Review Article

www.ekinjournal.com

Ekin International biannual peer-reviewed journal

Ekin
Journal of Crop Breeding and Genetics

5(2):68-73, 2019

Recent Developments in Triticale Breeding Research and Production - An Overview

Edward ARSENIUK

Department of Plant Pathology, Plant Breeding and Acclimatization Institute-National Research Institute, Radzikow, 05-870 Blonie, Poland

Corresponding author e-mail: e.arseniuk@ihar.edu.pl

Citation:
Arseniuk E., 2019. Recent Developments in Triticale Breeding Research and Production-An Overview. Ekin J. 5(2):68-73, 2019.

Received: 14.04.2019 ***Accepted: 19.05.2019*** ***Published Online: 30.07.2019*** ***Printed: 30.07.2019***

ABSTRACT

This paper reflects an overview and collates possibly new information about current triticale status in Poland and elsewhere. There will be considerable production, breeding research, biology, and agronomy of triticale. Considerable improvements were made in modern triticale cultivars with respect to agronomic performance, resistance to biotic and abiotic stresses and nutritional quality, in particular for human consumption and wider adoption as a viable commercial crop. In the past decades, new breeding tools and enabling technologies (doubled haploid, marker assisted selection, genomics selection, transgenic, functional genomics, and targeted genome editing) have been refined or developed anew and are successfully exploited in triticale improvement. Through, the integration of these tools and technologies with conventional plant breeding approaches, triticale biological potential has been enhanced to make this small grain species an economically successful crop.

Keywords**:** Triticale, breeding, biotechnology, resistance, somaclonal, androgenic variation, grain production

Triticale past

History of triticale dates back to XIXth century when hybrids between wheat and rye after spontaneous or intentional crossings were observed (Wilson 1876). Since then, almost over a century, triticale was considered as a scientific and/or breeding novelty. On the turn of XIX and XX centuries, many attempts were made to cross wheat and rye, but majority of them were ended with sterile triticale offspring. Such situation lasted until breeding techniques were elaborated and introduced to produce fertile hybrid plants called triticale. According to bibliographic data, in 1930's the name 'triticale' was coined combining *Triticum* and *Secale*, the Latin names of wheat and rye.

Crosses of durum wheat [*Triticum durum* (4x - AABB)] with rye [*Secale cereale* (2x - RR)] produced triploid embryo ABR F_1 (3x). After going through embryo rescue and chromosome doubling with colchicines (Pilch 2001) fertile hexaploid plants of primary triticale were obtained. For a better understanding, the simplified scheme is being shown in figure 1. Most often, the production of variety is much more complex. After a completion of crossing work, selection work is carried out in breeding plots to identify the high yielding genotypes.

It is known from numerous reports on triticale breeding research, that various types of primary triticale could be synthesized with different chromosomal constitutions after crossing different species of wheat with rye, e.g. crossings of *Triticum turgidum* (AABB) or *Triticum aestivum* (AABBDD) with rye produced either hexaploid (AABBRR) or octoploid (AABBDDRR) triticale, respectively. It is to indicate, that wheat is the mother plant and rye serves as the pollinator. It also has been tried to make the reversed crosses when rye served as mother plant and wheat as pollinator. The final product was called *Secalotricum*, but such attempts were unsuccessful so far. Secondary triticales have been produced by crossing two differently composed primary triticales. The diversity of triticale lines can be enlarged by production of substitution triticales. In such a cross soft, hexaploid wheat with a genome AABBDD serves as mother plant, pollinator is secondary, hexaploid triticale with a genome AABBRR to give in a progeny substitution hexaploid triticale with a genome AABBRR or AABBRD.

It needs to be emphasized, that among various types of triticales, hexaploid triticale (durum × rye) has commercially been the most successful because of showing superior vigour and reproductive stability. The octoploid triticale type was produced by crossing common wheat × rye. Unfortunately, in comparison to hexaploid type the latter one suffers from greater genetic instability and associated floret sterility (Mergoum et al., 2009).

Contribution of biotechnological methods into triticale breeding.

The cross-incompatibility barrier between (4x) wheat and rye has limited the genetic base for triticale breeding. To overcome this problem, biotechnological methods like embryo culture technique, somatic embryogenesis, androgenesis (doubled haploid technology), molecular markers, and genetic engineering have been used in breeding of the crop. It is to underline that since very beginning, triticale has been difficult to obtain as *in vivo* crosses except through rescue of embryo culture. According to Zimny and Loerz (1996), the production of haploid triticale plants was described for the first time by Ya-Ying in 1973. So far, microspore and anther culture have been most widely used and incorporated into triticale breeding programs (Ahmed & Allam, 2003, Arseniuk and Walczewski 2014). These provided an opportunity to create haploid and doubled haploid plants within a single season, thereby reducing the time and cost of cultivar development. So far, 12 sustainable and highly productive triticale cultivars have been released on the basis of anther culture technology in Poland (Table 1).

Despite the fact, conventional triticale breeding focuses on the selection of superior progeny from segregating populations, and selection is mostly based on phenotypic characters. The breeders are looking for new approaches and tools to reduce the environmental effect on the selection of appropriate triticale genotype, since there is a confounding impact of environmental factors on phenotype. Breeding of new variety, takes up to 15-20 years and the release of an improved variety is not really guaranteed and it depends on the utilization of the best parental combination. So, this is the reason that the recent approaches in triticale and cereal breeding have been focusing on application of molecular marker techniques and DNA technology.

The application of molecular markers in triticale breeding research is quite extensive and its main uses include:

- Assessment of genetic diversity and characterization of germplasm collections (Niedziela et al., 2016; Kang et al., 2016.);
- Variety fingerprinting for identification, accelerating the development of individuals that combine favourable alleles, contributing to hybrid performance prediction, establishment the distinctiveness of new cultivars prior to registration and protection (Ma and Gustafson, 2006);
- Estimation of genetic distances between populations, inbreds and breeding material (Niedziela et al., 2016);
- Facilitation of the introgression of chromosomal segments from alien species and even tagging of specific genes (Hakeem et al., 2016);
- Detection of monogenic and qualitative trait loci (QTLs)(Reszka et al., 2007);
- Purity and stability of the seed and plant material (Góral et al., 2005);
- Identification of sequences of useful candidate genes, etc. (Hakeem et al., 2016).

Response to biotic and abiotic stresses

Triticale was developed with a hope that in addition to the high yield potential and good grain quality of wheat, it will combine the resistance/tolerance to the biotic and abiotic stresses of rye. Initially, diseases did not appear to reduce triticale yields greatly. This could be explained by limited triticale acreage worldwide. At early stages, the area of triticale was insufficient for pathogens to adapt to the crop to cause serious outbreaks of diseases. The importance of diseases started to increase, as the amount of land planted with the small grain species has been steadily expanded in majority of triticale producing countries. Among adverse factors, at the beginning, like stem rust, ergot, *Fusarium* head blight (FHB), and leaf spots were recognized (Arseniuk 1996). Other adverse factors that downgraded triticale grain quantity and quality for end users included its late maturity than wheat, preharvest sprouting and pedoclimatic conditions. All these adverse factors contributed to lower triticale feed classifications and have reduced economic returns. On the other hand, lack of crop insurance coverage in quite a number of countries, inadequate research investment, lack of production technology, perception about triticale end-uses, lack of good-quality pedigreed seed, limited marketing options for farmers resulted in increases of economic risks to produce triticale.

It is to indicate, that triticale is a crop on which pathogens of wheat and rye meet, but there is evidence that on triticale embedded more so called “wheat pathogens”, than rye ones. For such a notable example many server races of *Puccinia recondita*, the causal agent of leaf rust. In the latter respect, triticale also appears to bridge direct contacts for a number of pathogens e.g. between physiological forms of the most important cereal rusts. Such contacts stimulate somatic hybridization on a triticale plant and may finally result in new pathogenicities and virulence factors. Such new emerged forms, are able to attack triticale, wheat and rye. In such cases, resistance genes are becoming ineffective. The first disease which occurred on this cereal in epidemic proportions was stem rust (*Pucinia graminis* f. sp. *tritici*) in Australia.

Leaf and stripe rusts caused, respectively by *P. recondita* f. sp. *tritici* and *P. striiformis*) also have gained importance everywhere in triticale grown areas, and especially in Poland. In recent years, at least in Poland, powdery mildew caused by *Blumeria graminis* occurred in epidemic proportions in quite a number of winter triticale cultivars. Similar phenomena have appeared with a number of other diseases caused by facultative pathogens, such as, the most damaging disease to triticale is the *Parasta gonospora* spp. leaf and glume blotch disease complex, *Zymoseptoria tritici* inciting speckled leaf blotch and other pathogens like *Cochliobolus sativus*, *Fusarium culmorum*, and *F. graminearum*, *Microdochium nivale*, *Bipolaris sorokiniana*, *Oculimacula yallundae* (Wallwork & Spooner) Crous & W. Gams) (synonym: *Pseudocercosporella herpotrichoides*), and *Gaeumannomyces graminis* var. *tritici* inciting head, leaf and seedling blights and foot, crown and root rots. In addition to fungal pathogens, triticale is affected by bacteria, viruses, virus-like organisms and nematodes (Arseniuk and Góral, 2015). Research reports have shown that triticale presents broad genetic diversity to abiotic stresses, like drought, frost and cold, pre-harvest sprouting, water logging, lodging, shattering, Al toxicities (Arseniuk and Walczewski 2014; Blum 2014; Arseniuk 2015). Triticale is also tolerant of low pH (acidic soils), grows well on sodic soils, and tolerates high in boron soils. Its high productivity and resilience to growing conditions become as important as wheat and it is so already in Poland.

Cultivation and production

Triticale was originally promoted as a new cereal crop that combines the superior agronomic performance and the end-use qualities of wheat with high resistance/tolerance to biotic and abiotic stresses and adaptability of rye to poorer pedo-climatic conditions. This small grain cereal species is also considered as germplasm resource of improvement genes for resistance to the above mentioned stresses in wheat. Unfortunately, so far, triticale has only been recognized to have potential as a fodder cereal and to some extent as promising cereal for energy supply because of its high biomass and grain yield. The harvested area varies from year to year, but this is steadily increasing. Over about 30 years, the progress in the total harvested area of triticale appeared quite rapid, e.g. in 1985, triticale globally was grown on 232,631 ha and in 2016, on 4,234,298 ha and in 2015, even on 4,559,828 ha. Thus, the growing area over 30 years increased 19,6 times (Figure 2).

On the other hand, in Poland in 1985 triticale was grown solely on 20,000 ha and in 2015 and 2016, cultivated on 1,516,168 ha and 1,373,529 ha, respectively, so over 30 years, the growing triticale area in Poland has been increased 75,8 times (Figure 3)

In 2016, top triticale grain producers were as follows: Poland produced 5,1 million metric tonnes (m. mt) on 1,4 million ha; Germany produced 2,4 m mt. on 396,1 thousands ha (th. ha), Belarus produced 1.6 m mt. on 0.5 m ha, France produced 1.4 m mt. on 334.2 th. ha, Russia produced 0.62 m mt. on 223 th ha and Hungary produced 0.5 m mt. on 139,1 th. ha (FAO Stat). Likewise, the grain tonnage, the growing area is also varying from year to year, but it also is steadily increasing. In 2016, worldwide, 15.2 million metric tons of triticale grain was produced on almost 4.2 million ha (Figure 4).

Figure 1. Illustration of primary triticale production by a single cross, Source: Adapted from https://search.credoreference.com/content/topic/triticale.embed

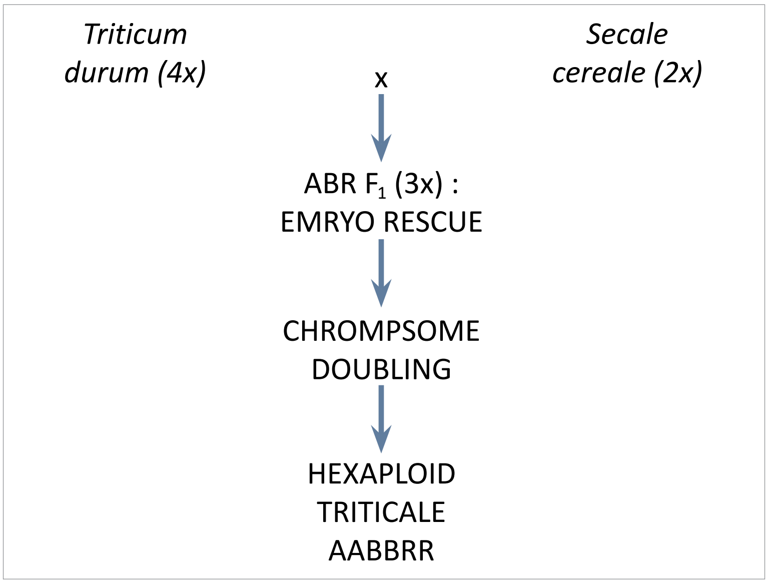


Table 1. Triticale cultivars developed by Polish breeders on basis of anther culture technology

DANKO breeders	**Standard and % of standard**	**STRZELCE breeders**	**Standard and % of standard**	**STRZELCE breeders**	**Standard and % of standard**
		Winter triticale		Spring triticale	
Standard's yield	81,1 dt/ha	Standard's yield	81,1 dt/ha	Standard's yield	87,7 dt/ha
Rotondo DH	103%	Panteon DH	105%	Dublet DH	102%
Twingo DH	94%	Borowik DH	102%	Sopo DH	105%
Torino DH	103%	Probus DH	112%	Mamut DH	107%
Winter wheat		Carmelo DH	104%	Mazur DH	105%
Standard's yield	90,3 dt/ha				
Izyda DH	101%				

Figure 2. Triticale, area harvested in world over 1975 – 2016 (Source FAOStat)

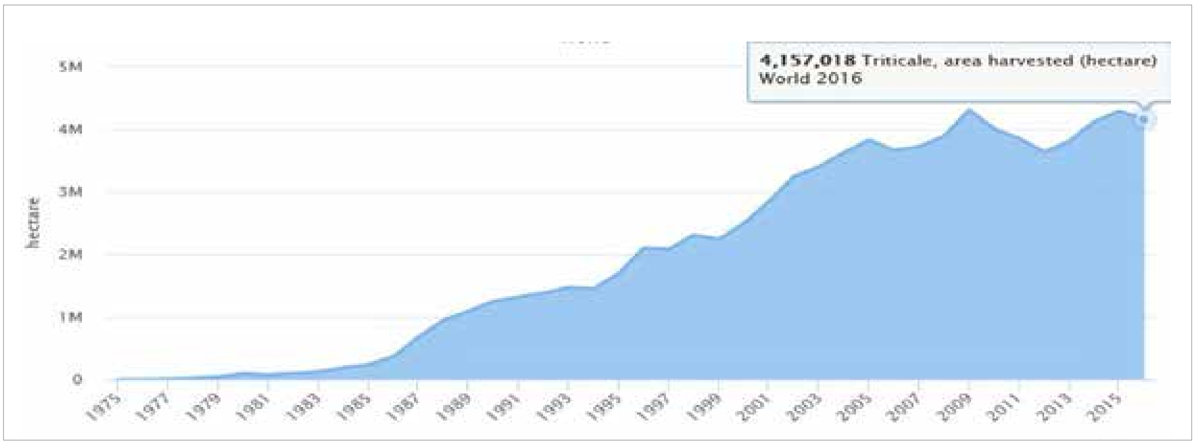


Figure 3. Triticale, area harvested in Poland in 1985 – 2016 (Source FAO Stat)

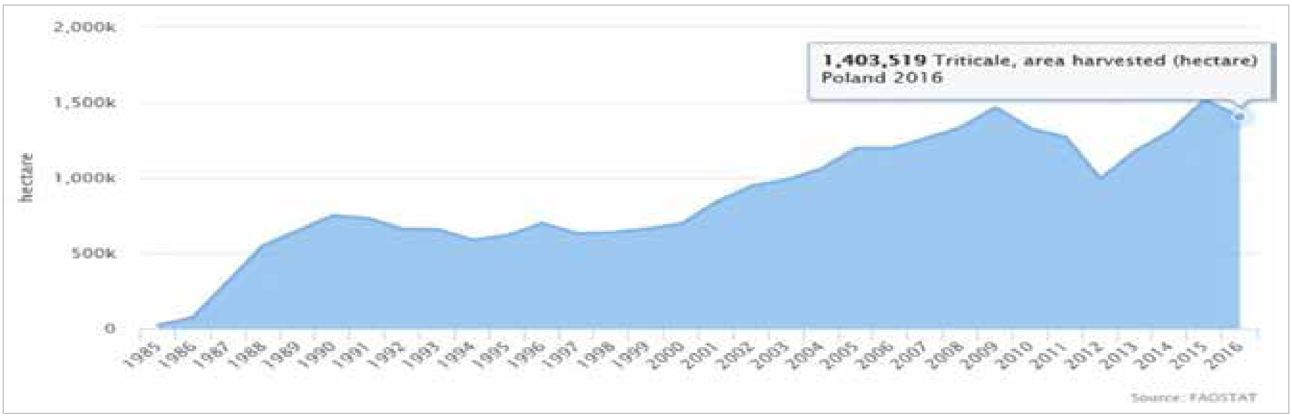
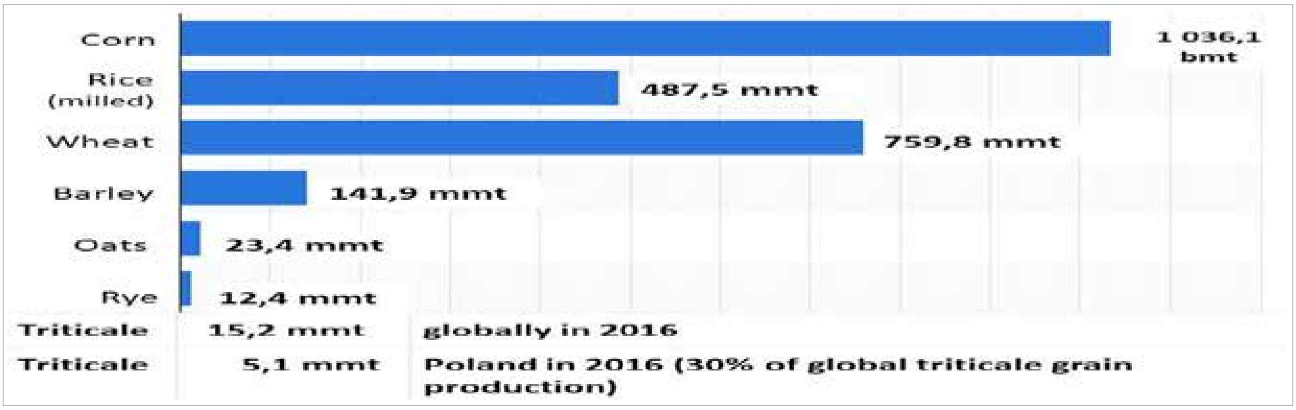


Figure 4. Global production of corn, rice and basic cereals, including triticale in Poland in 2016-2017 in billion (bmt) and million metric tonnes (mmt) (Source FAO Stat)



References

Ahmed K. Z., and Allam H. Z., (2003). Response of intergeneric hybrids of Egyptian wheat with ryeto *in vitro* techniques. African Crop Science Conference Proceedings, Vol. 6; 98-102.

Arseniuk E., (1996). Triticale diseases - a review. Triticale: Today and Tomorrow. Developments in Plant Breeding 5: 499-525.

Arseniuk E., (2015). Triticale abiotic stresses - an overview. [In:] Triticale Book, Agri-Food Canada Part II, ISBN 978-3-319-22550-0: 69-82.

Arseniuk E., and Góral T., (2015). Triticale biotic stresses - known and novel foes. [In:] Triticale Book, Agri-Food Canada Part II, ISBN 978-3-319-22550-0: 83-110.

Arseniuk E., and Walczewski J., (2014). Effect of dihaploid technology on resistance of winter wheat and winter triticale to *Stagonospora nodorum* blotch. In: Behl RK, Arseniuk E (eds) Proceedings of the international conference on biotechnology and plant breeding perspectives-towards food security and sustainability, 10-12 Sept 2012, IHAR-PIB Radzikow, Poland. Agrobios (International), New Delhi, pp 32-329.

Blum A., (2014). The abiotic stress response and adaptation of triticale – a review. Cereal Research Communications 42(3), pp. 359–375 (2014), DOI: 10.1556/CRC.42.2014.3.1.

FOA Stat., (2016). www.fao.org/statistics/en/

Furman B., (2016). Triticale: Overview. In C. W. Wrigley, H. Corke, & K. Seetharaman (Eds.), Encyclopedia of food grains (2nd ed.). Oxford, UK: Elsevier Science & Technology. https://search.credoreference.com/content/topic/triticale.embed.

Góral H., Tyrka M., and Spis L., (2005). Assessing genetic variation to predict the breeding value of winter triticale cultivars and lines. J. Appl. Genet. 46(2), 2005, pp. 125-131.

Kang H., Wang H., Huang J., Wang Y., Li D., Diao C., et al., (2016). Divergent development of hexaploid triticale by a wheat - rye - *Psathyrostachys huashanic* atrigeneric hybrid method. PLoS ONE 11(5): e0155667. doi:10.1371/ journal.pone.0155667. pages 1-14.

Ma X. F., and Gustafson J. P., (2006). Timing and rate of genome variation in triticale following allopolyploidization. Genome 49: 950-958.

Mergoum M., and Gómez-Macpherson H., (2004). Triticale improvement and production. FAO Plant Production and Protection Paper 179: 172 pp.

Mergoum M., Singh P. K., Pena R. J., Lozano-del Rio A. J., Cooper K. V., Salmon D. F., and Gomez Macpherson H., (2009). Triticale: A “New” Crop with Old Challenges. Chapter from book Cereals (pp.267-287).

Niedziela A., Orłowska R., Machczyńska J., and Bednarek P. T., (2016). The genetic diversity of triticale genotypes involved in Polish breeding programs. SpringerPlus 5(355):1-7.

Pilch J., (2001). Crossability effects of spring wheat (*Triticum durum* Desf.) with rye (*Secale cereale* L.) genotypes. Plant Breeding and Seed Science 45: 33-43.

Hakeem K. R., Tombuloğlu H., Tombuloğlu G., (2016). Plant Omics Trends and Applications. Springer, Switzerland. https://www.springer.com/gp/book/9783319317014

Reszka E., Song Q., Arseniuk E., and Cregan P. B., (2007). The QTL Controlling Partial Resistance to *Stagonospora nodorum* Blotch Disease in Winter Triticale Bogo. Plant Pathology Bulletin 16:161-167.

Wilson A. S., (1876). Wheat and rye hybrids. Edinb Bat Sac Trans. 12: 286–288.

Zimny J., and Loerz H., (1996). Biotechnology for basic studies and breeding of triticale. In: Triticale today and tomorrow. Kluwer Academic Publishers, (Eds. H. Guedes-Pinto, N. Darvey, V. P. Carnide), p. 327-337.