology, with its test weight slightly lower than that of wheat (NRC, 1989; Varughese, Pfeiffer and Peña, 1996; Boros, 2002; Van Barneveld, 2002).

Triticale grain is a relatively soft grain with a hardness index almost half of that observed for wheat and barley (Van Barneveld, 2002). The advantage is that less mechanical energy would be required to process triticale grain (i.e. grinding and rolling) compared to wheat and barley prior to mixing into livestock diets. The softer triticale grain, however, may be more susceptible to insect damage during storage than other feed grains (Van Barneveld, 2002). Care must be taken in regards to long-term storage of triticale grain.

Nutrient composition

Modern triticale is higher than maize in protein and essential amino acids, in particular lysine, which is usually the most limiting essential amino acid in typical pig diets[1]. Modern, high-yielding triticale cultivar grain is similar to or slightly lower than wheat in protein; however, lysine and threonine concentrations, as a percentage of the protein, are typically higher (Table 1) (NRC, 1989, 1998; Myer, Combs and Barnett, 1990; Radecki and Miller, 1990; Varughese, Pfeiffer and Peña, 1996; Boros, 2002; Van Barneveld, 2002). The higher concentrations of limiting essential amino acids, in particular lysine and threonine, permit less use of a supplemental protein source, such as soybean meal, when using triticale as opposed to maize in formulating diets for pigs and poultry. It should be pointed out, however, that much variation exists in the protein and amino acid concentrations of triticale. Protein and lysine concentrations of 9 to 18 percent and 0.33 to 0.71 percent, respectively, have been reported in the literature (Pettersson and Aman,

[1]Lysine content is important because pigs, like most simple-stomached, non-ruminant animals, do not require protein *per se*, instead they require specific levels of certain compounds that make up protein. These compounds are called amino acids. Some of these amino acids, termed essential amino acids, must be present in the diet for pigs to grow and perform well. A few essential amino acids tend to be limiting in typical pig diets. One essential amino acid, lysine, is usually the most limiting or first-limiting amino acid. This means that if a diet is formulated to supply the correct amount of lysine, then generally the levels of the other essential acids will be adequate. Therefore, lysine concentration is an important consideration when comparing cereal grains.

TABLE 1
Comparative composition of triticale, maize and wheat grain (as-fed basis)

Item	Triticale	Maize	Wheat[a]
Crude protein (%)	12.0	8.5	11.5
Lysine (%)	0.40	0.24	0.34
Crude fibre (%)	2.8	2.2	2.4
Acid detergent fibre (%)	3.8	2.8	3.5
Neutral detergent fibre (%)	12.7	9.6	11.0
Crude fat (%)	1.8	3.8	1.8
Calcium (%)	0.05	0.02	0.05
Phosphorus (%)	0.33	0.25	0.33
Metabolizable energy in pigs (*kcal/kg*)	3 200	3 350	3 350
Metabolizable energy in beef cattle (*kcal/kg*)	3 180	3 180	3 180
Metabolizable energy in poultry (*kcal/kg*)	3 200	3 400	3 210
Total digestible nutrients for ruminants (%)	79	80	79

[a]Soft red winter wheat.
Source: Radecki and Miller, 1990; Myer, Combs and Barnett, 1990; NRC, 1998, 2000; Hughes and Choct, 1999; Gursoy and Yilmaz, 2002; Van Barneveld, 2002.

1987; Radecki and Miller, 1990; Heger and Eggum, 1991; Leterme, Thewis and Tahon, 1991; Varughese, Pfeiffer and Peña, 1996). The variation is due to differences in cultivar and crop-growing conditions, such as soil fertility (Pettersson and Aman, 1987; Heger and Eggum, 1991; Feil and Fossati, 1995; Varughese, Pfeiffer and Peña, 1996; Moinuddin and Afrid, 1997; Bruckner, Cash and Lee, 1998). In general, the older cultivars will have higher protein levels than the newer ones.

The energy content of modern triticale grain cultivars averages about 95 to 100 percent of that of maize or wheat for non-ruminants (pigs and poultry) (Batterham, Saini Anderson, 1988; Charmley and Greenhalgh, 1987; Batterham, Saini and Baigent, 1990; Hill, 1991; Myer, Combs and Barnett, 1991; Flores, Castanon and McNab, 1994; Vieira *et al.*, 1995; NRC, 1998; Boros, 2002; Van Barneveld, 2002; Van Barneveld and Cooper, 2002). For ruminant animals, energy concentration has generally been found to be comparable to maize, barley or wheat (Charmley and Greenhalgh, 1987; ZoBell, Goonewardene and Engstrom, 1990; Hill, 1991; McQueen and Fillmore, 1991; NRC, 2000). The digestibility of protein and amino acids in triticale grain has been found to be quite good, being similar to or even slightly better than that observed for maize or wheat (Coffey and Gerrits, 1988; Myer *et al.*, 1989; Radecki and Miller, 1990; Hill, 1991; Van Barneveld, 2002).

Concentrations of various minerals in triticale grain are similar to those of wheat (NRC, 1989, 1998; Radecki and Miller, 1990; Varughese, Pfeiffer and Peña, 1996; Van Barneveld, 2002). As in wheat, the phosphorus level is higher than in maize, and more of the phosphorus is digestible for non-ruminants (NRC, 1989, 1998; Radecki and Miller, 1990; Leterme, Thewis and Tahon, 1991; Van Barneveld, 2002). Typically, 40 to 50 percent of the phosphorus in triticale and wheat is available (digestible), whereas only 20 to 30 percent is available in maize (NRC, 1998). The higher level and greater availability of phosphorus allows for less phosphorus supplementation when using triticale in diet formulation as opposed to maize.

Undesirable constituents in triticale grain

Prior to 1975, there were reports in the literature of various anti-nutritional factors that may have been responsible for reduced intake and performance of animals consuming triticale-based diets (NRC, 1989; Radecki and Miller, 1990; Hill, 1991; Boros, 2002). With modern triticale, various anti-nutritional factors, such as non-starch polysaccharides (pentosans) and protease inhibitors, while higher than in most other cereal grains, seem to have no effect on the growth performance of livestock consuming diets containing triticale grain (NRC, 1989; Batterham, Saini and Baigent, 1990; Radecki and Miller, 1990; Boros and Rakowska, 1991; Boros, 2002; Myer, 2002; Van Barneveld and Cooper, 2002). The possible exception is the anti-nutritional effect of pentosans in poultry nutrition. Poultry are rather sensitive to the anti-nutritional effects of these compounds. Pentosans are also present in wheat and rye. Pentosans in wheat and rye are known to interfere with digestion and absorption of various nutrients (Pettersson and Aman, 1988; Annison and Choct, 1991; Bakker *et al.*, 1998; Cheeke, 1998; Boros, 1999, 2002; Im *et al.*, 1999).

TABLE 2
Example pig diets using triticale grain

Ingredient	Grower (20-50 kg)	Finisher I (50-80 kg)	Finisher II (80-110 kg)
Ground triticale (%)	74.25	82.75	90.000
44% soybean meal (%)[a]	22.50	15.00	8.000
Base mix[b]			
Dicalcium phosphate (%)[c]	1.25	0.75	0.625
Limestone, ground (%)	1.00	1.00	0.875
Salt (%)	0.50	0.25	0.250
Vitamin-trace mineral premix (%)[d]	0.50	0.25	0.250
	100.00	100.00	100.000
Calculated composition (as-fed basis)			
Crude protein (%)	18.8	16.5	14.4
Lysine (%)	0.96	0.77	0.60
Calcium (%)	0.75	0.62	0.55
Phosphorus (%)	0.64	0.53	0.48
Metabolizable energy (*kcal/kg*)	3 150	3 170	3 200

[a]Can replace ten parts of 44 percent soybean meal with nine parts of 48 percent soybean meal and one part of triticale.
[b]A complete mineral-vitamin premix or a complete mineral premix and separate vitamin premix may be used instead of the suggested base mix. Follow manufacturer guidelines.
[c]Defluorinated phosphate or mono-dicalcium phosphate, if available, may be substituted for dicalcium phosphate. However, if a substitution is made, the diets need to be reformulated since these products contain different calcium and phosphorus levels than dicalcium phosphate.
[d]Amounts shown are typical for many commercial products. Follow manufacturer guidelines.
Source: Myer and Barnett, 1984.

Ergot infection, while a potential problem for triticale grown under cool and wet conditions, seems to occur much less in the new triticales than previously noted with the older cultivars (NRC, 1989). As with other cereals, triticale is susceptible to contamination by various moulds that can produce toxic mycotoxins, in particular scab, resulting in the accumulation of deoxynivalenol (DON) in the grain (Goral, Perkowski and Arseniak, 2002). Triticale grain, like wheat, however, is somewhat resistance to aflatoxin contamination (Bilotti, Fernandez-Pinto and Vaamonde, 2000).

GRAIN USES

Triticale grain for pig feeding

Modern triticale grain cultivars provide an excellent feed grain for use in mixed pig diets. Research has shown that triticale grain is a satisfactory replacement for maize, and because of its superior lysine content, it can replace part of the supplemental protein source, such as soybean meal, in typical maize-soybean meal based diets for all classes of pigs (Hale, Morey and Myer, 1985; Coffey and Gerrits, 1988; Myer *et al.*, 1989; NRC, 1989; Batterham, Saini and Baigent, 1990; Myer, Combs and Barnett, 1990; Radecki and Miller, 1990; Hill, 1991; Leterme, Thewis and Tahon, 1991; Myer, Brendemuhl and Barnett, 1996; Boros, 2002; Myer, 2002; Van Barneveld and Cooper, 2002).

Even though triticale grain contains more protein than maize or grain sorghum, diets should be formulated to meet the essential amino acid (especially lysine) requirements of the pig rather than the crude protein requirements. If diets containing triticale were formulated on the basis of crude protein alone, lysine levels could be inadequate and pig performance would suffer.

Because of the higher lysine content of triticale grain, farmers who mix their own diets using a protein supplement (i.e. soybean meal) plus a premix programme can save a substantial amount of the protein supplement per tonne of mixed diet over comparable maize or grain sorghum based diets. Examples of diets formulated with triticale are given in Table 2. The crude protein concentration of triticale-based diets is usually higher than that of comparable maize-based diets when both diets contain equal levels of lysine. The example diets are also formulated to take advantage of the higher level of phosphorus of triticale, resulting in a savings of 2.5 kg of dicalcium phosphate per tonne of diet over comparable maize-based diets. This gives an advantage to farmers who mix their own diets with any premixes.

The relative energy value of modern triticale grain, based on results of the research mentioned above, is about 95 to 100 percent of maize for pigs. Triticale should be ground or rolled for use in pig diets. A medium grind is preferred (no whole kernels should be visible). Finely ground triticale is not desirable because it easily absorbs moisture from the atmosphere and the pig's own saliva, which can result in feed spoilage and reduced feed intake.

Triticale grain for poultry feeding

As with pigs, modern triticale grain is a good feed grain for use in mixed poultry diets. The energy content of modern triticale grain for broilers and laying hens is comparable to other cereals, such as wheat, barley or grain sorghum. Apparent metabolizable energy (AME) concentrations of 12.8 to 14.3, 10.4 to 15.9, 10.4 to 12.2 and 14.9 to 15.8 mJ/kg for triticale, wheat, barley and grain sorghum, respectively, have been reported (Hughes and Choct, 1999).

As mentioned above for pigs, diets formulated with triticale should be on a limiting essential amino acid basis (i.e. lysine) and not on a protein basis. Even though poultry can utilize whole kernels, triticale grain should be ground or rolled to ensure proper mixing with other diet ingredients for a balanced diet.

As mentioned above, poultry are sensitive to the anti-nutritional effects of various non-starch polysaccharides, such as pentosans, more so than pigs and other livestock. Pentosans present in wheat and rye have been shown to depress the energy value of wheat for poultry by 5 to 10 percent and even more for rye (Pettersson and Aman, 1988; Annison and Choct, 1991; Cheeke, 1998; Im *et al.*, 1999; Boros, 2002). Pentosans may also result in the excretion of wet, sticky droppings. The anti-nutritional effect can be overcome with the addition of commercially available feed enzymes (primarily xylanases). Even though triticale typically contains higher levels of pentosans than wheat (but lower than rye), results are mixed regarding the effectiveness of these enzymes on improving the nutritive value of triticale (Pettersson and Aman, 1988; Bakker *et al.*, 1998; Boros, 1999, 2002; Im *et al.*, 1999). Thus the pentosans from triticale may not have the anti-nutritive effect as with other cereals. Nevertheless, if available, typical recommendations are to include an enzyme supplement, not so much to improve triticale but to improve the feed value of contaminate grains, such as rye and wheat, which may be present in feed-grade triticale grain (Boros, 2002).

Unlike maize, triticale grain contains no pigments (i.e. carotenoids and xanthophylls). If dark-yellow egg yolks and yellow-skinned broilers are desired, then a pigment source (i.e. corn gluten meal and dehydrated alfalfa meal) would have to be added to diets containing a high level of triticale (El Boushy and Raterink, 1992).

Triticale grain for ruminants

Ruminant animals (i.e. cattle, sheep, goats, deer, camels, buffalo and llamas) have an enlarged four-compartment stomach. Unlike non-ruminants, such as pigs and poultry, microbes (mostly bacteria) within the rumen (the first compartment) of ruminants can significantly alter nutrients flowing to the small intestine for absorption. Therefore, these microbes within the rumen can allow a ruminant animal to utilize high-fibre forages and low-quality protein sources that cannot be efficiently utilized by non-ruminants. Thus, in regards to protein, a feed formulator is more concerned about protein quantity rather than protein quality when formulating diets for ruminants as opposed to non-ruminants. However, because of this symbiosis with microbes within the rumen, rapid dietary changes are of more concern when feeding ruminants than non-ruminants. Rapid changes can cause digestive problems, such as bloat and acidosis.

Triticale grain is a good feed grain for cattle, sheep and other ruminants. Triticale grain can replace part or all of the maize, grain sorghum or other cereal grain in diets for these animals. Grain from modern triticale varieties has been reported to be comparable in energy value to other cereal grains for use in the mixed diets of beef and dairy cattle and sheep, and its protein is well utilized (Charmley and Greenhalgh, 1987; ZoBell, Goonewardene and Engstrom, 1990; Hill, 1991; McQueen and Fillmore, 1991; Brand and van der Merwe, 1994; Miller *et al.*, 1996; NRC, 2000; Gursoy and Yilmaz, 2002). Because of its relatively high protein content, additional protein supplementation may not be necessary in many cases (i.e. for finishing beef cattle) when triticale is used as the grain source. The starch in triticale, like wheat, is readily fermentable by the rumen microbes. For the most efficient use of its available energy, triticale should be blended with another feed grain with slower fermentable starch, such as maize or grain sorghum. In addition, care must be taken to avoid sudden diet changes to diets containing triticale grain, especially if a high level is used. Triticale grain should be processed (i.e. grinding, rolling and flaking) before mixing it into the diet.

FORAGE USES

Triticale forage for ruminants

Triticale has been and is increasingly grown for livestock grazing, cut forage (green chop), whole-plant silage, hay and forage/grain dual purpose. Worldwide, there are hundreds of different varieties of triticale, many of which have been developed for forage production. These varieties differ in winter hardiness, growth habit and

TABLE 3
Average composition of triticale forage

Item	Fresh forage	Silage[a]	Hay[a]
Dry matter (%)	20	35	89
Crude protein (*% dry matter*)	20	12	8
Acid detergent fibre (*% dry matter*)	30	35	40
Neutral detergent fibre (*% dry matter*)	50	60	70
Calcium (*% dry matter*)	0.4	0.4	0.2
Phosphorus (*% dry matter*)	0.3	0.3	0.2
Total digestible nutrients for ruminants (*% dry matter*)	(70)[b]	60	55
Metabolizable energy in beef cattle (*kcal/kg dry matter*)	(2 500)[b]	2 200	2 000

[a]Early-dough stage.
[b]Estimated.
Source: Sun and Wang, 1991; ZoBell, Goonewardene and Engstrom, 1992; Khorasani *et al.*, 1993; McCartney and Vaage, 1994; Royo and Tribó, 1997; Juskiw, Salmon and Helm, 1999; Maloney, Oplinger and Albrecht, 1999; Juskiw, Helm and Salmon, 2000; NRC, 2000.

productivity. The majority of triticale cultivars have prominent awns; however, some recent releases are awnless, thereby further increasing the potential for triticale as a forage crop (Gibson, 2002).

In general, dry-matter yield of forage for triticale compares very favourably to other small-grain forage cereals in studies done all over the world (Varughese, Barker and Saari, 1987; NRC, 1989; Jedel and Salmon, 1994; McCartney and Vaage, 1994; Varughese, Pfeiffer and Peña, 1996; Lozano *et al.*, 1998; Juskiw, Salmon and Helm, 1999; Maloney, Oplinger and Albrecht, 1999; Juskiw, Helm and Salmon, 2000; Rao, Coleman and Volesky, 2000). There is much variation, however, among triticale cultivars. Research on the evaluation of triticale as forage for ruminants has generally indicated comparative nutritive values to other forage cereal crops (Bruckner and Hanna, 1990; Andrews *et al.*, 1991; Carnide *et al.*, 1991; Sun and Wang, 1991; ZoBell, Goonewardene and Engstrom, 1992; Khorasani *et al.*, 1993; Jedel and Salmon, 1994; McCartney and Vaage, 1994; Varughese, Pfeiffer and Peña, 1996; Lozano *et al.*, 1998; Maloney, Oplinger and Albrecht, 1999; Juskiw, Helm and Salmon, 2000; Rao, Coleman and Volesky, 2000). Nutrient composition generally follows that of other forage cereal crops (Table 3) (Bruckner and Hanna, 1990; Lozano, 1990; Sun and Wang, 1991; Wright, Agyare and Jessop, 1991; ZoBell, Goonewardene and Engstrom, 1992; McCartney and Vaage, 1994; Maloney, Oplinger and Albrecht, 1999; NRC, 2000).

Triticale forage types

Triticale cultivars, grown for forage as well as for grain, can be classified into three basic types according to growth habit: spring, winter and intermediate (facultative).

Spring types, which do not require vernalization to go from vegetative to reproductive stages, are generally planted during the spring, but can be planted in the autumn in milder climates. Spring types exhibit upright growth and produce much forage early in their growth. They are insensitive to photoperiod and have limited tillering. Winter types, which need vernalization to go from vegetative to reproductive phases, are generally planted in the autumn, but can also be planted in the spring in some situations. Winter types have a prostrate type of growth in the early stages of development. In general, winter types yield more forage than spring types mainly due to their long growth cycle. Intermediate (facultative) types, as the name implies, are intermediate to spring and winter types, but do not require vernalization to evolve into the reproductive phase.

Spring triticale provides an excellent alternative to other spring cereals, such as barley and oats. Spring triticale has been shown to be more drought tolerant than other spring cereals (Hinojosa *et al.*, 2002). Facultative and winter types are particularly well suited for grazing as they generally have a better distribution of forage over the growing season (Lozano, 1990).

Potential forage systems

Triticale can be grown as a mono-crop, winter/spring blend, mixed with legumes, or mixed with other cereals and/or annual ryegrass. The advantage with blends is that the grazing season can be extended and/or forage nutritive value improved, in particular when blended with legumes.

Mono-crop (monoculture)

Results of studies done at various locations around the world have generally indicated that triticale performs well when compared to other small grains, such as barley, oats and wheat, in particular under dryland conditions (NRC, 1989; Jedel and Salmon, 1994; McCartney and Vaage, 1994; Stallknecht and Wichman, 1998; Juskiw, Salmon and Helm, 1999; Maloney, Oplinger and Albrecht, 1999; Rao, Coleman and Volesky, 2000; Hinojosa *et al.*, 2002; Juskiw, Helm and Salmon, 2000).

Winter-spring mixtures

Depending upon location, a mixture of a winter and spring type can be planted together in the autumn (mild climates) or spring. The advantage is that forage production is distributed more evenly over the growing season and the growing season can be extended. This option would be particularly advantageous for grazing.

Triticale-small grain mixtures

Mixtures of triticale with other cereals, in particular barley, work well in the production of high-quality silage. Advantages for these mixtures include extension of harvest period, disease control and decreased lodging.

Triticale-annual ryegrass mixtures

Initial grazing field research has suggested that planting triticale and ryegrass in combination could lengthen the grazing season, improve the trampling tolerance of the annual pasture and improve palatability when compared to their monocultures (Lozano del Río *et al.*, 2002). The nutritional quality was found to be similar to their monocultures (Lozano del Río *et al.*, 2002). Triticale has also been found to persist longer than rye in mixtures with ryegrass (NRC, 1989).

Triticale-legume mixtures

Intercropping legume crops with small-grain cereal crops can be an effective way to improve forage quality and the nutritive value of the crop. This cultural practice is particularly well suited for silage production. The best relationships between yield and quality were generally obtained when the cereal reached boot stage and the legume reached flowering stage (Carnide *et al.*, 1998). Mixtures where triticale was the cereal showed an advantage over mixtures with other cereals (barley and oats) in overall forage quality due to a higher proportion of legume in the forage crop harvested (Benbelkacem and Zeghide, 1996). This is due to the more upright growth habit of triticale compared to oats and barley. Mixtures with field peas (*Pisum sativum*) and hairy vetch (*Vicia villosa*) seem to work best not only for silage but also for hay production (Carnide *et al.*, 1998).

OTHER USES

Triticale as a grazing crop

Triticale can be and is planted as an annual crop to be grazed by ruminants. Triticale varieties are available that have been specifically selected for grazing. Depending upon location, the crop can be planted in the autumn or spring. To extend the grazing season, autumn varieties can be planted as a mono-crop or in a blend with spring varieties in the spring in cold climates. In warmer climates, the crop can be and is planted in the autumn, and depending upon moisture and temperature, can be grazed starting early the following spring. The crop is grazed until it senesces in early summer. Forage quality and biomass yield usually decline after heading. In colder climates, the crop can be grazed starting late spring and grazed through the summer and even into autumn.

Grazing should be started when the plants are about 25 to 30 cm high and before jointing. This will occur six to eight weeks after plant emergence for most grazing types under good growing conditions. Plants should not be grazed lower than 7 to 10 cm. Severe over-grazing should be avoided. Triticale grows rapidly in the spring, and as the plant nears maturity, nutritional quality declines. Early growth is quite lush and high in moisture, and diarrhoea in the animals is common at this stage of grazing. Providing dry-grass hay or straw while grazing can help minimize diarrhoea. A complete cattle-grazing mineral mix free choice is recommended while animals are grazing.

Triticale as silage

The cutting and subsequent storage of triticale forage for silage is similar to that of any small-cereal forage. The harvest date of triticale for silage is very important. As plants develop beyond the boot stage and into early grainfill, the protein and energy levels drop while the fibre level rapidly increases. Although there is a general increase in dry-matter yield as the crop matures, the increased yield is more than offset by the reduction in forage quality. Consequently, the best time to cut triticale for silage is in the boot to early-heading stage. Triticale cut earlier than the soft-dough stage will require wilting in order to make high-quality silage. The length of wilting time required will vary, depending on the drying conditions and stage of maturity. Approximately 35 to 40 percent dry matter is desirable for ensiling. Cutting length should be 1 to 5 cm for good ensiling. Silage should be packed tightly to exclude as much air as possible.

Generally, most cereal forages are cut for silage in

TABLE 4

Protein content and *in vitro* digestibility at different phenological stages of wheat, oat and facultative triticale in northern Mexico (dry matter basis)

Species	Protein content (%)			*In vitro* digestibility (%)		
	Stage of growth			Stage of growth		
	Jointing	Boot	Dough	Jointing	Boot	Dough
Wheat	20	17	7	75	73	58
Oat	21	19	12	77	72	58
Triticale	27	19	8	79	76	58

Source: Anonymous, 2001.

the soft-dough to mid-dough stage. Results of some trials with triticale suggest it would be best to cut earlier (i.e. boot stage) (Table 4) (Anonymous, 2001). Harvest at later stages of development will result in a greater yield, but quality will be lower. This forage (silage and hay) would be better suited for dairy dry cows and heifers, and beef cattle.

Triticale as a dual-purpose forage/grain crop

Triticale can be and indeed is used as a dual-purpose crop. In a dual system, triticale is grazed in a similar way as described above, but the animals are removed at plant jointing. The forage can also be cut for green chop or silage up to jointing. The triticale will then mature, and a grain crop is harvested. There are several advantages of this system other than the harvest of forage; for instance, the grain crop is less likely to lodge. A major disadvantage is that there is usually some grain yield loss, usually a 5 to 20 percent reduction (Andrews *et al.*, 1991; Wright, Agyare and Jessop, 1991; Royo, 1997; Royo and Tribó, 1997). Grain yield depends upon environmental conditions, moisture, soil fertility, plant genotype and stage of growth at the time of clipping or grazing. The yield decrease has been mainly due to reduced spike density and/or smaller grain kernels.

Triticale as a hay crop

Triticale, as with other small grains, can provide a good source of hay when properly cut, cured and baled. For best results and quality, triticale should be cut between late-boot and early-heading stages.

Triticale straw

Straw is an important by-product of triticale grain production and is often overlooked. Triticale produces more straw than other small-grain cereals. Straw is frequently the only source of livestock feed in developing countries (Mergoum, Ryan and Shroyer, 1992; Mergoum and Kallida, 1997). In general, nutritive value compares favourably with wheat straw, but there are large variety differences (Flachowsky, Tiroke and Schein, 1991).

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Triticale marketing: strategies for matching crop capabilities to user needs

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Marketing ideally begins by identifying the needs of potential customers, then developing products and marketing programmes to meet those needs. In practice, however, marketing often begins with a product that a developer or producer envisions can satisfy needs. That general vision about product potential leads to marketing efforts to find and serve specific customers who can benefit from the product. Although some marketers may discover triticale in their search for solutions to specific customer needs, most marketers now involved with triticale begin with a vision or belief that triticale can satisfy important needs, then strive to find specific uses and customers for which the crop provides value.

The primary objective of this chapter on triticale marketing strategies is to help farmers, triticale breeding organizations, seed suppliers, policymakers, agricultural development groups and others involved with or interested in triticale to identify, develop and fulfil marketing opportunities for this crop. The chapter also may alert those seeking solutions to specific needs that triticale may provide such a solution. The chapter begins with a general overview of triticale marketing encompassing all product levels (genetics, seed, forage and grain), then outlines a general framework for developing marketing strategies for triticale and concludes with specific examples of triticale marketing strategies.

Triticale marketing began with the first developers of the crop who envisioned how it could provide important benefits. As a result of that vision and over fifty years of plant breeding, production and use of triticale by dedicated "crop champions" (Waters, 1988) all over the world, triticale has become an important option for providing grain and forage and protecting the environment (Mergoum *et al.*, 1998). Whether in an area where triticale is not yet used, or one in which the goal is to expand that use, the marketing challenge is to match up the capabilities of triticale with specific human needs that triticale can meet more effectively and economically than other crops.

The specific marketing challenge may differ between developed and developing economies, between times of surplus and times of shortage, and among differing production and marketing systems. Regardless of the specific situation, the essence of the marketing strategies suggested here is to focus first on the uses for which triticale has maximum achievable and demonstrable value, then over time to expand the area of overlap between triticale's capabilities and human needs. That expansion can be accomplished by developing new triticale varieties and production systems to meet those needs more effectively, and by helping producers and users discover and increase value from triticale. In that sense, marketing strategies identify and fulfil the most promising immediate opportunities, while shaping products and customer demand to create future opportunities. Triticale marketing encompasses marketing at many levels, from seeking funding for triticale research and development programmes, to selling seed or grain. Each level involves somewhat different marketing challenges, but success at each level is interrelated with success at the other levels, and success at all levels ultimately depends on the ability to demonstrate the competitive advantage of specific triticale products to meet specific needs.

TRITICALE CAPABILITIES AND MARKETING OPPORTUNITIES

Compared to other crops, the capabilities of triticale in general include higher yields of grain and forage with fewer production inputs and potentially less impact on the environment. As reported in other chapters, the needs that triticale can fulfil include grazing, ensilage, hay, grain for feed, food and industrial use, protection of soil from erosion and nutrient uptake to prevent water pollution. Because triticale fulfils such widespread and fundamental needs, its potential impact is far-reaching and its market potential is large. Described below are some of the advantages of triticale:

- Triticale is better than common wheat in the use of soil nutrients, stress tolerance, pest problems and benefits for soil and water quality. The shift of some hectares from common wheat to triticale will provide environmental benefits by improving nutrient management and reducing the need for pesticides.
- The local production and use of triticale grain for

feed provides producers with additional local marketing opportunities and can help recycle nutrients from animal-feeding operations.

- The superior protein quality and phosphorus digestibility of triticale grain can reduce nitrogen and phosphorus effluent from livestock.
- Triticale's superior root system and high biomass production, combined with its superior tolerance to lagoon water, make it an ideal crop for managing nitrogen and phosphorus from dairies and other animal-feeding operations.
- In addition to direct economic and environmental benefits, triticale also provides indirect benefits by diversifying the production environment and the mix of crops being marketed.
- Triticale pasture is more productive, more tolerant of stress and has a longer season than pastures of common wheat. Triticale in place of common wheat planted early for grazing could significantly reduce the build-up and spread of pests to surrounding late-planted wheat.
- Where common wheat is now used for both grain and forage, greater use of triticale for forage would allow wheat breeders and producers to focus more on the breeding, selection and management of common wheat for grain milling and less for forage. Similarly, triticale feed grain can satisfy the need for 'feed wheat' varieties bred for high yields, which are of interest to some producers in areas where common wheat grain is sometimes used for feed. By meeting the need for forage and feed grain, triticale favours the development and production of common wheat targetted specifically for milling and baking.

The marketing opportunities for a particular triticale programme depend on its products and overall resources and capabilities, and the obstacles it would face in pursuing the opportunities. Inevitably, resources are insufficient to pursue all of the marketing opportunities, so priorities must be established and effort and resources directed accordingly. Priorities can be set by rating the potential opportunities and the ability of the programme to fulfil each of them based on:

- product concept;
- product development capability;
- current products;
- protection of intellectual property;
- production;
- distribution;
- promotion; and
- sales.

Each of those aspects of the programme can be rated as being empowering (i.e. a key competitive advantage), adequate, inadequate, or uncertain. The assigned rating is based on the nature of the opportunity, the capabilities of the programme and the obstacles that the programme faces to fulfil the opportunity. A first step to prioritizing opportunities for the programme is rating the strength of the product concept for each of the marketing opportunities, identified by geographic region and end-use, for example. After addressing these questions about 'is it worthwhile to do', the question is 'can we do it' based on the product development capability of the programme in light of the obstacles it must overcome. The short-term answer to that question already may be known if the programme already has products for that marketing opportunity. Rating the strength of products already developed for that marketing opportunity is the key basis for establishing immediate marketing strategies and priorities. For rating both immediate and long-term opportunities, the protection of intellectual property (e.g. plant breeders' rights) is an overriding concern for any triticale programme that must sustain itself with revenue from the use of the products it develops. Triticale seed is easy to multiply and to use without authorization from the plant breeder or other owner of the variety. In some geographic areas, the high risk of violation of plant breeders' rights significantly limits the potential of marketing opportunities for triticale there. Finally, the rating of marketing opportunities depends on the capability of the programme to produce, distribute and promote the product, and especially on its ability to translate those capabilities into sales.

The general capabilities of triticale as a species may generate interest, but the success of a specific marketing programme depends on the particular strengths and benefits of the specific triticale products that the programme has to offer the market. The triticale crop species consists of a diverse collection of varieties and germplasm in terms of both agronomic characteristics and suitability for various uses. Each variety has its own combination of strengths and weaknesses concerning types of uses, tolerance to cold and pests, soil problems and other potentially limiting factors. A first step in marketing a triticale product is to inventory its features and benefits for specific uses. The tremendous diversity of capabilities and uses for triticale underscore the need for thorough, disciplined evaluation of which uses offer the most promising marketing opportunity for the specific triticale products that are being marketed.

PRODUCT DIFFERENTIATION

An important part of any marketing strategy is product differentiation, in this case establishing how a triticale product that is being marketed differs in a positive way from other crops and other triticale products. A useful approach for identifying potentially important points of differentiation is to focus on the criteria that are most important in customers' buying decisions and on the features of the product that could provide the most benefits as perceived by the customers. Triticale often competes with common wheat in the growers' decision about what to grow and for some end-use markets, such as forage and feed grain. In a generalized comparison between the two crop species, triticale has important advantages over common wheat, including higher yield potential in many environments, better resistance and/or tolerance to biotic and abiotic stresses and a higher concentration of essential amino acids, such as lysine, although current varieties of triticale are not as valuable as common wheat for large-scale, commercial bread making.

Of course the key comparison in practice is how a specific triticale variety compares with the best available wheat variety. Increasingly, as use of triticale increases, the marketing challenge becomes less one of differentiating triticale from other crops and more one of differentiating the specific triticale product from other triticale. In competing against both other crops and other triticale, key points of product differentiation in important markets in the United States of America include: (i) forage yield for pasture, silage and hay; (ii) tolerance to heavy grazing, pests and drought; (iii) high uptake of nitrogen and phosphorus for managing nutrients from animal-feeding operations; and (iv) yield of grain used for feed. In Brazil, the main point of differentiation of triticale from common wheat is its adaptation to acid soils (Mergoum *et al.*, 1998), while in North Africa and Australia, drought tolerance, disease resistance and high biological yields are the main points of product differentiation of triticale from other crops (Mergoum, Ryan and Shroyer, 1992). In other parts of the world, the key points of differentiation may be different, but in all cases the identification of those key points is an important part of developing a marketing strategy.

TRANSLATING BIOLOGICAL POTENTIAL INTO MARKET POTENTIAL

Of course the potential of a particular marketing opportunity depends on much more than just the biological or technical potential of a triticale product for a particular use and market area. Among the other factors that should be considered are the prospects for convincing potential customers about the benefits of the triticale product, the means of providing customers with the triticale product and information supporting its use and the ability of those marketing the triticale products to sustain financially their efforts serving the targetted marketing opportunity.

The use for triticale that has the largest potential area of production or the largest potential benefits in aggregate or per hectare may not be the most promising marketing opportunity. For example, triticale may have tremendous biological potential for the production of forage and grain but government subsides may favour the production of other cereals, or limited use of purchased certified seed may limit seed sales.

MARKET SEGMENTATION

The grain, forage and conservation uses for which triticale is well suited in many cases involve large, extensive markets encompassing large geographic areas and many producers and users. Attempts to market a triticale product over so large a market from the beginning of the marketing programme can spread the marketing resources and efforts too thinly to be effective. One approach to a large, extensive market is to identify and concentrate on small segments within it for which the triticale product is particularly valuable and for which the marketing programme is well placed and well suited. Along with product differentiation, this process of market segmentation is an important one in developing and implementing a marketing strategy. The smaller, more finely targetted segments of a market can serve as 'models of success' that are worthwhile in themselves and that can be used to document and exemplify benefits for subsequent marketing to other segments in the larger, overall market.

This process of targetting small segments of a larger market is simply an extension of the more general evaluation used to identify which uses offer the greatest immediate opportunity for the triticale products that are being marketed. The goal of the evaluation and targetting is to identify and pursue the specific marketing opportunities that can provide the best immediate results and generate momentum and validation for marketing to larger markets. For example, triticale has significant potential as a feed grain for swine and poultry in the Southeast United States of America (see section "Triticale grain for the Southeast"). Within that large region and type of use, triticale has especially great potential where production conditions are particularly favourable for triticale compared to competing crops and end-users are familiar with triticale and prepared to offer a favourable price for it. By concentrating on those areas that are particularly favourable for the production and sale of triticale grain, the marketing effort has the greatest chance of immediate success and a basis for later extending the marketing effort into other areas within the larger target market.

LARGE COMMODITY MARKETS AND SMALL NICHE MARKETS

For most users of triticale feed grain or forage, that grain or forage is simply a bundle of nutrients. The demand is not for the triticale feed grain or forage *per se*, rather the demand for the grain or forage is derived from demand for the feed energy, amino acids and other essential nutrients needed to produce the livestock product. The fact that, for some uses, triticale can be viewed as a bundle of the same feed nutrients for which there are already large, established markets is an advantage in that the marketer can tap existing demand and markets rather than having to develop demand and markets for a totally new product. On the other hand, the fact that demand for triticale reflects the underlying demand for the nutrient content of the triticale poses problems because triticale must compete with many substitute products that can provide the same nutrients. Most current uses for triticale, for example, are grazing, silage and hay, for which close substitutes are readily available. The availability and cost of those substitutes are important in determining interest and demand for a triticale product.

Similarly, on the supply side, farmers typically have other similar crops that they have been growing instead of triticale. The similarities between triticale and the other crops, such as common wheat, facilitate triticale marketing from the standpoint that farmers already have the knowledge and equipment needed to produce the crop; but at the same time, it constrains triticale marketing because of competition from the similar, substitute crops that the farmer could grow instead of triticale. The additional benefits to farmers from growing triticale instead of those competing crops must be large enough to motivate a change to triticale.

Marketers of triticale products for commodity markets for feed nutrients, for which there are many substitute sources, must evaluate the strength of their product compared to all those other sources, not only against other triticale products. A triticale product may be the best triticale available for meeting a specific need, but might still not be successful because other substitute products may be superior for meeting that need. A thorough, objective evaluation of the relative strengths of the triticale product compared to all possible substitutes is essential to understanding the marketability of the triticale product. Conducting this evaluation can be difficult for triticale marketers, many of whom have had to be "crop champions" with the vision, commitment and persistence to overcome the many obstacles faced in the establishment of a new crop such as triticale. The challenge is to be realistic and practical while retaining the passion and persistence needed to succeed.

For a triticale variety that yields substantially more with comparable inputs than a competing crop that produces a similar bundle of feed nutrients, the most easily developed markets in the short run may be those commodity-like feed nutrient markets because those markets are readily available if the price of the product is competitive for the buyer. In the long run, however, the most attractive markets for a triticale variety may be those for which the variety, or at least triticale in general, is uniquely suited and for which there are no close substitute products. One example is the use of triticale for food products that specify triticale on the label, or that depend on triticale for a unique product characteristic, such as flavour, health benefits, or simply novelty.

Demand for triticale for food use is currently very limited, but provides a stable, worthwhile niche for some producers. Because many varieties of triticale tend to have fewer significant pest problems and produce more for a given level of inputs than other competing crops, triticale may be a good option for organic production for food or feed use.

Another marketing opportunity for which triticale is differentiated from other products is for use in nutrient management plans for some dairies that specify that triticale be used to take up nitrogen and phosphorus and minimize the movement of those nutrients into surface water and groundwater. To comply with the required management plan, dairy producers must plant triticale rather than other competing crops.

These specialized uses for which triticale has unique benefits that differentiate it from other products are typically more difficult and time-consuming to develop and are small compared to the large commodity-type markets, but may provide more rewarding and stable returns in the long run.

A TRITICALE MARKETING CHAIN

The marketing of triticale occurs at multiple links in a chain that extends from genetics to the ultimate use of forage and grain. An individual marketer or organization may have products at only one single link, or may vertically integrate multiple links in that chain. For example, a triticale breeding organization may focus exclusively on developing varieties and then sell the rights to produce and market seed of those varieties to seed companies, or it may itself engage in the production and marketing of seed and perhaps even grain of the varieties it develops. Even if they do not directly participate in marketing at more than one link in the chain, every marketer of triticale should be attuned to production and marketing at the other links.

A production or marketing problem at any link in the chain can disrupt marketing at all the other links. The importance to marketers at any one link to what is happening at the other links is even greater for triticale than it is for other crops, such as wheat, because the marketing chains for the other crops are already well established. The greater importance of knowledge about the entire marketing chain, and possible need to participate at other links in that chain, adds to the challenges of triticale marketing and is an important distinguishing feature of triticale marketing compared to the marketing of wheat and other well-established crops.

A useful tool for analysing a triticale marketing chain is a role chart that lists all the links and all the roles that must be filled to put each link in place (Table 1). The role chart highlights the fact that the marketing of triticale encompasses the marketing of many different types of products, from genetics to food, each with its own set of potential customers and buying criteria. Each link in the chain entails:

- financing to cover cost;
- management to guide completion of the link; and
- the actual performance of the work involved.

All three roles at a link might be performed by one organization or they may be divided among multiple organizations.

The role chart can be used by an individual marketing organization to map out its own position along the chain and to map out the positions of other organizations that compete with it or perform complementary roles. Charting which organizations perform which roles may reveal weak links that must be strengthened, or suggest where alliances could be formed to strengthen the overall chain. One organization may provide multiple links, which need not be consecutive. For example, an organization that is strong financially and strong in the contracting and handling of triticale grain may be well positioned also to finance and handle the production of triticale seed. Unlike other crops for which the handling of seed is quite unlike the handling of the ultimate crop produced from that seed, the bulkiness of triticale seed, and consequently the large amount of seed needed for planting per unit area, may favour a marketing chain in which organizations that handle grain also handle seed, especially if the organizations are contracting the production of grain by the grower customers who purchase the seed.

In addition to being important because success at any one link depends on success at the others, the way marketing is conducted at one link may directly affect how it is done at another link. In fact, measures taken at one link can solve problems at another link that would be difficult to solve at that link in isolation. For example, 'closed loop' programmes in which seed is only sold to farmers who are part of a cooperative effort to produce and market grain can help coordinate grain supply and demand to the benefit of both farmers and grain users as well as deter illegal seed production and sales. More generally, integrating activities and products across multiple links to produce an overall system solution, a package of products and services, can enhance the value of each product and service to the ultimate customer and thereby contribute to success at all links.

Triticale genetics and seed are an integral part of most triticale marketing efforts at this point in the development of the crop. Although not specific to triticale, Johnson Douglas' book on the planning and management of seed programmes provides useful guidelines for successfully promoting the use of seed of improved varieties (Douglas, 1980). These guidelines are targetted primarily for seed programmes in developing countries.

In addition to the marketing that occurs at each of the links in the chain, triticale marketing also encompasses the overall marketing of triticale as a crop in a more general sense. Efforts to raise awareness about triticale in general and the benefits it can provide are important for all those involved with triticale at any link in the chain because it strengthens demand for the crop at all links. Policymakers in particular may be the focus of, or themselves focus on, the general marketing of triticale as a crop, for example, for addressing issues related to subsidies that favour other crops over triticale.

Another potentially important audience for triticale marketing is organizations that provide products or services that are potentially complementary with triticale. For example, the producers of crystalline amino acids, which together with triticale grain can totally replace soybean meal in some livestock diets, could be potential

TABLE 1
Example role chart for a triticale grain programme

Activity	Who performs?	Who manages?	Who finances?
Identify customer needs and product opportunities			
Develop, release and protect crop varieties to meet needs and fulfil opportunities			
Demonstrate the benefits of the product to growers and grain users			
Develop and communicate information to motivate and instruct sales representatives, customers and influencers			
Affirm commitment from grain users to buy triticale grain at a predictable price; obtain contract from grain users			
Assess demand and set production area target			
Produce, process, assure quality of, store and manage parent seed			
Produce, process, assure quality of, store and manage commercial seed			
Make seed conveniently available in desired form			
Manage unsold inventory			
Reiterate and individualize benefits of product offering to grower customers			
Obtain signed production contracts from growers			
Deliver seed and collect payment			
Provide technical support for optimal product use			
Receive grain			
Pay growers or if a marketing pool, manage records and inventory for future payment			
Store, transport and analyse grain as needed to fulfil grain buyers' specifications			
Collect payment from grain buyers			
Follow up with grain growers and users to reinforce benefits and refine programme			

allies in the development of markets for triticale grain.

For each marketer, the interdependencies among links of the marketing chain and the benefits of effective coordination among those links add to the importance of developing good working relationships with the people involved at those other links.

CREATING NEW MARKETING OPPORTUNITIES FOR TRITICALE

This discussion of triticale marketing strategies has emphasized the role of marketing in identifying and fulfilling the current potential of triticale. Marketing strategies also have important roles to play in developing new triticale varieties and in creating new marketing opportunities. Marketers can assist triticale breeders by identifying and prioritizing marketing opportunities, for example, by elucidating the combinations of grain yield and quality that provide the highest value of feed grain production per hectare. Marketers can create new opportunities by encouraging changes in agricultural production that favour triticale, for example, by encouraging greater reliance on cool-season cereal forage such as triticale as a means to reduce water use and environmental impact while still achieving high yields of high-quality forage.

Whether fulfilling current opportunities or creating new ones for the future, marketers of triticale are fortunate in that triticale has the potential to fulfil a diverse range of fundamental needs across a wide range of production environments. To the extent that triticale can fulfil those fundamental needs more effectively and efficiently than other products, there will always be markets for triticale regardless of whether the emphasis at the time is on productivity, costs of production, or environmental impact. Marketing strategies that match triticale varieties with the needs for which they are the best solution create a solid, sustainable base for the development of triticale into a major crop.

In summary, the key aspects of strategies for marketing triticale include:

- Identify the features and potential benefits of the specific triticale product (i.e. the crop capabilities) that differentiate it from other crops and other triticale products.
- Identify and focus on the uses and customers (the segments of the market) for which those features and benefits are particularly valuable (i.e. find the strongest match between crop capabilities and customer needs).
- Assess the ability of the marketing programme to reach those potential customers with the marketing message and then with the product and to obtain the payback needed to sustain the programme.
- Among the customers for whom the triticale product has value, focus marketing efforts first on specific market areas and customers that are readily accessible by the marketing programme, which would serve as influential models of success.
- For those models of success, and ultimately for the broader marketing effort, individually, or in cooperation with others, forge all links in the marketing chain that extends from the breeding of triticale varieties, to seed, to end products and finally to the ultimate user of the triticale product. Strive to have each link performed by those most effective and efficient at performing it so that the overall chain creates maximum net benefits for customers and for those performing the necessary roles.
- Build the programme by demonstrating, documenting and communicating the benefits provided to customers by the product and by preventing unauthorized use of the product.
- In addition to the marketing of specific triticale products, promote triticale in general as a crop that deserves consideration and equitable treatment by policymakers, regulatory and funding agencies and producers of complementary products that enhance the production or use of triticale.
- Expand markets by improving triticale varieties and systems of use and by helping producers and users discover and increase value from triticale.

A CASE STUDY: TRITICALE MARKETING STRATEGIES IN THE UNITED STATES OF AMERICA

An important feature of the marketing strategies exemplified in the following case study is the importance placed on building linkages along the complete marketing chain from genetics to end-users. Communication, coordination and building of strong relationships are key to building those linkages. Enough value must be created, preserved and shared to assure that participants at all links in the chain are adequately repaid for the roles they play. Prospects for doing so are best if each role is performed by those who are the most efficient and effective at performing that role and if those different roles are coordinated to enhance the overall efficiency and effectiveness of the entire chain.

Triticale forage markets

Forage markets have proven to be good starting points for the commercial development of triticale in the United States of America. In most cases, in those markets the grower of the triticale is also the user of the product produced, so the marketing chain is shorter and the coordination of supply and demand is much less of an issue than where different producers and users must be brought together to create a market. The use of triticale for grazing in the Southern Plains of the United States of America is the oldest and largest market for triticale forage in the United States of America (Fohner, 1990).

Triticale for the Southern Plains

The match between triticale and critical needs

Wheat and beef cattle are mainstays of the farm economy in the Southern Plains. Wheat is the region’s primary crop in terms of area and total value. In addition to the value of the grain it produces, wheat pasture contributes significantly to the region's beef production. In recent years, wheat pasture has become increasingly important economically relative to wheat grain. Even as a grain crop, the value of wheat is linked to the livestock industries because in many years a large proportion of the wheat grain is used for feed grain.

Triticale has important advantages over wheat for pasture, hay and feed grain (Table 2). Insects, diseases and limited moisture are major constraints on the use of wheat for pasture. The superior tolerance of triticale to these constraints allows earlier planting, extended grazing and higher forage production. These tolerances also contribute to higher grain yields in triticale.

The opportunity and need for triticale are increasing as government farm programmes become more flexible and less sufficient for maintaining farm income. The need is particularly great for dryland farms and for irrigated farms facing restricted availability and higher cost of water. As a complement to wheat, triticale can contribute significantly to the profitability of agriculture in the Southern Plains. A market study conducted in 1995 gauged the potential opportunities for triticale in that region (Resource Seeds, 1995).

TABLE 2
Potential of triticale to satisfy critical needs in the Southern Plains

Critical needs of agriculture in the Southern Plains
• More productive, longer duration pasture for beef cattle
• Profitable crops for dryland farms
• Profitable crops that require less water than maize or alfalfa for water-restricted, irrigated farms
Key features of triticale for forage in the Southern Plains
• Higher forage yields than wheat or rye
• Not a weedy contaminant like rye or ryegrass
• Better adapted than wheat for early planting and autumn grazing
• Longer grazing in the spring than wheat or rye
• Superior tolerance to drought, pests and low pH
Key features of triticale for grain in the Southern Plains
• Higher grain yields than wheat or rye
• Lower production costs and water requirements than maize
• Higher protein content and quality than maize
• Higher feed value and profit potential than sorghum

Forage area

Although a dual role as both a forage and feed grain is the eventual goal for triticale in the Southern Plains, grazing is its most immediate opportunity. Even without including 'permanent' pasture, over 12 million ha of cropland are used for forage production in the three 'core' states of the Southern Plains: Kansas, Oklahoma and Texas. Of this, approximately 4.8 million ha are small-grain pasture and hay, of which about 90 percent is wheat and 10 percent is triticale, oats, rye and barley. More than 4.5 million ha of the small-grain total is used for pasture (Bureau of the Census, 1994).

Wheat pasture and graze out

Most wheat used for pasture is also harvested for grain. However, depending on growing conditions and the prices of wheat and cattle, some wheat hectares are used only for grazing and are not harvested for grain. The number of these 'grazed-out' hectares varies from year to year. In 1992, a typical year, 1.5 million ha of wheat in the Southern Plains were grazed out, used only for pasture and not harvested for grain. These 1.5 million ha are a primary target for triticale (Resource Seeds, 1995).

Wheat area on livestock farms

Further segmenting the market using data from the 1992 United States of America Census of Agriculture, the market study conducted in 1995 obtained additional insights (Resource Seeds, 1995). In addition to the 1.5 million ha of wheat grazed out, another 2.1 million ha were grown on farms for which beef cattle was the primary source of income. Combined, the grazed-out hectares and wheat grown on farms where livestock is the primary enterprise, these two market segments represent about 3.6 million ha of wheat oriented around livestock production and positioned to capture directly the maximum economic benefits of triticale through the combination of crop and livestock enterprises.

Cattle ownership by cash grain farms

The opportunity for maximum benefits from triticale are not confined to livestock farms, however. In some parts of the Southern Plains, especially Kansas, a significant proportion of stocker cattle are owned by farms for which cash grain is the primary source of income (Bureau of the Census, 1994). Similar to livestock farms that have significant wheat area, crop farms that have significant stocker herds can directly capture the maximum benefits of triticale.

Positioning triticale for current marketing opportunities

In the future, changes in government farm programmes and improved baking quality of triticale may make triticale a more direct substitute for wheat in the Southern Plains. For now, however, triticale is best viewed for that region as a complement to wheat as part of whole-farm 'graze and grain' programmes for crop and cattle production (Table 3).

To provide pasture, approximately half of the wheat hectares in the Southern Plains are planted earlier than is optimal for grain production. Early planting of wheat has two major drawbacks: (i) early-planted wheat generally yields far less grain than later-planted wheat, up to 50 percent less in research by Texas A & M University (Winter, 1994); and (ii) early-planted wheat becomes a source of diseases and insects that spread to surrounding wheat and reduce its productivity (Sears, undated). Consequently, early-planted wheat can reduce yield on surrounding, later-planted fields in addition to having lower yield itself (Sears, undated).

Triticale is an ideal replacement for early-planted wheat because of its superior forage production and greater resistance to diseases and insects. That resistance minimizes yield losses and avoids the build-up of pests that would spread to surrounding fields. Triticale performs well even when planted earlier than is common for early-planted wheat.

In addition to early-season benefits, triticale provides important late-season benefits. Triticale provides substantially more forage in the spring than does wheat in terms of both amount and duration. The greater production from triticale pasture can reduce spring grazing pressure on the farm's wheat hectares so those wheat hectares can be managed more favourably for grain yield while the farm's forage production and cattle gains are maintained.

Triticale can increase farm profitability directly as a more productive source of forage and feed grain and indirectly by helping improve the management and health of wheat on the rest of the farm. Wheat varieties can be chosen and managed with greater emphasis on grain production. In that respect, triticale is a particularly valuable complement to value-added wheats in the Southern Plains, such as white and high-protein varieties.

TABLE 3
Strategic framework for marketing triticale in the Southern Plains

Description
• A comprehensive management programme for optimal use of wheat, triticale and stocker cattle
Objective
• Maximize net farm income from cash grain and livestock enterprises
Programme highlights
• Early planting of triticale on areas that would otherwise be early wheat planted for grazing
• Later planting of wheat to avoid stress and pests and to increase grain yields
• Wheat variety chosen and managed with greater emphasis on grain yield and value
• Earlier, heavier grazing of triticale in the autumn; light winter grazing of wheat
• In spring, concentration of cattle on triticale
• Longer graze-out season on triticale than is possible with wheat
Variations in programme
• Graze out triticale
• Instead of grazing out triticale, harvest it for hay or feed grain
• Grow a dual-purpose triticale variety that has been developed for grazing and subsequent harvest for grain
Benefits of triticale in the programme
• Earlier autumn grazing
• More forage production per unit area
• Avoids build-up of insects and diseases on early-planted wheat
• Increase in wheat grain yield per unit area while enhancing farm's stocker cattle programme
• Extended grazing season to increase production and widen marketing window
• Graze out or take advantage of the significantly higher grain or hay yields of triticale compared to wheat or rye

Economic benefits of triticale

Partial budget analysis – comparing differences in gross revenue adjusted for differences in production expenses – indicates that in livestock-producing areas in the Southern Plains triticale is more profitable than wheat on hectares not receiving government deficiency payments. For both irrigated and dryland production, triticale provided substantially higher net income than wheat from graze out or a combination of grazing and grain harvest. Primarily as a result of its greater forage productivity, on average triticale had a per hectare advantage in dryland and irrigated production of US$62 and US$133, respectively, over wheat planted in early September and US$82 and US$168, respectively, over wheat planted in late September (Resource Seeds, 1995).

Although seed cost per hectare is typically higher for triticale than for wheat, its payback for farmers was over four times that added cost.

The economic benefits of triticale are also pronounced when analysed within the context of a ‘representative’ farm having 259 ha used for a combination of grazing and grain production. As a replacement for early-planted wheat, triticale provides higher income than the early-planted wheat it replaces and reduces the incidence of insect and disease on the farm’s other wheat hectares. Consequently, net farm income is increased by higher yields from the other wheat on the farm in addition to the higher income from the triticale itself. In the analysis, the combination of direct and indirect benefits resulted in increased net farm income for dryland and irrigated farms from US$74 to US$232 per hectare of triticale on the farm (Resource Seeds, 1995).

Obstacles to successful triticale programmes

Two obstacles have limited the success of triticale programmes in the Southern Plains. The first obstacle is United States government loan and insurance programmes that favour common wheat over triticale. These loan and insurance subsidies available for wheat but not triticale discourage the planting of triticale throughout the United States of America. The second obstacle does not limit the planting of triticale directly, but has greatly limited investment in the development of triticale varieties and programmes for the Southern Plains. This obstacle is the frequent violation of plant breeders’ rights in the region and the low percentage of triticale and wheat hectares planted with certified seed or even professionally produced seed. Low use of purchased certified seed has also been cited as a problem for triticale breeding programmes in Europe (Arseniuk and Oleksiak, 2002; Weissmann and Weissmann, 2002).

The ideal measures to protect plant breeders’ rights are ones that also increase yield. For example, blends of multiple triticale varieties that have complementary growth habits can be superior to any single variety in terms of the duration, total quantity and reliability of pasture production. These blends also discourage unauthorized seed use and violations of breeders’ rights because they tend to be difficult to harvest and manage for seed production and because the component varieties rarely produce seed in proportion to their percentage in the original blend.

The development of hybrid triticale would increase yield as well as limit the use of unauthorized seed. The significant heterosis found for yield and the prolific pollen dispersal and extended receptivity found among triticale varieties suggest that hybrid triticale could provide substantial benefits for farmers and could be economically feasible to produce with the systems of cytoplasmic male sterility (CMS) and other approaches now being developed (Warzecha and Salak-Warzecha, 2002; Burger, Oettler and Melchinger, 2002). For some markets, such as the grazing market in the Southern Plains, even the use of hybrids may not deter unauthorized use and illegal sale of seed. When hybrid wheat was marketed into that region in the 1990s, widespread harvest and planting of F_2 seed (i.e. seed harvested from the hybrid plants) was reported for some areas where grazing was the primary use.

This pattern of seed use reflects other underlying obstacles to triticale marketing in the Southern Plains. These obstacles include the high risk of crop loss and low economic returns for farming in many parts of the Southern Plains and a traditional aversion to any constraints on the free use of farmer-saved and locally traded seed. Some estimates are that the certified seed is used on less than 5 percent of the wheat area in the state of Texas, which is a primary target market for triticale in the Southern Plains. Wheat, triticale and other small grains are typically planted in the Southern Plains with seed saved on the farm, sold among farmers, or sold by unauthorized seed cleaners who do not pay the plant breeder for use of the variety. Despite these two significant obstacles, triticale area continues to increase in the Southern Plains, and a small number of private and public breeding programmes continue to provide varieties for production there.

Triticale for dairy ensilage

Another forage market that has become a good market for triticale is the market for dairy ensilage in the western part of the United States of America, where most of the growth in the country’s dairy production is occurring. Critical issues for the dairy industry in the western United States of America include nutrient management, availability and cost of water and cost of forages. Varieties of triticale adapted for forage production in that region are providing high yields of high-quality forage, while helping manage nitrogen and phosphorus in the dairy effluent and requiring less water for production than most other forages (Table 4). The triticale dairy silage crop is typically planted in the autumn and harvested in the spring in combination with a summer annual forage, such as maize silage. In the most productive, long-season areas,

TABLE 4
Features and benefits of triticale forage

Features	Benefits
Annual growth habit	Quick source of forage Quick payback on production costs Flexible in crop rotations Fast response to changing economic and production conditions
Cool-season crop	Efficient use of soil moisture Less vulnerable to drought Double crop with warm-season crops Complements warm-season crops in terms of workload, production inputs and feed supply Reduces soil erosion Aids management of nitrogen and manure during the cool season; utilizes nitrogen and prevents run-off and percolation into groundwater
High biomass production	High return of forage and income per hectare and per unit of other inputs
Many potential uses	High potential uptake of nitrogen and phosphorus Versatile source of products for a variety of needs: vegetative or boot stage for high-quality forage post-boot stage for high yields of intermediate-quality forage grazing grain and straw
Deep-rooted and efficient uptake of nutrients from the soil	High yields per unit of available soil nutrients High potential uptake of nitrogen and phosphorus from throughout the soil profile
Competitive with weeds	Minimizes costs, regulatory requirements and undesirable effects of herbicides Helps control weeds that affect other crops in the rotation Helps establish new stands of alfalfa and enhances declining stands with interseeding
Relatively few economic pests	Minimizes costs, regulatory requirements and undesirable effects of pesticides Low risk of major crop loss to pests if crop variety is chosen prudently
Widely adapted	Wide range of varieties allows production under diverse conditions
Low input requirements	Low input cost and financial risk Equipment required is modest and usually already owned for other enterprises
Provides rotational benefits	Helps control pests that affect other crops in the rotation, reducing production costs and increasing yields

that double-crop combination can provide approximately 35 tonnes of forage dry matter per hectare.

For introducing triticale forage into a dairy area, marketing can begin by focussing on the current use of other small-grain cereals for forage. In the past, in the western United States of America, for example, wheat and oats have been the most widely grown small grains for dairy forage. The first step in marketing triticale into that dairy market has been in competition with wheat silage because of the similarities between the two crops, which aids the substitution of one with the other. The recent availability of awnless or 'beardless' triticale will facilitate the substitution of triticale for oats for hay production and thereby strengthen another immediate marketing opportunity.

While focussing on the immediate opportunities to substitute triticale in place of other small-grain cereal forages, marketing strategies should also provide for long-term opportunities to substitute triticale for other forages in production fields and dairy rations. Fulfilling those opportunities requires convincing dairy nutritionists and other key 'influencers' that triticale forage will be a good substitute, a task complicated by the fact that the nutritional attributes of triticale forage, as with all other small-grain cereal forages, depend greatly on the growth stage at which the crop is harvested (Cherney and Marten, 1982). Also, past use of unsuitable varieties and poorly timed harvests have given some nutritionists in the western United States of America the impression that triticale does not provide high-quality forage. The task of demonstrating the benefits of triticale forage for dairy feed is further complicated by the fact that some measures of forage quality, such as neutral detergent fibre (NDF) and acid detergent fibre (ADF), are poor predictors of digestibility and energy value of small-grain forages (Resource Seeds, 1998; Fohner, Shultz and Aksland, 1994). Documenting forage quality and communicating results to dairy nutritionists and others who influence forage production and feeding systems are key parts of marketing strategies to expand the use of triticale forage. Eventually, in addition to displacing other small grains, the economic and environmental benefits of triticale will offer marketing opportunities to increase the use of triticale in the place of other forage crops.

Triticale grain markets

Grain markets have proven to be difficult to develop for triticale in the United States of America. In the last few years, however, the availability of higher yielding varieties and the increased importance of environmental issues have renewed interest in grain triticale in several parts of the country. Three case studies exemplify the marketing strategies that have emerged from this renewed interest, two from the Pacific Northwest and one from the Southeast United States of America.

Triticale grain for the Pacific Northwest

Marketing group I

One effort to develop and serve markets for triticale grain in the region began with university research that demonstrated that two new varieties of triticale developed in Europe produced substantially higher grain yield than common wheat or previously available triticale (Karow and Marx, 1999). The magnitude of the yield advantage suggested that growers in at least some parts of the region could increase income by switching from common wheat to triticale. Previous efforts to develop grain markets for triticale in the region had been hampered by a lack of coordination between producers and users of the grain. Producers were hesitant to grow triticale grain until they were confident that there were buyers for the grain who would pay a satisfactory price. Users of feed grain were reluctant to commit to purchasing triticale grain or to specifying a price until they were confident that supply would be adequate to justify changing to triticale and until they assessed the value of the triticale grain for meeting their needs. The availability of the new, higher yielding varieties provided stronger incentive and renewed interest in trying to bring supply and demand together to form a market for triticale grain.

The institution with rights over the two varieties sought participation from other companies and organizations that together could fulfil all the necessary roles in the marketing chain from genetics to use of grain. Decisions about how to fulfil those roles were influenced by four key considerations: (i) access to the genetics; (ii) coordinating supply and demand; (iii) assurances for grain growers and users; and (iv) maximizing value of the crop.

In light of these considerations, the institution with rights to the two varieties formalized and solidified arrangements with two other organizations to form the core of the marketing effort. Of these two, the first organization was the university group that first demonstrated the potential of the two triticale varieties for growers in the region. In addition to doing excellent research to further document the performance and potential of the triticale varieties, the reputation and communication capabilities of the group was ideal for helping to present the opportunity to growers. The second organization was an agricultural marketing company that markets agricultural inputs, including seed, fertilizer and chemicals, to farmers and also purchases and sells products, such as grain and hay, from farms. This company spanned several links in the marketing chain and could internally coordinate production and marketing of triticale grain.

With the participation of the three organizations, the following programme was implemented:

- The marketing company develops markets and creates demand for grain of the two varieties. Prior to planting time, the company assesses the level of demand for the grain and establishes production targets. Subject to those targets and seed availability, seed of the two varieties is sold to any grower in the region who agrees to use the seed in accordance with the production agreement, which stipulates that the grower will market through the marketing programme all the grain of the two varieties produced under the terms of a signed pre-plant production contract with the marketing company. In addition to paying the grower for the grain, the marketing company is responsible for the cost of operating the marketing programme, for payments due to the grain commission and for additional research assessment and market development costs. Alternatively, with prior arrangements with the marketing company, the grower may use the grain for on-farm feeding or for transfer to a neighbour for feeding. The marketing company does its best to accommodate individual situations. The primary approach for on-farm or local use arranged by the grower is for the grower to repurchase some or all of the grain from the marketing company. To repurchase grain, the grower must warrant in the agreement with the marketing company that the grain will be used to feed livestock on his or her farm or on those of neighbours. All grain is weighed and subject to audit regardless of whether or not it is repurchased. One last variation on possible use of the crop would be if the grower elects to harvest the crop for forage instead of grain, then a nominal fee specified in the grain production contract may be charged at the discretion of the marketing company for voiding the grain production contract.

- Seed is sold to growers at a price comparable to proprietary wheat seed and without being tied to the purchase of other production inputs from the marketing company.
- The price paid to the grower by the marketing programme for the grain is based on a price formula that reflects the value of the grain relative to competing grains as determined in research studies and commercial use. The production contract signed prior to seed sale and planting specifies the method that will be used to set the payment price at the time grain is sold to the marketing company for marketing. The marketing programme strives to assist growers who would like to 'lock in' a fixed contract price prior to harvest and delivery, either directly or by providing information that would help them and their advisors hedge prices.

Briefly, the basic structure of the programme is that the marketing company: (i) contracts seed production with growers in the region; (ii) develops and arranges to supply grain users with the triticale grain; and then (iii) sells seed and contracts grain production of the two varieties with growers in the region to match the demand that the marketing company has generated from grain users. To assure reliable markets for producers, reliable supply for grain users and observance of property rights, seed is only available to growers who participate in the marketing programme or who coordinate their own use of the grain with the marketing programme, thereby creating a 'closed loop' between the seed and grain.

Marketing group II

A different approach to marketing triticale grain was taken by a second group located in a different part of the same region targetted by group I. The group had the same objectives and overriding considerations, but took a different approach reflecting the differences in its strengths compared to those of the organizations in the first marketing group. This second group was led by a company that specializes in applied research and market development. This development company had access to the most promising triticale varieties in the region, the facilities and know-how to multiply and process parent seed stocks and the capability to do small-plot and large-scale testing and demonstration of the varieties. It lacked the financial resources or infrastructure to contract production and handle or manage inventories of large quantities of seed or grain.

The development company sponsored research to quantify the value of the triticale grain for swine and poultry producers in the area, then developed relationships with those buyers to obtain their commitment to buy the grain at a price determined by the research studies and by the lysine content of the grain being sold. To complete a marketing chain from the genetics, to which it had access, all the way through to the end-users of the grain, the development company organized a pool of grain growers who were interested in producing triticale grain and in helping to support financially the marketing of that grain to end-users in their area. The development company also organized a group of grain handlers who wanted to participate in the storage and handling of the grain. Similar to the marketing company in the group I programme, the development company in group II gauged how much grain could be sold to the swine and poultry companies that would use the product, then sought to match that with production from the grower pool. The development company sold seed to the growers either directly or indirectly through the grain handlers who got the seed from the development company, or who were licensed to produce their own. The grain produced by the growers went into storage, was analysed for crude protein and lysine and then was supplied to the swine and poultry producer as requested at a price determined by the lysine content and the prices of alternative feeds at the time of the sale. For the large buyers, price was typically determined by a linear programming model and the matrix of prices of alternative feeds available at that time to the buyer. For some buyers, price was determined with a formula based simply on the price of maize and soybean meal, which are the dominant feeds in the area.

As in the marketing programme conducted by group I, seed of the triticale grain varieties sold by group II was only sold to growers who signed contracts to sell all the grain back to the marketing programme, or who obtained approval from the programme to feed it on-farm or to sell it elsewhere. Coordinating seed sales with grain production contracts helps keep supply and demand in balance at a price that is profitable for growers and competitive for grain users and deters unauthorized use of the varieties, which would deprive the breeders and seed suppliers of revenue needed to support their efforts.

Triticale grain for the Southeast

Several factors favour the development of triticale grain as a feed crop in the Southeast United States of America. Firstly, triticale is grown in the area for forage, and small quantities have been grown for grain in the past. Although previous varieties have not yielded enough to motivate large-scale production for grain, growers and livestock producers are familiar with the crop and supportive of efforts to develop its potential. In addition to there being a history of commercial acceptance of triticale in the Southeast United States of America, triticale is of interest to university researchers and others in the region who conduct research and demonstrations. The potential for supporting triticale breeding with commercial seed sales in the Southeast appears to be adequate. Although seed prices tend to be low, use of professionally produced certified seed of wheat and triticale is fairly high. An important indicator of the potential for triticale grain in the region is the fact that in many years the price at harvest of the soft red wheat grown in the Southeast is typically very close to the price of maize, and a large proportion of the wheat crop grown in the area is used for feed. Triticale varieties that have higher grain yield than wheat would have a higher market value per hectare than the wheat sold in the same feed market, although this yield advantage can be overshadowed by government subsidies for wheat and by growers' reluctance to plant triticale and forgo any chance at occasional high wheat prices for food use. In the competition between triticale and wheat in the Southeast, the triticale varieties have been favoured by their resistance to powdery mildew, which lowers risk of crop loss and the need for fungicides, compared to the susceptibility of most of the wheat varieties. Barley grain production in the region is minimal, but offers another potential market niche where triticale grain could get started.

The Southeast is a leading production region for swine and poultry, and as a region does not produce nearly enough feed to meet the needs of that livestock industry. The livestock producers, and in particular the swine producers, have had excellent results feeding triticale grain. The presence of a large, receptive livestock industry in a feed-deficit area offers a significant opportunity for triticale grain.

One of the most important factors currently stimulating interest in triticale in the Southeast is the environmental problem associated with the large livestock industry in the region. Each year, millions of tonnes of maize and soybean meal are shipped into the Southeast for feed. A significant portion of the nitrogen and phosphorus in that feed ends up in the effluent from animal feeding operations, thereby creating a major environmental problem for the region. Triticale is already being used as a forage crop to help manage effluent and to minimize the movement of nitrogen and phosphorus into streams. Use of locally grown triticale grain as feed would reduce the amount of feed that needs to be brought in from other regions and in effect would recycle livestock effluent back into feed, thereby helping to improve the overall nutrient budget of the region. Use of triticale instead of maize can substantially reduce the amount of phosphorus effluent from feeding operations because of the significantly higher bio-availability of the phosphorus in triticale grain compared to maize. The higher bio-availability results in more efficient use and less excretion of the phosphorus by the animal. Use of triticale grain supplemented with lysine and threonine amino acids can replace soybean meal as well as maize in the ration, producing equally good animal weight gains and meat quality as the maize-soybean ration while reducing the amount of nitrogen excreted from the animal by over 25 percent.

Within this generally favourable environment for triticale grain production, the triticale breeding company that targetted the Southeast for triticale grain developed a strategy that sought to build on the feed and environmental needs of the region and on the interest in triticale among university researchers and the commercial sector (Table 5). The strategy emphasized the benefits of triticale for the growers, livestock producers and those charged with implementing solutions to the environmental challenges of the region.

After identifying the potential benefits of triticale and its place within the region's agriculture, the marketing strategy entailed identifying and involving the organizations needed to fulfil all the roles of the marketing chain. Universities in the region have played a significant role from the beginning by conducting yield trials that document the superior performance of the triticale varieties, feed quality analyses and feeding studies to document feed value and refine feed use, and nutrient management studies to document and refine the use of triticale to improve the use of nitrogen and phosphorus.

TABLE 5
Strategic framework for marketing triticale grain in the Southeast

Critical needs of agriculture in the Southeast

- Profitable crops, especially where soil conditions, frequent summer drought, disease or other factors limit the profitability of wheat and maize
- Management of nutrients in effluent from animal feeding operations to minimize environmental impact

Description of feed grain and nutrient management programme

- Production of triticale feed grain and straw where soil conditions, climate or management practices favour higher net profit from triticale than from wheat or maize
- Use of triticale feed grain to reduce cost of grain in swine and poultry production, reduce phosphorus effluent and in combination with crystalline amino acids reduce nitrogen effluent
- Use of triticale straw for poultry bedding material

Objective

- Increase net income of crop and livestock producers and reduce phosphorus and nitrogen effluent

Crop production highlights

- Grow triticale as part of an annual rotation or double crop with soybeans where light soil, disease or late planting limit wheat yields
- Grow triticale on some hectares in high wheat yield areas for diversification in order to take advantage of superior triticale yields in years when wheat does not command large premiums over maize or triticale
- Grow triticale where soil or climate make maize an expensive, risky choice
- Reduce the cost and environmental impact of crop production by taking advantage of the higher disease tolerance of triticale compared to wheat

Feed use highlights

- Take advantage of the superior amino acid content and profile of triticale compared to maize and wheat to reduce soybean meal requirements and feed cost for swine and poultry
- Achieve further reductions or total replacement of soybean meal to reduce nitrogen effluent and feed costs by using crystalline amino acids with triticale to match the amino acid content of the feed more exactly to the nutritional requirements of the swine and poultry
- Take advantage of the higher phosphorus content and bio-availability of triticale compared to maize to reduce feed cost and phosphorus effluent
- Reduce the total net influx of nitrogen and phosphorus into the farm and region by increasing the use of locally produced feed

Straw for bedding

- Increase income from crop production by selling straw
- Harvest and sell straw to remove more nitrogen and phosphorus from cropland where they are excessive
- Alleviate the shortage of bedding material with locally produced triticale straw
- Use straw-based poultry litter as cattle feed

Variations in programme

- Instead of growing triticale for grain, graze it or harvest it for silage or hay
- In addition to using triticale as a milled feed, experiment with the practice of adding whole-grain kernels to poultry feed. Add 10 to 30 percent whole-grain triticale kernels to poultry feed to fine-tune protein density of the feed as birds grow and to improve animal health and gizzard function, which can improve gut development and protein digestion and reduce nitrogen excretion and wet litter. Improved structural development of the gut from whole grains may reduce tearing during processing and the risk of bacterial contamination as part of an integrated grower-to-processor Hazard Analysis Critical Control Point (HACCP) programme. Feeding of whole-grain triticale can reduce feed cost by reducing milling costs per tonne of finished feed

Based on the work of the university, the breeding company initiated pilot production with progressive farmers and supplied grain to livestock producers for evaluation. While these steps were taken to generate interest among growers and users of grain, seed companies were approached about production and distribution of seed.

In one area, the company approached about seed production and distribution had experience in contracting the production of grain and supplying it ‘identity preserved’ to end-users who sought that particular product. This company was capable of performing several roles at both the seed and grain links in the marketing chain, encompassing the production and distribution of the seed and the purchase of the grain to be supplied to the end-users.

In a second area within the Southeast, the company approached about seed production was the leading supplier of seed to the area, but was not involved with the grain. To provide the link between the growers and users of the triticale grain, the breeding company approached a prominent grain broker who handles grain produced by a large group of leading growers in the targetted area. The role of that broker was first to assess the information supplied by the breeding company about the yield potential of the triticale varieties and about the demand from specific livestock operations for the grain. Based on that assessment, the broker arranged for seed to be delivered to the growers and then merchandised the grain produced by the growers to livestock companies. The involvement of the well-respected broker reassures growers about the overall triticale programme, reliability of markets and payment for the grain they produce and provides the expertise and resources needed to supply the grain to the livestock companies reliably, conveniently and efficiently.

In both areas in the Southeast, the breeding company began at the two ends of the marketing chain: developing superior varieties at one end and securing commitments from livestock companies to purchase the grain at the other end. A key part of developing superior varieties is documenting and communicating that superiority with the help of university researchers and others who are credible third parties. A key part of gaining a commitment from livestock companies to buy triticale grain is to establish the basis on which price will be set. A clear understanding and shared expectation among growers and grain buyers about how the price of the grain will be set is vital to avoid misunderstanding and damage to the marketing programme. Currently the price of triticale grain in the Southeast is equal to that of maize and feed wheat, and in fact triticale grain is commonly mixed with feed wheat. In general, higher valuation of triticale grain is favoured by its higher lysine and threonine concentrations, but that tends to be offset by slightly lower energy values than maize. Some varieties of triticale may command a premium over the price of maize once they are available in quantities large enough to warrant separate storage and adjusted feed formulation. Recent research documenting the benefits of triticale for phosphorus feed use and effluent management may help strengthen demand and prices.

The efforts at the two ends of the marketing chain create and establish the total value of the product and the context within which all the other necessary links in the marketing chain must be filled. The outcome of the ongoing marketing efforts will reveal whether that total value is enough to sustain the efforts of the breeding programme and all those whose fulfil the other necessary links in the two marketing programmes in the Southeast.

A CASE STUDY: TRITICALE MARKETING STRATEGIES IN MEXICO

Potential of triticale to meet important needs

Mexico has long been an important centre of triticale breeding and research, but almost thirty years after the release of its first triticale varieties the area planted to triticale there remains small. Farmers who are familiar with the crop consider it to be a productive alternative, but uncertainties about markets for the crop limit its adoption. A vicious cycle persists of farmers not growing the crop because of uncertainties about markets and end-users not using it because of insufficient availability and lack of knowledge about the functionality of new varieties.

Despite the slow rate of adoption and obstacles to more widespread production, the potential for triticale in Mexico remains compelling. The foundation of this potential is the superior productivity of triticale compared to wheat, its superior tolerance to drought, diseases and low and high pH, and its suitability for some of the same uses for which wheat is currently used in Mexico. As a result of the North American Free Trade Agreement (NAFTA) among Canada, Mexico and the United States of America, wheat from Canada has displaced domestically produced wheat for food products in Mexico. Wheat produced in Mexico is now used primarily for animal feed. Triticale grain could be used for these same feed uses and in fact could be worth more than wheat for those uses depending on the amino acid and energy content of the specific varieties involved. Higher yields and comparable or superior feed value make triticale a superior alternative to wheat production for Mexican farmers, especially in the high-plateau and low-rainfall areas where the performance of triticale has been particularly good compared to wheat. In addition to the potential of triticale grain as a feed grain, Mexican livestock and forage producers have found that triticale forage is superior to oat forage for meeting the need for

TABLE 6
Representative yields and crop values for triticale in Mexico, 2002

Triticale crop	Range of yields (*kg/ha*)	Range of crop values per kg (*pesos/kg*)	Range of crop values per ha (*pesos/ha*)
Flower-stage forage	3 400-5 000	1.00-1.25	3 400-6 250
Grain-stage forage	4 000-7 000	1.00-1.25	4 000-8 750
Rainfed grain	2 000-7 000	1.50	3 000-10 500
Irrigated grain	>8 000	1.50	>12 000

forage for milk and meat production. In addition to its use for feed, triticale can meet an important need in Mexico for food use. Mexico does not produce enough maize to meet demand for food. A blend of 10 percent triticale and 90 percent maize would address that deficit without detracting from product quality. Triticale grain is reported to have a sweeter taste than wheat and is considered superior to wheat for blending with maize. The potential of triticale to meet these fundamental needs in Mexico motivates ongoing efforts to develop markets for the crop there.

Current use of triticale

Although grain for feed and eventually for food is the ultimate objective of efforts to expand production of the crop in Mexico, most of the triticale currently grown in Mexico is used as forage for cattle. The harvested triticale forage is fed to cattle as green forage at harvest time, or made into silage or hay for feeding during the dry season when forage is in short supply. Most of the triticale forage used for milk production is harvested at the flowering stage of development, while some is harvested later at the dough stage when the kernels are between a milky and hard-grain consistency. Protein is higher at the flowering stage, while the later harvest stage is rich in energy and has higher yield. Farmers report that triticale produces higher forage yield than oats and that beef cattle and dairy cows produce more meat and milk with triticale forage than with oat forage; and the meat produced is better. Forage yield is between 3 400 and 5 000 kg/ha at flower stage and between 4 000 and 7 000 kg/ha at hard-grain stage (Table 6). The triticale forage is valued from 1 to 1.25 pesos/kg (10 pesos/US$1).

One limitation to the production and use of triticale forage in the dough and hard-grain stages when yield is highest is the presence of awns on the plants of the main varieties of triticale now grown in Mexico. Awns, or ‘beards’, are needle-like projections on the grain heads that can injure livestock and make the forage less palatable. ‘Beardless’ or reduced-awn varieties that are becoming increasingly popular in the south-central United States of America bordering Mexico are not currently available in Mexico. Seed production of these varieties in Mexico is difficult because they are late-maturing, winter types, and seed cannot be imported because Mexico prohibits the importation of triticale seed from the United States of America.

Efforts to expand production and use of triticale grain

Expansion of the production and use of triticale in Mexico is hindered by several obstacles that limit the adoption of crop technology in general and by some obstacles that are specific to new crops such as triticale. The more general obstacles include lack of awareness about new technology, lack of financial resources to purchase the technology and limited access to inputs and information to complement the new technology.

Improved crop varieties are an important form of potentially beneficial new technology. Lack of financial resources is a major obstacle for many Mexican farmers for purchasing seed of the improved varieties. The significance of that financial constraint, and the linkage between improved varieties and inputs, is highlighted by the patterns of use of certified seed in Mexico over the past thirty years. During the period from 1970 to 1990, 90 percent of the wheat seed planted by Mexican wheat farmers was certified. During that period, average wheat yield increased every year because of the use of certified seed, fertilizer, irrigation and mechanization. In 1990, Banrural, which gave credit to the *ejidos* farms for purchase of certified seed and fertilizer, was closed, and the use of certified wheat seed dropped to less than 50 percent. Consequently, the rate of increase in yields declined. Amazingly, in 1996 in the state of Mexico, which for over 50 years has been the location of many important research centres (International Wheat and Maize Improvement Center [CIMMYT], Instituto Nacional de Investiaciones Forestales, Agrícolas y Pecuarias [INIFAP], Colegio de Postgraduados in Chapingo, Instituto de Investigación y Capacitación Agropecuaria, Acuícola y Forestal del Estado de

México [ICAMEX] and others), less than 2 percent of the area planted to maize was planted with certified seed of improved hybrids. A survey of farmers by the state of Mexico revealed that they recognized the benefits of certified seed, but indicated that they would not buy certified seed because it was too expensive.

In 1997, the federal and state governments in Mexico began funding in matching amounts a programme called Alianza para el Campo to support Mexican farmers, which addresses the lack of financial resources and other general obstacles to the adoption of improved crop technology. The Kilo por kilo programme, which is part of Alianza para el Campo, offers farmers certified seed of improved varieties at a price equal to the price of grain. The name, Kilo por kilo, conveys the notion that a farmer can purchase a kilogram of certified seed for the same price as a kilogram of the grain that the farmer might otherwise withhold from sale as a commodity and retain for planting. The intent of the programme is to encourage and enable farmers to use certified seed of improved varieties that will increase the yield and profitability of their crops. The programme is limited to purchases of seed for a maximum of 5 ha per farmer. To implement the programme, the government buys seed at the price at which it is being sold in the market, then sells it to farmers at the much lower price of grain. Typically, the market price of certified seed is four times the price of grain, and in the case of improved certified seed of maize, the price is 10 to 25 times that of grain. For example, during 1997, the first year of the programme, certified seed of maize, beans, wheat, oats and barley were all sold to farmers at 1.50 pesos/kg regardless of species or variety. At that time, the market price of maize seed was 15 pesos/kg for open-pollinated varieties and 25 to 35 pesos/kg for hybrids.

The difference between the market price of the seed and the grain price at which the government sells the seed to farmers represents a subsidy to the use of the certified seed. In 1998, the programme was modified to limit the subsidized price to a maximum of 25 pesos so that if a farmer chose to purchase a maize hybrid developed by a private company that has a market price of 35 pesos, the farmer would pay 11.50 pesos/kg, based on the 1.50 pesos for the Kilo por kilo price of grain plus the 10 pesos that the market price exceeds the maximum subsidized price. Triticale has been included in the Kilo por kilo programme since 1999. Notably, triticale was added by the federal government at the strong urging of the farmers' union of small-grain cereals, which is a promising indication of the level of interest in the crop among growers. The Kilo por kilo programme is particularly important for triticale because it facilitates the introduction and adoption of the crop itself and does not simply provide improved certified seed of an established crop. The prices of seed and grain for triticale are similar to those for wheat, 6 pesos/kg for seed and 1.50 pesos/kg for grain. Although federal support for the Kilo por kilo programme was discontinued in 2002, state governments such as the state of Mexico have continued the programme and have involved private seed dealers in the storage, sale and distribution of the seed using state storage facilities.

Beginning in 1997, its first year, the impact of the Kilo por kilo programme has been evident. For example, from 1996 to 1997 the area planted to certified seed of improved maize hybrids increased from 2 to 10 percent. That increase has been maintained, and average yield has increased from 3.0 to 3.8 tonnes/ha as a result of improved certified seed and crop management. Although the Kilo por kilo programme tends to be used most by progressive farmers who are not the group most in need of economic and social assistance, the programme is a good way to communicate and emphasize to farmers the importance of certified seed.

In addition to the government efforts addressing the general obstacles to new crop technology, other government efforts in Mexico have been directed specifically toward expanding the use of triticale. These efforts are most notable and best exemplified by those in the state of Mexico, where the state government's institute for research training and technology transfer (ICAMEX) has promoted both the production and use of triticale grain. In 1996, ICAMEX began an aggressive programme of diffusion (promotion), technology transfer and seed production to encourage production of triticale grain for feed and food use. Diffusion of information about triticale to raise awareness about the crop was accomplished through diverse media, including newspapers, bulletins, ballots (brochures), radio and field days. Triticale production technology was transferred to farmers through numerous 0.4 ha plots of triticale placed with several farmers in each of the potential production areas. Production of triticale seed was accomplished by helping organized groups of farmers produce and market the seed, including helping them to transport seed to grain farmers in areas that are unsuitable for seed production. In promoting triticale and assisting production, ICAMEX focuses on the farmers who are most capable of success and are located in production regions where triticale is well adapted and one of the best crop choices. The ICAMEX encourages those farmers in the targetted regions to produce triticale by supplying them with inexpensive, good-quality seed to get them started.

As a result of the promotion, technology transfer and seed production efforts of ICAMEX over the past five years, and the availability of more and better varieties, the production area of triticale in the state of Mexico is now two to four times larger than it was in 1996 and most likely is larger than the area of triticale production throughout the rest of the country. Based on the acceptance of triticale among farmers who have become familiar with the crop, in each of the last three years ICAMEX has produced and marketed an average of 300 tonnes/year of high-quality seed produced directly by ICAMEX or by farmers who have been assisted by ICAMEX. This available, improved seed is almost half of the seed used by farmers for current triticale production. Although official data on production area are not available, annual planting of triticale in the state of Mexico may now exceed 4 000 ha. To help meet the need for planting seed for that area, in the summer production cycle in 2002, ICAMEX sold 182 tonnes of certified seed of the variety Siglo-21 through the Kilo por kilo programme, enough to plant almost 1 500 ha. Despite recent increases, the area of triticale production in the state of Mexico is less than 10 percent of the potential area for triticale production in the state.

Production of triticale grain in the state of Mexico and the rest of the country is limited by the lack of well-established markets for the grain. In addition to encouraging production of triticale grain, ICAMEX has sought to increase demand for it for both feed and food use. Development of feed markets has been caught in a vicious cycle of limited production because of uncertainties about markets for the grain and limited use because of uncertainties about supply. Farmers are understandably reluctant to produce triticale grain without assurances about markets for it, while livestock producers will not alter their feeding rations if they are not certain they can obtain an adequate supply or that triticale grain will have any advantages for them as a feed. The livestock producers indicate that 1 000 tonnes of grain are needed for meaningful evaluation of triticale grain as a feed at a commercial level. No individual farmer is likely to be willing to produce such a quantity under these circumstances, so ICAMEX is working to organize groups of farmers who together can produce the needed quantities.

For food use, one goal has been to make the food industry aware of the availability of improved, new varieties of triticale that are good for flour production and for blending with wheat to make cookies and bread. ICAMEX is trying to convince the major food company, Bimbo, to use triticale in the production of cookies, doughnuts and tortillas. It also is working with the Integral Development of the Family (DIF) government organization to convince them to use triticale for cookies and tortillas provided to children for breakfast in public schools. ICAMEX is seeking other large companies as customers for triticale grain. As soon as more is learned about whether triticale flour can be blended with maize flour to produce better tasting tortillas, ICAMEX will encourage the use of triticale by Maseca and Minsa, the companies that process maize for almost all the *tortillerias* (tortilla-making establishments) in the country. Those two companies process more than 5 million tonnes of maize annually, so that a blend with 10 percent triticale and 90 percent maize would represent demand for more than 500 000 tonnes of triticale. Satisfying demand of that amount would require all the grain produced in the high-plateau regions of Mexico. The grain yield of triticale in rainfed conditions is between 2 and 7 tonnes/ha, while under irrigation it is more than 8 tonnes/ha.

In conjunction with the market development efforts by ICAMEX, some farmers are seeking to increase the selling price of the triticale grain that they produce by storing it so they can deliver it to grain users throughout the year. One possibility for storage facilities is the use of infrastructure that once belonged to the Compañia Nacional de Subsistencias Populares (CONASUPO), the organization of the federal government that was formerly in charge of aggregating, storing and setting the price of maize, beans, rice and wheat produced by Mexican farmers. Although current markets for triticale grain in Mexico are still small and uncertain, if ICAMEX continues to organize and assist triticale producers and to develop markets for the grain, it is likely that markets for triticale grain in Mexico will be established for both feed and food use within three years.

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Country reports

Triticale in Algeria

A. Benbelkacem

Algeria is a country that is extremely deficient in food grains as well as in feed grains. A good proportion of the cereal land is highly eroded and thus low in fertility. In addition, annual rainfall on which the cereals depend is very erratic. During the last two decades, 1.8 million tonnes of cereals per year have been produced on average in Algeria. This level of production covers only one-third of the consumption needs (human and livestock) (Benbelkacem, 1998).

Triticale (X *Triticosecale* Wittmack) was grown in Algeria on a total area of about 20 500 ha in 2001 (Table 1). More than 60 percent of the area was grown in the northeast region of the country. Triticale is grown with the aim of reducing maize and barley imports. The crop is mainly grown for forage production as a grain feed or for dual purpose (forage and grain).

The area cropped to triticale reached a maximum of 35 000 ha in 1996/97 (Table 1). This area has been stable at around 21 000 ha during the last decade. Grain yield average is 1.5 tonnes/ha, which is relatively higher than other cereals with an average of 1.2 tonnes/ha (Statistiques Agricoles, 2000).

TABLE 1
Area, production and grain yield of triticale in Algeria, 1991-2001

Year	Area (*ha*)	Production (*tonnes*)	Grain yield (*tonnes/ha*)
1991/92	15 000	27 000	1.8
1992/93	17 000	27 200	1.6
1993/94	19 750	27 650	1.4
1994/95	21 500	25 800	1.2
1995/96	23 000	48 300	2.1
1996/97	35 000	66 500	1.9
1997/98	21 500	27 950	1.3
1998/99	22 500	24 750	1.1
1999/00	18 000	27 000	1.5
2000/01	20 500	28 700	1.4
Average	21 375	33 085	1.5

TRITICALE PRODUCTION

In general, the cultivation of triticale does not differ from that of other cereals. There are three main different agro-ecological regions where cereals are grown in Algeria.

Littoral and sub-coastal area

This region is characterized by deep, good soils and a Mediterranean climate with cool, wet winters (rainfall more than 550 mm/year). Rainfed cereals are the dominant crops. Livestock production is often integrated in the farming systems of the region. The main biotic stresses are fungal and viral cereal diseases, mainly rusts, powdery mildew, the different Helminthosporium species of wheat and barley, and barley yellow dwarf virus (Sayoud, 1994).

Interior and high plains

Rainfall in these areas is irregular over the year and ranges from 350 to 500 mm in uneven distribution. The winters are mild to cold with high frequencies of frost during the year. Soils are deep to shallow moving from north to south. Most of the cereals are grown intensively. The major abiotic stresses are early drought, cold winters and late heat during the grainfilling period. The biotic stresses include few diseases with less severity in the higher regions.

High plateau

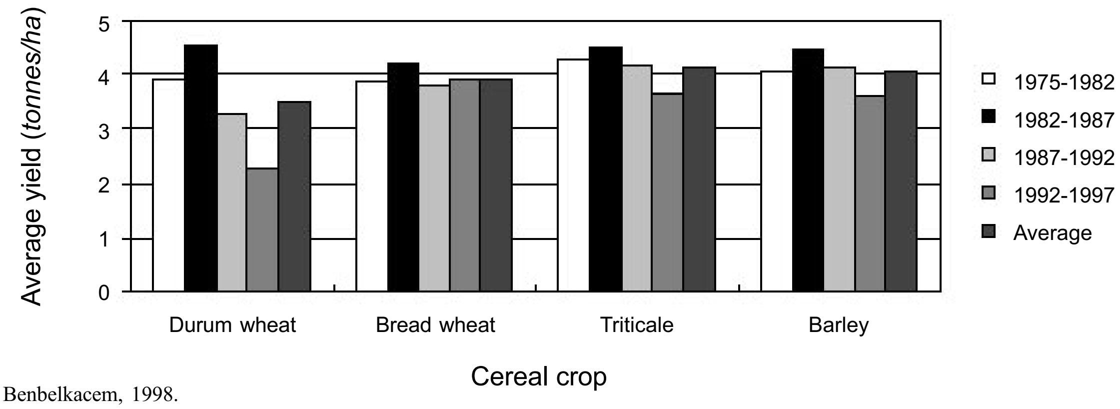
The average altitude in this region is over 1 000 m. The climate is continental with cold winters and hot summers. Soils are shallow. This area is referred to as a semi-arid region. Cereals are grown extensively. Barley is the main crop integrated with livestock production, mainly sheep and goats. The main abiotic stresses are cold and frost during the flowering period. Some diseases in wet years and Russian wheat aphid and root rot can cause some problems (Sayoud, 1994).

Most of the triticale is grown in the interior plains and in the sub-littoral area (favourable area). However, in the high plateau triticale production is better than the other cereal species.

USES OF TRITICALE

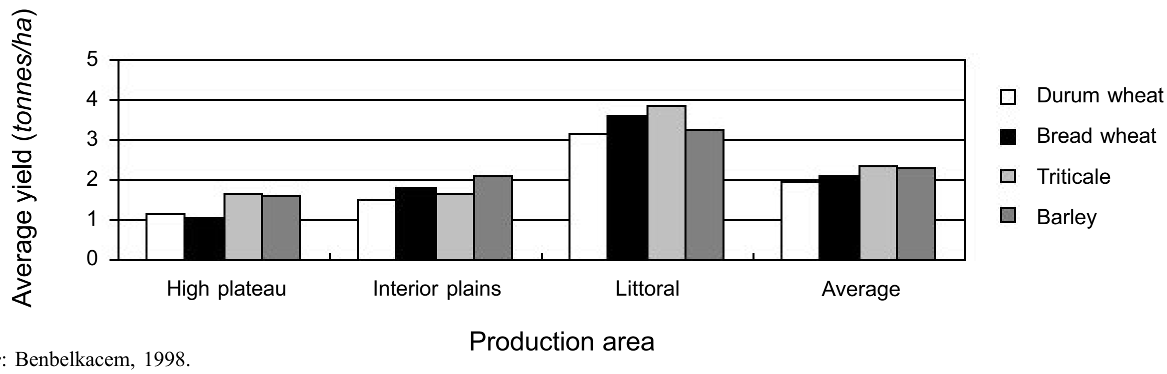
The utilization of triticale in Algeria is roughly as follows: human consumption 5 percent, forage crop (hay or silage)

FIGURE 1
Average yield per period of time for different cereal crops grown in Algeria, 1975-1997



Source: Benbelkacem, 1998.

FIGURE 2
Average yield per cereal crop for different cereal-producing areas in Algeria, 1992-1995



Source: Benbelkacem, 1998.

60 percent, feed grain 30 percent and the remaining 5 percent is kept for seed increase (unpublished data). As forage, triticale is favoured for its ability to be grazed early in the winter when no other green fodder is available (Plate 1) and to be cut later in the season as a silage, hay or grain crop (Plate 2). Late harvest is not suitable because the high percentage of dry matter can be problematic for forage conservation in silos. The grain is mostly used as a substitute for maize in animal feed. The shortage of silage has been a primary constraint on the development of dairy cattle during the winter season and early spring (Benbelkacem, 2002).

TRITICALE IMPROVEMENT

The data collected from different sites (Figure 1) show that on average triticale, globally over years, outyielded barley, bread wheat and durum wheat by 2, 6 and 16 percent, respectively. This trend is also valid when the data from the same table are compiled per period of time. Except in two cases, triticale performed better than wheat or barley (Benbelkacem, 1998).

Grouping the data according to the agro-ecological area shows the net advantage of triticale cultivars over other cereal crops in yield performance (Figure 2). As expected, in the high-plateau area triticale yielded up to 137 percent of bread wheat, 130 percent of durum wheat and 104 percent of barley. In the intermediate zones (plains), triticale was less yielding than bread wheat or barley but gave 8 percent more than durum wheat. In the most favourable zones, triticale also outyielded bread wheat, barley and durum wheat by 6, 16 and 19 percent, respectively. The winter-type triticales introduced in Algeria in 1992 were not adapted and thus performed poorly (Pfeiffer and Fox, 1991).

TABLE 2
Yield performance in early introduced and released triticales

Cultivars	Grain yield (*tonnes/ha*)	Percentage to check (*%*)
Cinnamon	2.65	100
M2A	2.59	98
Bacum	2.78	105
Beagle	3.05	115
Average	2.77	-

Source: Benbelkacem, 1988.

TABLE 3
Yield performance of triticale cultivars over different locations, 1982-1997

Cultivars	Grain yield (*tonnes/ha*)	Percentage to check (*%*)
Chenoua=Beagle	3.21	100
Cherea=DOC7	3.96	123
Chelia=Eronga	3.88	120
Meliani=Clercal	3.05	95
Trick	3.13	97
Rhino 4.1	4.24	132
REH/HARE	3.86	120
MER/JLO	3.87	120
Lamb 2	4.08	127
Fahad 5	4.04	125
IFTT314=IFRI	2.86	89
BGL/CIN//MUSX/4/DE LF99/3/M2A/SNP/BGL	3.73	116
Average	3.66	-

As in every other programme in the world that started with the incomplete Armadillo-derived type cultivars, yield gains were slow in the beginning. In that period, in the late 1970s, Cinnamon (check) performed on average 2 percent better than Maya 2 Armadillo but 5 to 15 percent less than Bacum or Beagle (Table 2) (Benbelkacem, 1988).

In the following 15 years (1982-1997), it appears that the introduction of the complete-type triticales improved the yield potential. Compared to Beagle (check), cultivars such as Rhino 4.1, Lamb 2 or Fahad 5 showed a yield gain of 132, 127 and 125 percent, respectively (Table 3).

Nowadays, the varieties most used by farmers are: Chelia, Cherea, Lamb 2, Meliani and IFRI. All these varieties are in a slow seed increase process. Seed availability is a problem because most of the triticale fields are grazed, cut as forage or silage or harvested and used as whole grain for feed (Benbelkacem and Zeghida, 1996).

Fresh fodder

Triticale is higher than oats, barley or durum wheat for total biomass, forage dry matter and height by 104 to 144 percent, 105 to 170 percent and 104 to 144 percent, respectively (Table 4) (Benbelkacem, 2002).

Grain quality

Compared to wheat, triticale shows better protein and lysine contents (Table 5) with 2.8 and 0.19 percent more, respectively.

Fodder nutritional quality

For silage and fresh feed crops, it is important that the plants contain varied nutritional components. In order to identify the feeding value, the nutritional components of triticale, barley and wheat were determined before silage was harvested. The results (Benbelkacem, 2002) proved that triticale had a higher and fresher feed resource and forage quality than barley or wheat in all traits (protein,

TABLE 4
Plant height, grain yield, total biomass, straw to grain ratio and forage dry matter of triticale compared to other cultivated cereals at Elkhroub Station, Constantina, Algeria, 1998-2001

Crop	Plant height (*cm*)	Grain yield (*tonnes/ha*)	Total biomass (*tonnes/ha*)	Straw to grain ratio	Forage dry matter (*tonnes/ha*)
Durum wheat	90	3.08	6.8	2.20	5.1
Bread wheat	85	4.12	7.9	1.92	5.9
Barley	105	3.67	8.6	2.34	6.8
Triticale	130	3.96	9.8	2.47	8.7
Oats	125	3.80	9.5	2.50	8.3
Mean	107	3.72	8.5	2.28	7.0

Source: Benbelkacem, 2002.

TABLE 5
Protein and lysine content in triticale and wheat, 1998-2001

Crop	Protein range (%)	Average (%)	Lysine range (%)	Average (%)
Triticale	10.25-21.50	15.2	0.29-0.67	0.51
Wheat	7.90-19.82	12.4	0.23-0.42	0.32

TABLE 6
Forage quality of triticale compared to barley and wheat, 1999-2001

Crop	Water (%)	Protein (%)	Fat (%)	Cellulose (%)	Sugar (%)	Ash (%)	Carotene (*mg/g*)
Triticale	71.22	4.44	1.12	10.24	2.31	4.01	1.21
Barley	76.33	3.55	0.91	8.74	3.12	2.63	0.82
Wheat	68.41	3.01	0.78	7.98	2.41	2.32	0.97

Source: Benbelkacem, 2002.

TABLE 7
Milk quality and milk yield of oat, barley and triticale silage from a sample of dairy cattle farmers in northeastern Algeria, 2001/02

Silage	Protein (%)	Fat (%)	Lactose (%)	Water (%)	Daily milk (*yield/day/cow*)
Oat	3.04	3.17	4.68	88.77	37
Barley	3.12	3.31	4.59	89.02	35
Triticale	3.21	3.43	4.71	86.65	40

Source: Benbelkacem, 2002.

fat, cellulose, ash and carotene) except for water content and sugars (Table 6).

Application of triticale as feed

Triticale silage is very popular for feed nowadays at the farmer level. It is performing better than barley or oats in quantity and quality. Feeding trials from different northeastern counties of Algeria indicated that the quantity of milk produced by feeding triticale silage was 12.5 and 7.5 percent more over barley and oats, respectively. In addition, the quality of milk from cows fed with triticale is better (Table 7).

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PLATE 1
Animals grazing on triticale in Algeria
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PLATE 2
Use of triticale for silage
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