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GENETIC RESOURCES OF TRITICALE IN THE POLISH GENE BANK

ABSTRACT

The aim of the research, conducted at the Institute of Plant Genetics, Breeding and Biotechnology of the University of Life Sciences in Lublin since 1982, is the systematic gathering and multi-annual characterization of triticale accessions collected in the Polish gene bank, as well as regeneration of materials preserved in the seed stores in case of reduced germination capacity or a small sample of grains. Valorisation of accessions is carried out in a 4-year cycle of field experiments and includes botanical identification and a description of morphological and useful traits (agricultural and qualitative), conducted every year according to the same methodology. The valorisation data include both traits determined in field evaluation (assessment of emergence, overwintering, lodging, fungal disease resistance, and heading and full maturity dates) and measurements of biometric features (plant height, spike length, number of spikelets per spike, number and weight of grains per spike, 1,000 grain weight, protein content in grain). As part of the research, accessions have been made available for use in breeding programmes and have been donated to research and development institutes as a broad spectrum of variation for genetic similarity analysis and to provide genetic sources of such traits as resistance to pre-harvest sprouting, response to toxic aluminium ions, and disease resistance.

Key words: genetic resources, triticale, yielding traits

INTRODUCTION

Germplasm collections of cultivated plants are an important source of knowledge about the biodiversity of a species. Their purpose is the systematic collection of cultivars and valuable breeding strains (Shands, 1990; Ukalska and Kociuba, 2013). An understanding of the variability of the large number of accessions in a collection gathered over the years can provide better insight for selecting parents in a breeding programme in terms of adaptation and productivity traits (Cui *et al.*, 2001; Mohammadi and Prasanna, 2003;Jaradat *et al.*,

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2004, Ukalska and Kociuba, 2013, Kociuba and Kramek, 2014). Progress in the breeding of new cultivars depends mainly on the choice of appropriate forms for crossbreeding. Consequently, it is necessary to collect and protect both new and old accessions for plant breeding and research as valuable sources of genetic variability for important useful traits (Banaszak and Marciniak, 2002; Kociuba, 2007, 2010; Kociuba *et al.*, 2010; Kociuba and Kramek, 2014).

The triticale collection has been maintained in Poland since 1982 by the Institute of Genetics, Plant Breeding and Biotechnology at the University of Life Sciences in Lublin. The triticale genetic resources collected in the Polish gene bank include all genetic combinations produced in the breeding process, i.e. registered cultivars, cultivars removed from the register, breeding lines and valuable hybrid materials. These accessions come from both domestic and foreign triticale breeding centres and represent a wide range of variability of useful traits. This collection is the subject of evaluation and description during which standard observations and measurements of the most important usable traits are conducted to determine variability. These materials are located in the seed stores of the National Centre for Plant Genetic Resources: Polish Gene Bank of Plant Breeding and Acclimatization Institute – National Research Institute in Radzików, and therefore are available for use by research and breeding institutions. The triticale accessions have full valorisation data, i.e. the results of field evaluation and yield values from four years of research. In this way varieties removed from the register, as well as valuable genetic materials obtained at breeding and research institutions, are protected against irrecoverable extinction (Kociuba, 2000).

Triticale (*X Triticosecale* Wittmack ex A. Camus) is a man-made cereal crop developed around 1870 in Scotland. It was derived from intergeneric crosses between the female parent wheat (*Triticum* ssp.) and the male parent rye (*Secale* ssp.). Recent breeding and research efforts have mainly focused on improving hexaploid triticale (Oettler, 2005; Goyal *et al.*, 2011; Kociuba and Kramek, 2014). Triticale is uniquely different from other cereals in nutritional quality and has broader adaptability. It also has a higher yield potential, is generally more competitive with weeds than wheat, and displays better tolerance to drought and pests than its ancestral species (Oettler, 2005;Beres *et al.*, 2010).

The aim of the present study was to characterize major yield traits of the genetic resources of winter and spring triticale (*X Triticosecale* Wittm. ex A. Camus) collected in the Polish Gene Bank. The variability of triticale accessions originating in different parts of the world in the soil and climatic conditions of Poland was assessed as well. The results may provide a source of valuable information for breeders and researchers concerning the range of variability of the parameters analysed, which will facilitate the selection of interesting accessions as starting material for breeding programs.

MATERIALS AND METHODS

The research material consisted of 2,474 triticale accessions, of which 1417 were winter forms and 1057 were spring forms. The accessions came from different geographic regions of the world. Material from foreign breeding centres comprised the largest share of the collection (54% of the winter triticale collection and 71% of the spring triticale). Domestic accessions accounted for 39% of the winter triticale and 6% of the spring triticale, and the remaining accessions were of unknown origin (Fig. 1).

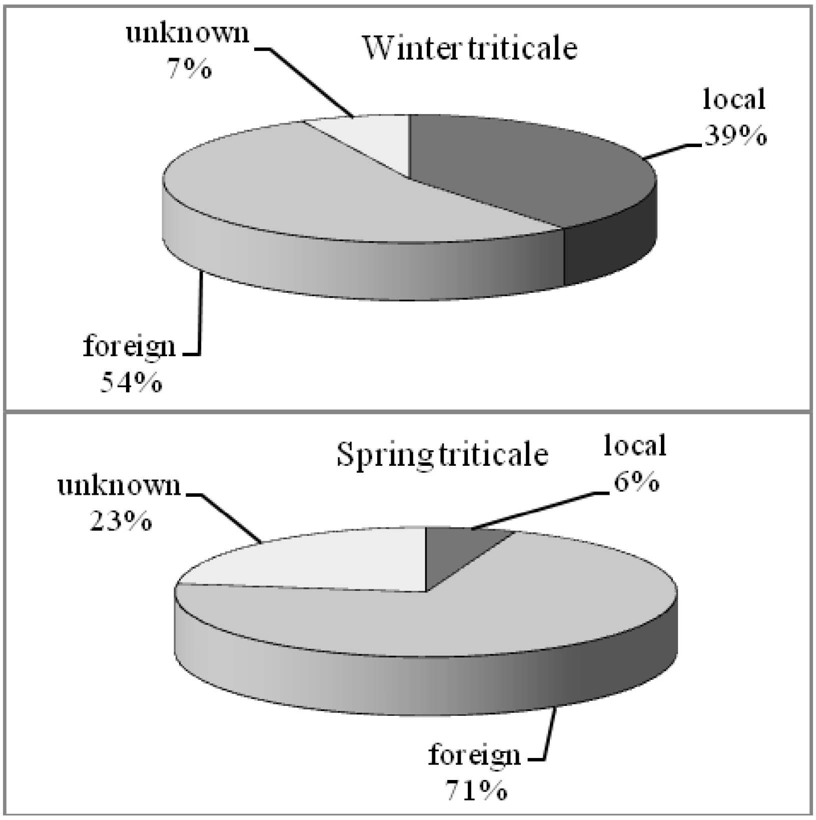

Fig. 1. The origin of collected winter and spring triticale genetic resources accessions

The research, conducted from 1982 at the Institute of Plant Genetics, Breeding and Biotechnology of the University of Life Sciences in Lublin, involved valorisation of triticale collection materials in a four-year cycle of single-replication field experiments, according to a uniform method of evaluation and measurements. The field experiments were set up at the Experimental Farm of the University of Life Sciences in Czesławice on loess soil with a brown substrate. Seeds of all forms tested were sown by hand on 2 m^2 plots with five rows at 20 cm row spacing and 630 seeds sown on each plot.

Due to the partial allogamy of triticale, some of the spikes were isolated after heading. For this purpose, two or three cellophane crossing bags were placed on each plot. After the end of flowering the crossing bags were removed and the isolated spikes were collected separately. The grain from these spikes was used for sowing in the next growing season.

In the growing period of the plants, all the collection materials were marked with the dates of their development stages (emergence, heading and full maturity). In addition, emergence, overwintering, lodging and infection by fungal diseases were assessed on a 9-point scale according to the Research Centre for Cultivar Testing (COBORU) in SłupiaWielka (Poland), where 9 represents the most favourable condition and 1 the least favourable. The height of the plants was measured at three randomly selected locations on each plot.

During the full maturity period, 50 spikes of each form were randomly selected. Spike length and spikelet number per spike were measured in 20 spikes. The grain number and grain weight per spike and the 1,000-grain weight were calculated on the basis of threshing of 50 spikes. Protein content in the grains was determined by the Kjeldahl method. Since 2013 this procedure has been carried out in a Kjeltec (FOSS) analyser (CLA/PSO/13/2013 version 3 of 19 December 2013; PN-75/A-04018) at the Central Agroecological Laboratory of the University of Life Sciences in Lublin, using a nitrogen/protein coefficient factor of 6.25.

After four years of valorisation the accessions were transferred to the IHAR (Plant Breeding and Acclimatization Institute) seed stores in Radzików to secure an appropriate amount of grain from cultivars removed from the register as well as valuable genetic materials obtained at breeding and research facilities. There are currently 2474 triticale objects in the seed stores, of which 1417 are winter forms and 1057 are spring forms. They have complete valorisation data, i.e. the results of field evaluation and values of yield traits from four years of research.

The results presented in this paper cover the multi-year averages, range of variability, and coefficients of variation for the most important agricultural features, i.e. plant height, grain weight per spike, 1000 grain weight, and protein content in the grain of materials from winter and spring triticale collections obtained in the years 1982–2016.

RESULTS

According to the data presented in Table 1, the winter and spring triticale materials collected in the Polish gene bank are characterized by high variability of yield characteristics, with greater variation noted in the winter triticale collection. The most variable traits in both collections were grain number and weight per spike, as evidenced by their high coefficients of variation: CV = 18.9% and CV = 22.4%, respectively, for winter triticale and CV = 17.6 and CV = 19.3% for spring triticale. There was also a wide range of variation for these characteristics. Grain number per spike ranged from 10.7 to 85.1 in the winter triticale collection and from 11.9 to 89.9 in the spring triticale collection, while the ranges for grain weight per spike were 0.4–4.6 g and 0.6–3.4 g. In both collections the most frequent range for grain weight per spike was 1.6–2.5 g (Fig. 2). The winter triticale collection had a larger share of accessions with a grain weight per spike of more than 3.1 g. A high level for this feature together with a high grain number per spike is an important element in the selection of valuable starting material for breeding new varieties.

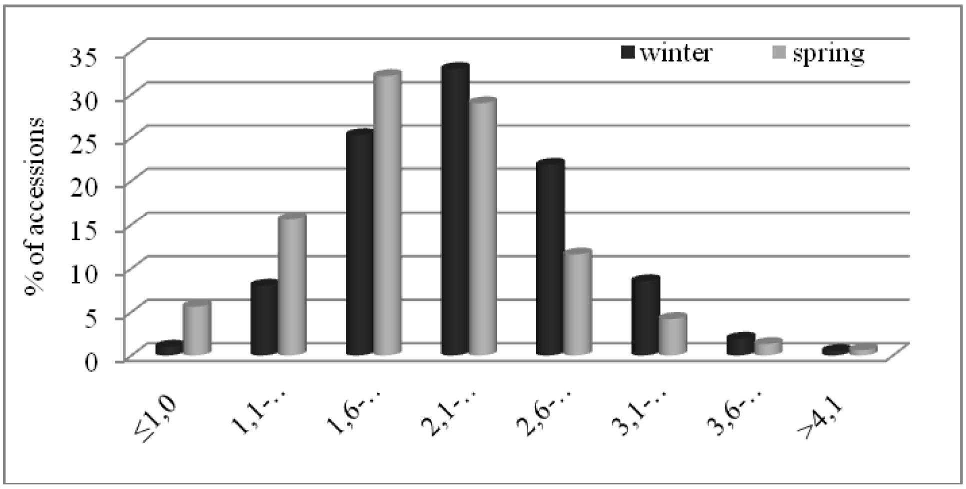

Fig. 2. The distribution of weight of grains per spike in the collection of winter and spring triticale

Table 1

Mean values, variability ranges and variation coefficients (CV) of analyzed useful traits in winter and spring triticale genetic resources accessions

Examined trait	Form	Number of accessions	Mean	Variability range min - max	CV [%]
Plant height [cm]	winter	1417	117.0	62.0 – 186.3	14.4
	spring	1057	107.7	62.3 – 168.0	12.7
Number of grains per spike	winter	1417	46.6	10.7 – 85.1	18.9
	spring	1057	44.6	11.9 – 89.9	17.6
Weight of grains per spike [g]	winter	1417	2.2	0.4 – 4.6	22.4
	spring	1057	1.9	0.6 – 3.4	19.3
1000 grain weight [g]	winter	1417	46.2	21.6 – 83.7	12.2
	spring	1057	43.5	20.0 – 81.1	11.6
Protein content in grain [%]	winter	1417	11.1	5.9 – 23.3	14.9
	spring	1057	13.0	8.6 – 20.1	10.4

The 1000 grain weight showed less variability, both in the winter triticale collection (CV = 12.2%) and the spring triticale (CV = 11.6%). The mean value was 46.2 g in the collection of winter triticale genotypes, with a range from 21.6 to 83.7 g, and 43.5 g in the spring triticale collection, with a range from 20.0 to 81.1 g (Table 1). The largest share of genotypes of both winter and spring triticale had a 1,000 grain weight from 45.1 to 55.0 g. Both collections also had a small percentage of accessions (about 4%) with a 1000 grain weight exceeding 60 g. These genotypes can be valuable starting material for breeding new, high-yield triticale cultivars (Fig. 3).

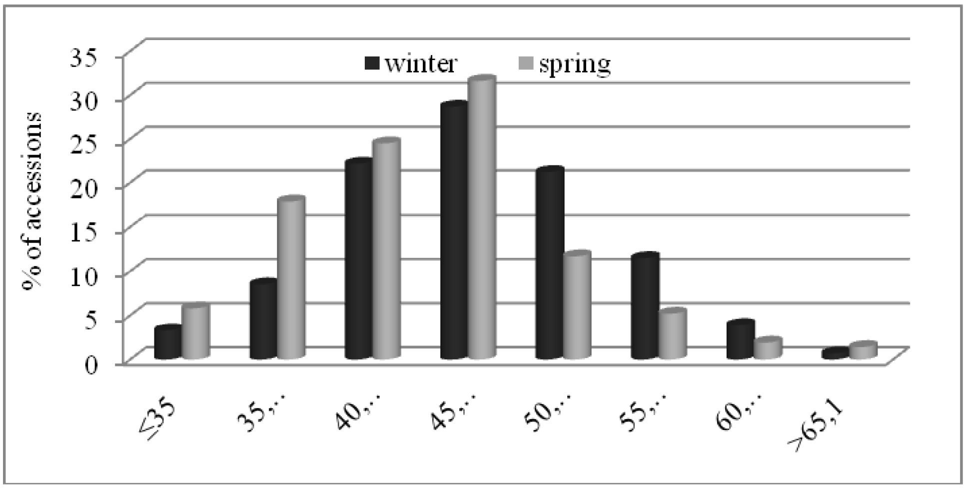

Fig. 3. The distribution of 1000 grains weight in the collection of winter and spring triticale genetic resources

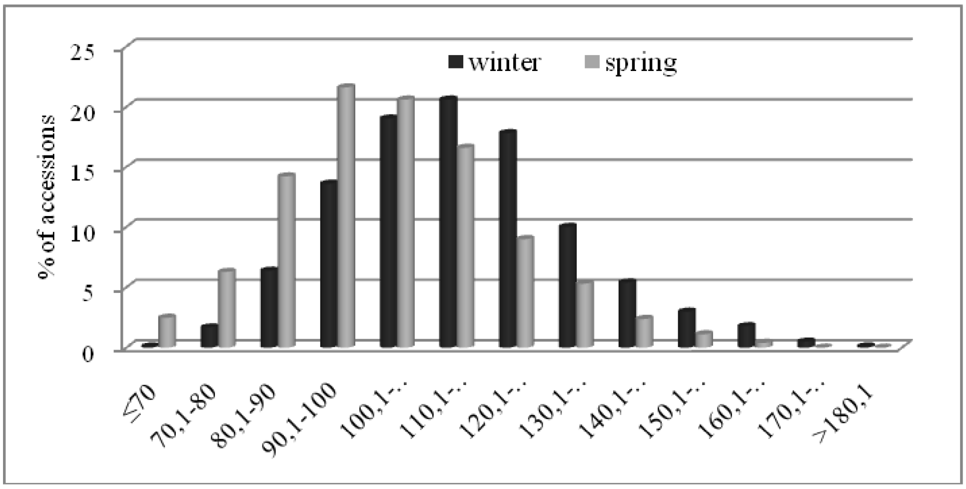

Fig. 4. The distribution of plant height in the collection of winter and spring triticale genetic resources

The height of the triticale plants was very diverse and it varied in the years of research, both among the winter triticale material (from 62.0 to 186.3 cm) and the spring triticale (from 62.3 to 168.0 cm). This was linked to the inclusion of new varieties with reduced plant height in the research, as well as older accessions from world collections whose height often exceeded 140 cm. The mean plant heights for winter and spring triticale were 117.0 cm and 107.7 cm, respectively (Table 1, Fig. 4). As can be seen from the data presented in Fig.4, the greatest share of accessions had a plant height in the range from 100.1 to

130.0 cm in the winter triticale collection and from 90.1 to 120.0 cm in the spring triticale collection. Both collections also contain short and stiff straw genotypes that are resistant to lodging, as well as very tall forms (over 140 cm) with higher protein content in the grain.

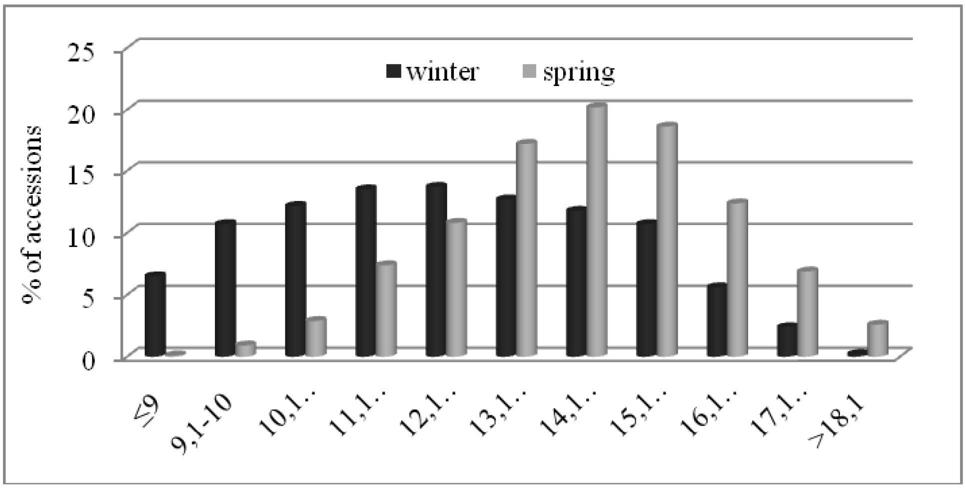

Fig. 5. The distribution of protein content in grain (%) in the collection of winter and spring triticale genetic resources

The data in Table 1 show that the spring triticale material has higher average protein content in the grain (13.0%) than the winter forms, with an average level of 11.1% in 1982–2016. In addition, this feature showed high variation in both collections: from 5.9% to 23.3% for winter triticale and from 8.6% to 20.1% for spring triticale. Accessions with protein content of 11-13% made up the largest share of the winter triticale collection, while in the spring collection more than half of the accessions had between 13% and 16% protein in the grain (Fig. 5). In terms of practical breeding, accessions with increased protein content in the grain (over 17%) merit attention.

DISCUSSION

The existence of wide genetic variation for yield and other agronomic traits in a plant population is important for an effective breeding programme. Development of high-yielding cultivars requires information on the magnitude of variability present in the germplasm (Goyal *et al.*, 2011;Thiemt and Oettler, 2008). Directional selection in breeding has resulted in material whose useful traits are more similar (Kociuba, 1992, 1996, 1998, 2000, 2007). The results of our work were similar to those obtained by Kociuba (2007, 2010), Kociuba and Kramek (2014), and Kociuba *et al.* (2007, 2010). They show the highest coefficients of variance for the number (CV from 18.5% to 23.4%) and weight of grains per spike (CV from 21.4% to 27.1%).

The characteristics that primarily determine the yield of cereal crops are the grain number and weight per spike. It is therefore important that the accessions have high values for these traits, which, if the density of spikes on a unit of surface area is good, will affect the yield. It should be remembered that the larger proportion of triticale genotypes with a higher grain number and grain weight per spike is due to the production of valuable material by breeders in Poland and abroad. Valuable genotypes are those in which the grain number per spike exceeds 60 g. Valuable initial materials useful in recombination breeding for improving yield can be selected from the germplasm of Polish triticale cultivars (Maćkowiak *et al.*, 1998;Wolski *et al.*, 1998; Cyfert, 2008; Kociuba *et al.*, 2007; Tokarski, 2010; Ukalska and Kociuba, 2013, Kociuba and Kramek 2014).

In addition to the aforementioned traits, yield is also influenced by the 1000 grain weight. Hence, one of the main objectives of breeding work on triticale is to improve grain plumpness, measured as 1000 grain weight. Triticale grains are less well-filled than wheat grains, so accessions with a high 1000-grain weight are an interesting starting material for breeding (Kociuba, 2000).

Significant progress has recently been made in triticale breeding, as evidenced by an increase in the yield obtained per unit area and in better grain fill, which may have been improved by systematic breeding and heavy selection pressure. Modern triticale cultivars have the potential to be competitive with wheat in terms of grain yield under optimal growing conditions. In commercial production, where triticale cultivars are mainly grown under suboptimal or stress conditions, they are generally superior to wheat and rye. However, such one-directional selection has caused a decrease in total protein content in the grain. The high protein content of early triticale materials was the result of shrivelled grain. As a consequence of increased plumpness, protein content in grain decreased (Oettler, 2005). State research on assessment of cultivars has shown that the protein content of the grain of currently grown winter triticale cultivars is comparable to that of wheat and rye. In the new cultivars, however, a slight decrease in this feature is observed, possibly due to better grain filling than in the past (Cyfert, 2008; Tokarski, 2010). The results of research on collections (Kociuba, 1992, 1996, 1998, 2000, 2007, 2010) indicate that lower average protein content in winter triticale grain could be associated with better grain filling, which in turn is also associated with a higher 1000 grain weight.

Breeding work on the height of winter triticale plants is aimed at obtaining traditional cultivars with a plant height of 120 to 140 cm, but with stiff straw, and short-straw cultivars (less than 120 cm) whose lodging resistance is significantly improved (The Polish National List of Agricultural Plant Varieties, 2016). The first materials from winter triticale collections had a plant height between 140 and 160 cm and were susceptible to lodging. By introducing the partially dominant dwarfing gene from the wheat cultivar Tom Pouce, the semi-dwarf cultivar Bókoló was developed in Hungary (Oettler, 2005). Cultivars of this type have been obtained in Poland as well. Fidelio was the first Polish semi-dwarf cultivar of winter triticale, registered in 1997. Subsequent breeding work has resulted in the registration of the semi-dwarf cultivars Pinokio (1997), Magnat (2000), Woltario (2000), Zorro (2002), Baltiko (2006), Gniewko (2006), Grenado (2007), Alekto (2008), Borwo (2008), Pigmej (2008), Atletico (2009), Agostino (2011), Mikado (2011), Twingo (2012), Wiarus (2012), whose plant height is below 120 cm, which significantly improves their resistance to lodging.

CONCLUSIONS

The results presented indicate that the genetic resources of triticale collected in the Polish gene bank in the years 1982–2016 represent a broad spectrum of variation in the yield traits analysed, with greater variation observed in the winter triticale collection.

The greatest variation was noted for the yield traits of the spike, i.e. grain number and grain weight per spike, as indicated by their high coefficients of variation as compared with other traits analysed.

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