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A comparative study of spring triticale varieties in the Western Siberian forest-steppe zone under different conditions of vegetation

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Spring triticale (× *Triticosecale* Wittmack) for Western Siberia is new and poorly studied culture. The objective of this study was to investigate the potential of spring triticale varieties and breeding lines and their adaptation to different conditions in Western Siberia. A field experiment was conducted in Novosibirsk region, Russia in 2014. The experiment included seven spring triticale genotypes: the elite variety Ukro, three mutant forms of the facultative type of development (Sirs 57/2/4, Cecad 90/5, O.312/38) and three hybrids (Sirs 57/2/4 × Ukro, Ukro × K-3881, the complex hybrid winter wheat Filatovka × winter rye Korotkostebelnaya 69304 × Sirs 57/2/4). They were studied at two sowing rates (400 seeds per m^2 and 800 seeds per m^2) and on two sowing dates (15 May 2014 and 27 May 2014). The following attributes were measured: grain yield, number of ears, plant height, yield components (ear length, number of spikelets per ear, number of grains per ear, grains weight per ear) and yield quality (1000-grain weight and test weight of one-liter grain volume). The three-factor analysis of variance revealed that sowing rate effect explained the major part of the total experimental variation in almost all of the traits, except 1000-grain weight and test weight, the variation of which was determined predominantly by genotype effect. The highest grain productivity of varieties was obtained for the 15 May sowing date at the 400 seeds per m^2 sowing rate. The three mutant forms used in the experiment showed a lower level of adaptability in comparison with the variety Ukro.

Key words: adaptation; density; sowing period; spring triticale; yield components.

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Изучение форм ярового тритикале в лесостепи Западной Сибири при разных условиях летней вегетации

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Яровой тритикале (× *Triticosecale* Wittmack) для Западно-Сибирского региона является относительно новой и малоизученной культурой. Цель данного исследования – определение возможностей адаптации сортов и гибридов ярового тритикале к различным условиям произрастания в Западной Сибири. Эксперимент проводился в 2014 г. на опытном поле Сибирского федерального научного центра агробиотехнологий РАН. Изучались семь форм ярового тритикале: три мутантные формы факультативного типа развития (Сирс 57/2/4, Цекад 90/5, О.312/38), три гибрида F_5 (Сирс 57/2/4 × Укро, Укро × К-3881, сложный гибрид озимая пшеница Филатовка × озимая рожь Короткостебельная 69 × Сирс 57/2/4) и сорт Укро – образец из коллекции ВИР с каталожным номером К-3644. Опыт был проведен при двух нормах высева (400 зерен на 1 м^2 и 800 зерен на 1 м^2) и двух сроках посева (15.05.2014 и 27.05.2014) в четырех повторностях. Образцы оценивались по девяти признакам, связанным с урожайностью и качеством зерна (общий вес зерен, число продуктивных побегов, высота растения, длина колоса, число колосков в колосе, число зерен в колосе, вес зерен колоса, масса 1000 зерен, натура зерна). В результате проведенного трехфакторного дисперсионного анализа установлено, что различия в плотности сева являлись главным источником вариации большинства изучаемых признаков. Только вариации массы 1000 зерен и натуры зерна были обусловлены преимущественно генотипическими особенностями растений. Наибольшая зерновая продуктивность образцов получена при сроке посева 15.05.2014 и плотности посева 400 зерен на 1 м^2. Мутантные формы ярового тритикале в проведенном опыте показали более низкий уровень адаптивности к различным условиям произрастания по сравнению с сортом Укро.

Ключевые слова: яровой тритикале; плотность посева; сроки сева; адаптация сортов.

Being a cross between wheat and rye, triticale combines the high-yield potential of wheat with the biotic and abiotic stress tolerance of rye, making it suitable for production in marginal areas (Badiyal et al., 2014; Arough et al., 2016). The main triticale-growing areas are Belarus, France, Germany and Poland (FAO, 2015; Losert et al., 2017).

In the Western Siberian region also, winter triticale is widely cultivated. For more than 10 years, Siberian farmers have been planting the varieties Cecad 90 and Sirs 57, developed by the Siberian Research Institute of Plant Production and Breeding – Branch of the Institute of Cytology and Genetics (SibRIPP&B). These varieties have an awnless spike and are donors of short straw, inherited from the rye variety Korotkostebelnaya 69 that possesses a dominant gene for short stem (Styopochkin, 2001). These varieties occupy an area of more than 30,000 hectares in Western Siberia. However, the Siberian climate provides a permanent risk of freezing injury for all winter crops, including triticale.

Spring triticale for Western Siberia is new and poorly studied culture. Most of the samples from the world VIR (N.I. Vavilov All-Russian Institute of Plant Genetic Resources) collection studied at SibRIPP&B are not adopted enough to the forest-steppe conditions of Western Siberia. They have a long straw, an awned spike and a tendency to lodging. Such as Ukrainian cultivar Ukro. It is necessary to evaluate the best samples of the world collection and some breeding forms under different natural conditions for their grain production potential and components of productivity.

In the populations of winter cultivars Cecad 90, Sirs 57, and a selection form O.312, mutant plants were found, which were capable of shifting to the generative development without vernalization. Sown in autumn, they develop as winter forms; sown in spring, they develop as spring forms. Thus, these mutant forms have actually the facultative type of development. The aim of the research was to study the main yield components of these three mutant forms in comparison with other three hybrids of spring triticale and the cultivar Ukro under different growth conditions in the Western Siberian region.

Grain yield of triticale is usually positively correlated with number of ears per square meter and the yield components of the ear – ear length, number of spikelets per ear, number of grains per ear, and grain weight per ear (Stoyanov, Baychev, 2015; Cheshkova et al., 2016). All of these yield components are highly influenced by different environmental and technological factors (Dumbrava et al., 2016; Kuhling et al., 2017) and by genotype of plants (Tams et al., 2004). Thus, for the completeness of the study, it is necessary to take into account all the components of triticale productivity.

Materials and methods

Study area and conditions. The study was conducted in Novosibirsk region, Russia (54°55′11″ N, 82°59′27″ E) in 2014. The experimental field was located in the forest-steppe zone, the soil composition of which is leached black soil of average thickness (40 cm) with humus content = 6–8 %, total nitrogen = 0.3–0.4 %, P_2O_5 = 0.17 %, K_2O = 20–25 mg/100 g, pH = 5.0–5.1.

The meteorological conditions during the period of photosynthetic activity, growth and development of plants were not sufficiently balanced in temperature regime and moisture supply. The crop-growing period of 2014 was characterized by an increased sum of the effective temperatures (1577.4 in comparison with the multi-year average value of 1317) and an nonsignificant lack of moisture (the sum of rainfall during the growing season was 193.2 mm or 91.0 % of the multi-year average value). In June, July and August, the mean monthly temperature was 17.4, 20.2 and 18.4 °C, respectively, – or 0.5, 0.8 and 2.2 °C above the multi-year average. The amount of rainfall in June was 32.0 %; in July, 126.0 %; in August, 48.0 % of the multi-year average value.

Plant material. The experiment included seven triticale genotypes (Table 1).

Experimental design and measurements. Seedlings were grown manually in fallow soil at two sowing rates (400 seeds per m^2 and 800 seeds per m^2) and on two sowing dates (15 May 2014 and 27 May 2014). The experimental field was divided into four main plots 1.5 m wide × 4.5 m long for each of 2 × 2 combinations of sowing rates and sowing dates. In each plot, 7 genotypes were arranged in 7 × 4 subplots in a randomized complete block design with four replications.

At maturity, the number of productive stems (number of ears) was recorded from 0.09 m^2 for each experimental variant. Then plants were harvested from that area, grain weight was recorded, and grain yield was determined.

The plants from each replication were taken for the analysis of plant productivity elements. The following plant traits were measured: plant height, ear length, number of spikelets per ear, number of grains per ear, and grain weight per ear.

Weight of 1000 grains was calculated from the weight of three sets of 100 randomly chosen grains for each experimental variant. Test-weight of one-liter grain volume was calculated using the method of grains measure in a micro-vessel (Stepochkina, Stepochkin, 2015).

Statistical analysis. The package 'R' (R Development Core Team, 2014) was used for the statistical analysis. A mixed model was fitted, in which sowing rates, sowing dates and genotypes were considered fixed factors and replications were considered random effects. Normality of model residuals was assessed by Shapiro–Wilk test, and homogeneity of variance was assessed by Levene's test. Fisher's least significant difference (LSD) test was used to identify differences between treatment means at $p \leq 0.05$ (Teetor, 2011).

Results

The June drought adversely affected the development of plants. Many drought-weakened plants at the beginning of the tillering phase were damaged by insect pests. The most damaged were the hybrid FKS and two mutant forms, Cecad 90/5 and O.312/38.

The analysis of variance showed that all main factors for almost all traits under study were significant (Table 2); only test weight was not affected by the sowing date. The variability induced by sowing rate constituted a major part of the variation in number of ears, ear length, number of spikelets per ear, number of grains per ear, grain weight per ear and grain yield; while variation in plant height, 1000-grains weight and test weight was explained to a greater extent by genotype effect.

Among the genotypes examined (Fig. 1), Ukro had the highest values for ear number, plant height, grain weight per ear, 1000-grain weight and grain yield. Sirs 57/2/4 showed

Table 1. Triticale lines and cultivars studied

Name	Origin	Description
Ukro (UK)	Ukraine	A cultivar from VIR collection, catalog number K-3644
Sirs 57/2/4 (S57)	Russia, Novosibirsk	Mutant form
Cecad 90/5 (C90)		
O.312/38 (O312)		
Sirs 57/2/4 × Ukro (S×UK)	»	Hybrid, F_5
Ukro × Mexican sample of VIR collection K-3881 (UK×K)		
Winter wheat Filatovka × winter rye Korotkostebelnaya 69 × Sirs 57/2/4 (FKS)	»	Complex hybrid, F_5

Table 2. Analysis of variance (percentage of the sum of squares) for morphological traits and yield components of triticale varieties grown at different sowing rates and under different sowing dates

Source of variation	d.f.	Number of ears	Plant height	Ear length	Number of spikelets per ear	Number of grains per ear	Grain weight per ear	1000-grain weight	Grain yield	Test weight
Genotype	6	19.7***	62.9***	27.6***	23.3***	19.1***	26.5***	69.8***	22.1***	65.5***
Sowing date	1	4.53***	10.5***	6.44***	6.18***	5.57***	8.56***	3.77***	7.98***	0.29
Sowing rate	1	32.3***	0.43*	36.4***	34.7***	41.4***	27.3***	0.99***	39.6***	6.93***
Genotype × sowing date	6	6.13**	7.32***	1.87	1.69	2.15	2.65	4.60***	3.77**	0.62
Genotype × sowing rate	6	5.24**	3.62***	4.65***	9.72***	2.69	3.87*	5.95***	6.67***	7.63***
Sowing date × sowing rate	1	0.10	0.73**	0.94**	1.58**	0.0001	0.35	0.10	0.74*	0.42
Genotype × sowing date × sowing rate	6	3.33	5.03***	2.27	3.69**	1.69	2.38	3.82***	1.00	2.77**
Error	84	28.6	9.54	19.8	19.1	27.4	28.4	10.9	18.2	15.8

*, ** and *** Significant at 0.1, 0.05 and 0.01 significance level, respectively.

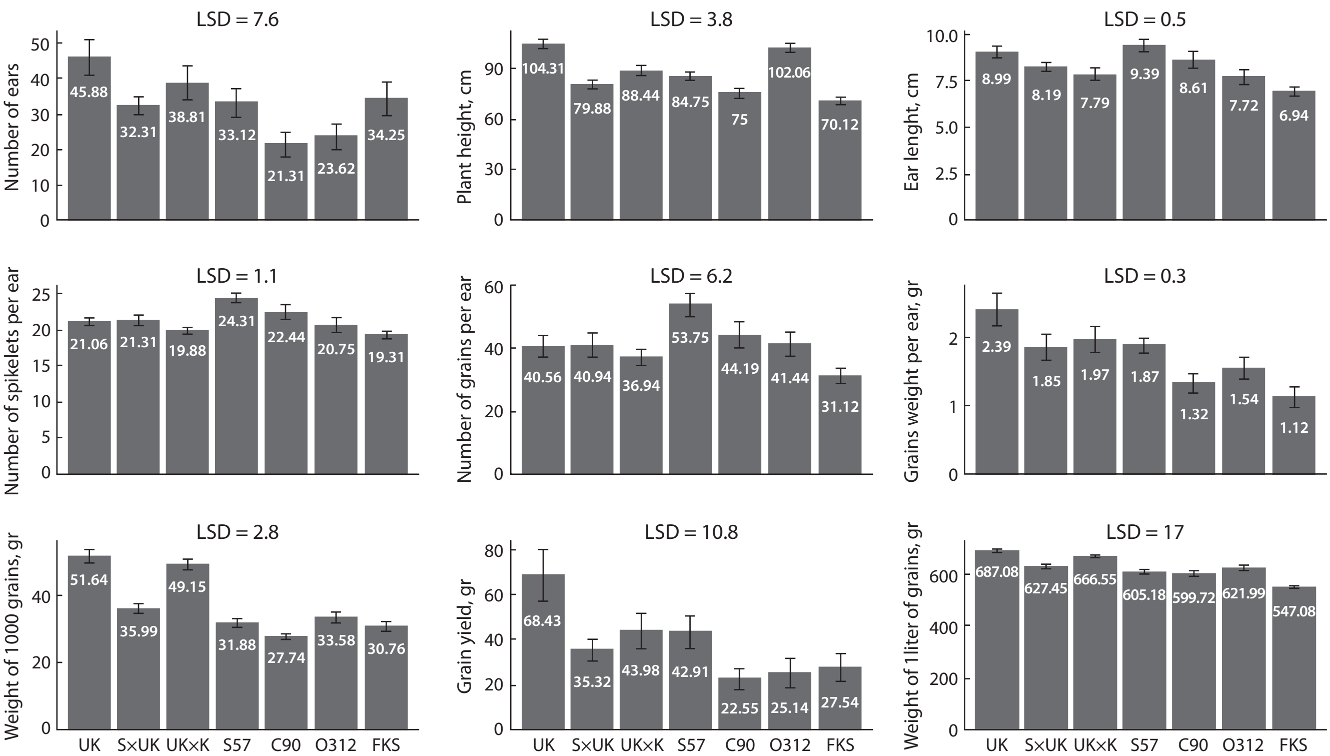

Fig. 1. Mean values (±SE) of morphological traits and yield components of triticale varieties.
LSD, Least Significant Difference with $p < 0.05$.

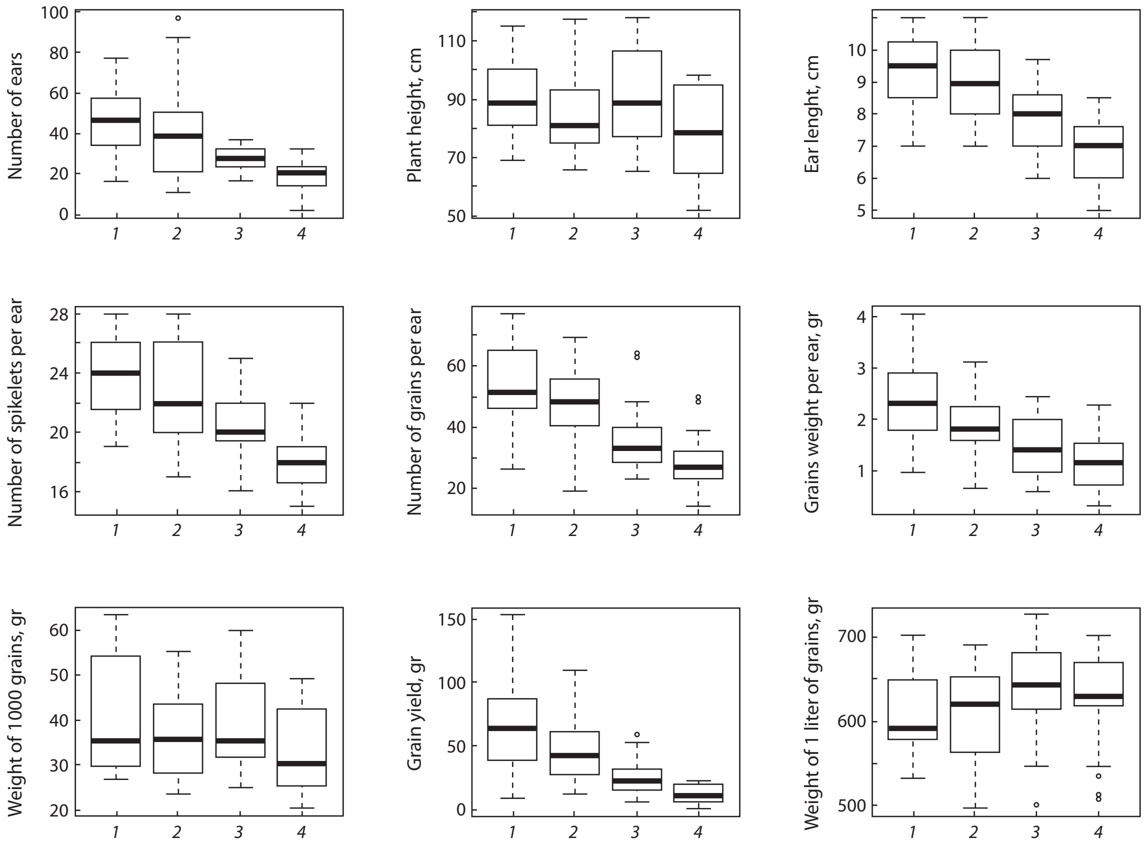

Fig. 2. Boxplots for traits under study at four experimental plots.

Numbers on *X*-axis are: *1*, seeded on 15 May at 400 seeds per m^2; *2*, seeded on 27 May at 400 seeds per m^2; *3*, seeded on 15 May at 800 seeds per m^2; *4*, seeded on 27 May at 800 seeds per m^2.

the highest values for ear length, number of spikelets per ear and number of grains per ear. The lowest values of grain yield were found for Cecad 90/5 and the complex hybrid FKS.

Sowing date × sowing rate interaction was significant for plant height, ear length and number of spikelets per ear (Fig. 2). The highest mean values for almost all the traits were obtained for the 15 May sowing date at the 400 seeds per m^2 sowing rate. The lowest, for the 27 May sowing date at the 800 seeds per m^2 sowing rate. Thus, the later date of sowing and the higher sowing density adversely affected the yield components. However, the largest mean value for test weight was for the 15 May sowing date at the 800 seeds per m^2 sowing rate.

Genotype × sowing date interaction was significant for number of ears, plant height, 1000-grain weight and grain yield. Differences in the mean values of traits under study between triticale varieties seeded on 15 May and those seeded on 27 May are shown in Figure 3. Most of the triticale varieties had higher values of traits for the earlier than for the later sowing date. Only the hybrid Sirs 57/2/4 × Ukro had lower number of ears, plant height, 1000-grain weight and grain yield for the first date compared to the second date.

Genotype × sowing rate interaction was significant for number of ears, plant height, ear length, number of spikelets per ear, 1000-grain weight, grain yield and test weight. The differences in mean values of traits between triticale varieties seeded at 400 seeds per m^2 and those seeded at 800 seeds per m^2 are shown in Figure 4. For all triticale varieties, mean values of number of ears, ear length, number of spikelets per ear and grain yield were higher for the sowing rate of 400 seeds per m^2 than for 800 seeds per m^2. However, 1000-grain weight was larger at 800 seeds per m^2 for Sirs 57/2/4, Cecad 90/5 and Sirs 57/2/4 × Ukro; and test weight was larger at 800 seeds per m^2 for all varieties, except FKS.

Discussion

The experiment showed that the mutant forms studied, Sirs 57/2/4, Cecad 90/5 and O.312/38, had a lower grain production potential than the cultivar Ukro. This was attributable to the fact that the mutant forms were obtained from winter varieties adapted to the prolonged autumn-summer vegetation. These results are in agreement with experiments on vernalization response conducted by Herndl et al. (2008) and Košner, Pánková (2002).

The highest grain productivity of varieties was obtained for the 15 May sowing date at the 400 seeds per m^2 sowing rate. Later sowing date (27 May) and higher seed rate (800 seeds per m^2) can be considered stress factors, as these factors decreased almost all yield components, except 1000-grain weight and test weight. These two traits, on the contrary, showed higher values at the higher seed rate and were not much affected by the sowing date. Similar results were reported by Aparna et al. (2014), who indicated that stress conditions reduced yield through lower grain number,

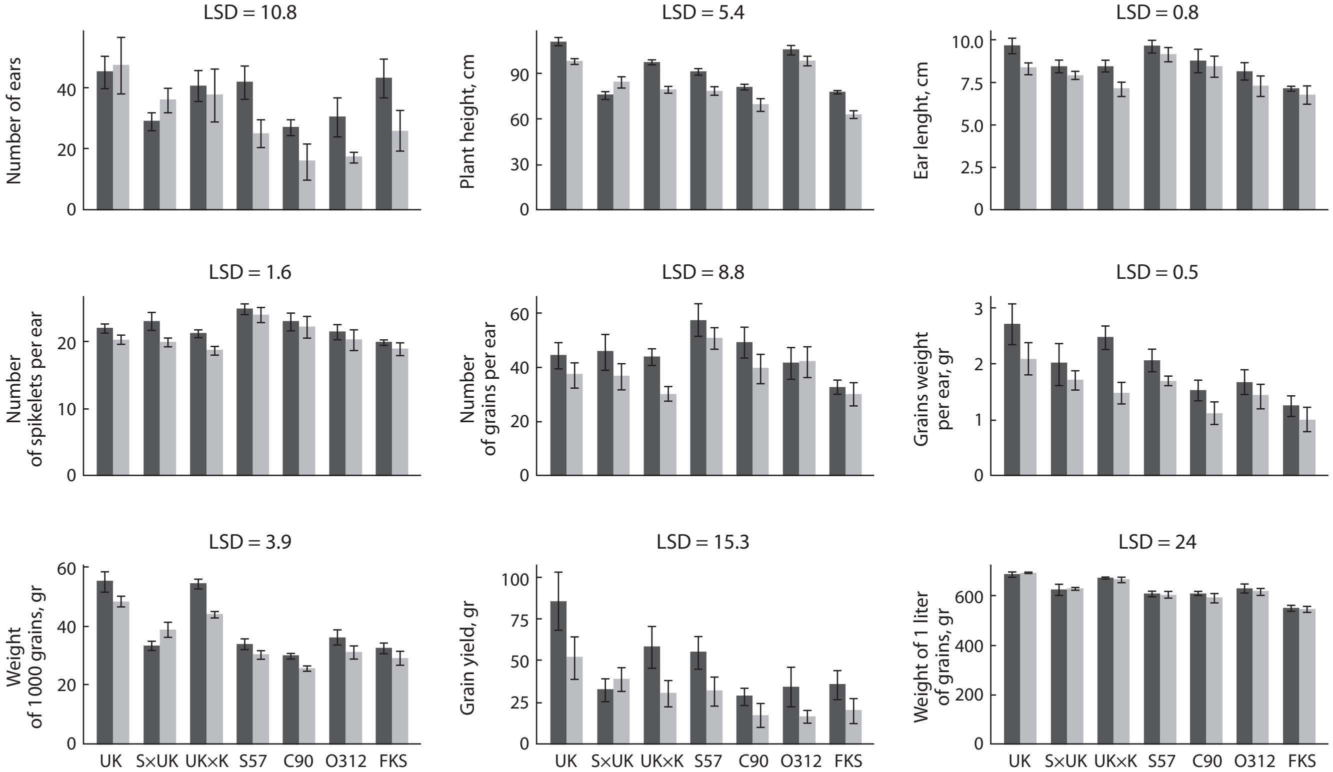

Fig. 3. Effect of genotype × sowing date interaction for morphological traits and yield components of triticale varieties.

Dark bars indicate mean values (± SE) for each variety seeded on 15 May 2014, light bars indicate mean values (± SE) for each variety seeded on 27 May 2014. LSD, Least Significant Difference with $p < 0.05$.

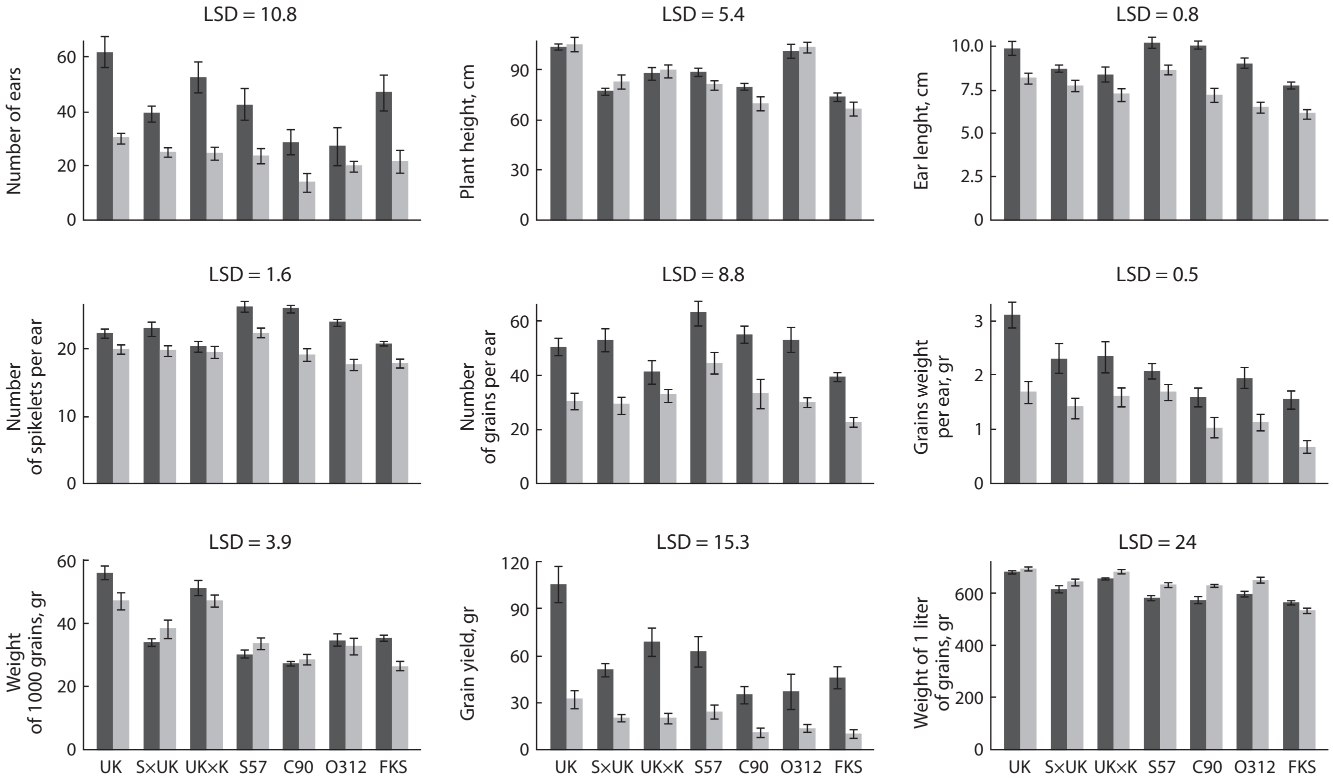

Fig. 4. Effect of genotype × sowing rate interaction for morphological traits and yield components of triticale varieties.

Dark bars indicate mean values (± SE) for each variety with 400 seeds per m^2 sowing density, light bars indicate mean values (± SE) for each variety with 800 seeds per m^2 sowing density. LSD, Least Significant Difference with $p < 0.05$.

but not through reduction in 1000-seed weight. In addition, Dumbrava et al. (2016) concluded that high values of the test weight were determined by the small number of ears per m^2 and the small number of grains per ear, which influenced the apparent density of grains.

The three-factor analysis of variance revealed that sowing rate effect explained the major part of the total experimental variation in almost all of the traits, except 1000-grain weight and test weight, the variation of which was determined predominantly by genotype effect. That corresponds with earlier reports by Burdujan et al. (2014).

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Conflict of interest

The authors declare no conflict of interest.

References

Aparna K., Hash C.T., Yadav R.S., Vadez V. Seed number and 100-seed weight of pearl millet (*Pennicetum glaucum* L.) respond differently to low soil moisture in genotypes contrasting for drought tolerance. J. Agron. Crop. Sci. 2014;200:119-131. DOI 10.1111/jac.12052.

Arough Y.K., Seyed Sharifi Raouf, Seyed Sharifi Reza. Bio fertilizers and zinc effects on some physiological parameters of triticale under water-limitation condition. J. Plant Interact. 2016;11:1 167-177. DOI 10.1080/17429145.2016.1262914.

Badiyal A., Chaudhary H.K., Jamwal N.S., Hussain W., Mahato A., Bhatt A.K. Interactive genotypic influence of triticale and wheat on their crossability and haploid induction under varied agroclimatic regimes. Cereal Res. Commun. 2014;42:700-709. DOI 10.1556/CRC.2014.0017.

Burdujan V., Rurac M., Melnic A. Productivity and quality of winter triticale (×*Triticosecale* Wittmack) in multifactorial experiments. Scientific Papers. Series A. Agronomy. 2014;LVII:119-122.

Cheshkova A., Aleynikov A., Stepochkin P. Analysis of covariation of quantitative characters of triticale. Achievements Sci. Technol. AIC. 2016;30:50-52.

Dumbravă M., Ion V., Epure L.I., Băşa A.G., Ion N., Duşa E.M. Grain yield and yield components at triticale under different technological conditions. Agric. Agric. Sci. Procedia. 2016;10:94-103.

FAO, 2015: Statistical Yearbook. World Food and Agriculture. Rome, 2015.

Herndl M., White J.W., Hunt L.A., Graeff S., Wilhelm C. Field-based evaluation of vernalization requirement, photoperiod response and earliness per se in bread wheat (*Triticum aestivum* L.). Field Crops Res. 2008;105:193-201. DOI 10.1016/j.fcr.2007.10.002.

Košner J., Pánková K. Vernalisation response of some winter wheat cultivars. Czech J. Genet. Plant Breed. 2002;38:97-103.

Kuhling I., Redozubov D., Broll G., Trautz D. Impact of tillage, seeding rate and seeding depth on soil moisture and dryland spring wheat yield in Western Siberia. Soil Till. Res. 2017;170:43-52. DOI 10.1016/j.still.2017.02.009.

Losert D., Maurer H.P., Marulanda J.J., Würschum T. Phenotypic and genotypic analyses of diversity and breeding progress in European triticale (×*Triticosecale* Wittmack). Plant Breed. 2017;136:18-27. DOI 10.1111/pbr.12433.

R Development Core Team. R: A language and environment for statistical computing. 2014. R Foundation for Statistical Computing. Vienna, Austria. Available at: http://www.R-project.org

Stepochkina N.I., Stepochkin P.I. The use of micropurka in determining grain nature of single plants of triticale and wheat. Achievements Sci. Technol. AIC. 2015;11:39-40.

Stoyanov H., Baychev V. Correlations between spike parameters of first generation direct and reciprocal crosses of Triticale (×*Triticosecale* Wittm.). Agricult. Sci. 2015;18:25-34.

Styopochkin P.I. Working out and studies of Siberian triticale genepool. In: Proceed. Intern. Conf. "Genetic Collections, Isogenic and Alloplasmic Lines". Novosibirsk, Russia, 2001:235-237.

Tams S.H., Bauer E., Oettler G., Melchinger A.E. Genetic diversity in European winter triticale determined with SSR markers and coancestry coefficient. Theor. Appl. Genet. 2004;108:1385-1391. DOI 10.1007/s00122-003-1552-1.

Teetor P. R Cookbook. O'Reilly Media, 2011;413.