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YIELD PERFORMANCE OF CULTIVAR MIXTURES OF SPRING TRITICALE

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Abstract. An experiment on a cereal mixture of two spring triticale cultivars, 'Gabo' 'Wanad', included two factors, notably: I. Sowing method of spring triticale cultivars – A. Sole cropping of cv. 'Wanad', B. Sole cropping of cv. 'Gabo', C–G. Mixed cropping of cvs. 'Gabo' and 'Wanad'; II. Crop protection method in spring triticale stand: a) mechanical – harrowing after sowing as well as at the cracking stage and at the 4-5 leaves stage of spring triticale, b) mechanical and chemical – harrowing after sowing as well as at the cracking stage and at the 4-5 leaves stage of spring triticale, and also additionally herbicide, retardant and fungicide application, c) chemical – application of plant protection products. Mixed croppings of the spring triticale cultivars 'Wanad' and 'Gabo' produced significantly higher yields than in the case of sole cropping of these cultivars. Mixtures of these cultivars composed of at least 50% of cv. 'Wanad' produced the highest yield. Intercropping of the spring triticale cultivars had a beneficial effect on canopy and ear parameters of the crop plant in question, such as: grain weight per ear, number of ears per 1 m^2, and plant lodging. Spring triticale grain yield was also significantly differentiated by crop protection method. The highest grain yield was obtained in the chemically treated plot (4.68 t ha^{-1}), the treatment with chemical and mechanical crop protection produced a significantly lower yield (4.34 t ha^{-1}), whereas grain yield was the lowest in the case of mechanical crop protection (4.11 t ha^{-1}).

Keywords: cereal mixture, cultivation methods, sowing methods, yield components.

INTRODUCTION

An essential advantage of cereal mixtures is their more reliable and more stable yield performance compared to sole cropped cultivars. This results from better use of nutrients and water by the components of a mixture. Due to biological variation within the stand, mixed crops are more tolerant to worse habitat and agronomic conditions. Unfavourable growth conditions for one of the mixture components can be favourable for the other one and in such a case the other component gains a dominant position in the stand, compensating for the loss in yield of the first component (Leszczyńska 2003, Szempliński and Budzyński 2011).

Thanks to the introduction of biodiversity, mixed cropping can play an important role in a crop rotation system, mitigating the negative effects of growing a particular crop in the same field too frequently. Research has shown that mixed stands are less susceptible to diseases and pests, which means that they do not require high expenditure on crop protection and fertilisation, thereby reducing environmental contamination (Manthey and Fehrmann 1993, Buczek *et al*. 2007, Newton *et al*. 2008). Mixed cropping of cereals additionally increases their resistance to lodging and weed competitiveness (Juskiw *et al.* 2000).

The growing popularity of mixed cereal cropping is also associated with farmers' attempts to cut down cultivation costs and to reduce yield fluctuations arising from different weather patterns between years and from soil variation in the field (Finckh *et al.* 2000, Bowden *et al.* 2001). Therefore, yield of mixed crops is a result of the species and quantitative variation in the mixture and its response to habitat conditions. For this reason, an appropriate selection of species for mixtures and their proportions is a condition for obtaining high yields.

The aim of the present study was to determine the effect of three crop protection methods on yield and yield components of two spring triticale cultivars grown in sole cropping and in mixed cropping using cultivar mixtures of this plant with different compositions.

MATERIALS AND METHODS

Plant material and growth conditions. The study was conducted during the period of 2007-2009. It was carried out in a family farm located in the village of Rozbórz, commune of Przeworsk (50°3'28.08"N, 22°32'46.75"E), on a brown soil derived from silt loam, characterised by acidic pH (5.22 in 1 M KCl), a low content of available forms of phosphorus (72 mg kg^{-1} of soil) and potassium (83 mg kg^{-1} of soil), as well as a high content of magnesium (123 mg kg^{-1} of soil). The soil humus content was 1.76%. The experiment included two factors, notably: I. Sowing method of spring triticale cultivars - A. Sole cropping of cv. 'Wanad'(W), B. Sole cropping of cv. 'Gabo'(G), C–G. Mixed cropping of cvs. 'Wanad' and 'Gabo' at the following proportions: 'Wanad' 20% + 'Gabo' 80%, 'Wanad' 40% + 'Gabo' 60%, 'Wanad' 50% + 'Gabo' 50%, 'Wanad' 60% + 'Gabo' 40%, 'Wanad' 80% + 'Gabo' 20%; II. Crop protection method in spring triticale stands: a) mechanical – harrowing after sowing (BBCH-10) as well as at the cracking stage and at the 4-5 leaf stage of spring triticale (BBCH-14), b) mechanical and chemical – harrowing after sowing as well as at the cracking stage and at the 4-5 leaf stage of spring triticale, and additionally at full tillering (BBCH-22) Chwastox Turbo 340 SL was used against weeds at the rate of 2 dm^3 ha^{-1} [MCPA + dicamba], at stem elongation (BBCH-30) the retardant Cecefon 465 SL was used against crop lodging at the rate of 1.5 dm^3 ha^{-1} [chlormequat chloride + ethephon] as well as at the heading stage (BBCH-51) the fungicide Bravo Plus 500 SC was applied against diseases at the rate of 2 dm^3 ha^{-1} [chlorothalonil]; c) chemical – use of crop protection agents against weeds, lodging and diseases as in point "b".

The Gabo variety sown in this experiment has an average height of plants, fairly low resistance to lodging and average level of yields. Plants of Wanad variety reach a height of 110 cm, have low lodging resistance, but with a normal level of agricultural technology produce very high yields.

The experiment was set up in a randomised block design in triplicate, in 20 m^2 plots for sowing and harvest. Seeding rate of varieties and mixtures was 420 grains per 1 m^2. Sowing was performed at the recommended date. Mineral fertilisation, in kg of nutrient per hectare, was as follows: P – 60, K – 110, N – 90. Phosphorus and potassium fertilisers were applied in full before sowing, whereas nitrogen fertilisers were incorporated at two equal rates: before sowing and at stem elongation. The preceding crop for spring triticale was a legume-cereal mixture (field pea + vetch + oat) grown as a stubble crop to be ploughed in. After the stubble crop was ploughed under at the flowering stage, the field was harrowed twice and then during the third 10-day period of October autumn ploughing was done to a depth of 30 cm. Harrowing was done in the spring and subsequently, at optimum field capacity, the soil was additionally tilled with a tillage implement.

Grain yield was determined for the whole plot area and expressed as t ha^{-1}, at 15% grain moisture content. The degree of plant stand lodging was determined using a 9-point scale in which 1 means plants completely lodged, whereas 9 – plants standing erect (Methodology of economic value of varieties, 1998). The number of ears before harvest on 1 m^2 was determined by means of a frame with dimensions of 0.5 x 1 m, placed at two randomly selected locations. The number and weight of grains per ear was determined by dividing the total number of grains and their weight by the number of spikes (30 pieces) collected from each plot. The mass of a thousand grains was determined on the basis of 500 grains, which weight was multiplied by two.

Statistical analysis. The study results were statistically analysed by analysis of variance, while the differences between means were estimated by Tukey's test at a significance level of $\alpha = 0.05$. Statgraphics 5.0 software was used for statistical analysis.

Weather conditions at the study site. The farm where the field research was conducted is located in moderately continental climate zone. This location is characterised by a fairly long, lasting 210-220 days, growing season, with an average annual air temperature above 8°C (Tab. 1).

Table 1. Agroclimatic conditions at the Rzeszów-Jasionka Station

Months	Rainfall (mm)			1981-2006	Temperature (°C)			1981-2006
	2007	2008	2009		2007	2008	2009	
April	27.0	46.0	4.0	53.9	9.0	9.3	11.1	8.8
May	40.0	105.0	103.0	79.3	15.6	13.6	13.3	14.3
June	71.0	87.0	146.0	87.8	18.9	18.0	16.6	16.8
July	74.0	118.0	98.0	100.6	20.0	18.7	20.0	19.2
August	88.0	55.0	45.0	75.4	19.1	18.9	18.8	18.4
Sum/Mean	300.0	411.0	396.0	397.0	16.5	15.7	16.0	15.5

RESULTS

The statistical analysis showed a significant correlation between experimental factors (Tab. 2). The weather conditions in the particular seasons during the study period differentiated spring triticale grain yield at the level of 17.3%.

The crop protection method changed significantly spring triticale grain yield, by as much as 13.9%. In the case of mechanical crop protection, grain yield was obtained at a level of 4.11 t ha^{-1}. If the mechanical method was complemented with herbicides and other chemical agents, there was a significant increase in grain yield compared to mechanical crop protection (a 5.6% increase), whereas the use of chemical crop protection alone resulted in a further significant increase in yield, also relative to the mechanical and chemical method (a 7.8% increase).

The sowing method of spring triticale cultivars, considered independently of the other experimental factors, had an effect on grain yield at a level of 13.7%. The lowest spring triticale grain yield was found in the sole cropped plots with cv. 'Gabo' – 4.01 t ha^{-1}. Cv. 'Wanad' in sole cropping produced a higher yield (by 10.7%), while the mixtures of both cultivars at a proportion of 50:50 and 80 ('Wanad'): 20 ('Gabo') produced an even higher yield. The increase in yield of the first mixture in relation to sole cropped cv. 'Gabo' was 0.53 t ha^{-1} (13.2%), whereas in the case of the other mixture by 0.55 t ha^{-1} (13.7%). The cultivar mixtures, except for the mixture at the proportion of 20% 'Wanad' + 80% 'Gabo', significantly increased grain yield compared to sole cropped cv. 'Gabo'.

Number of ears per unit area in the spring triticale crop before harvest was most differentiated by years (565-631 pcs m^{-2}) (Tab. 3). The crop protection method differentiated ear density. Significantly the lowest number of these organs (on average

568 pcs m^{-2}) was found in the mechanically treated plots, this number was higher (598 pcs m^{-2}) in the plots with the mechanical and chemical crop protection, while it was the highest in the chemically treated plots – 624 pcs m^{-2}. Taking into account the sowing method alone, cultivar ‘Wanad’ in sole cropping produced significantly more ears per unit area compared to cv. ‘Gabo ’. Significantly greater numbers of ears per unit area were found in the case of the mixture sown at the proportion W 80% + G 20% compared to sowing at the proportion W 20% + G 80%.

Table 2. Grain yield of spring triticale (t ha^{-1})

Sowing method	2007	2008	2009	Cultivation method			Mean
				m*	m-ch*	ch*	
Wanad	4.69	3.96	4.67	4.28	4.43	4.62	4.44
Gabo	4.01	3.82	4.20	3.58	4.22	4.23	4.01
W 20% + G 80%	3.99	4.02	4.87	3.98	4.16	4.74	4.29
W 40% + G 60%	4.29	4.01	4.82	4.22	4.25	4.66	4.38
W 50% + G 50%	4.53	4.29	4.79	4.24	4.57	4.80	4.54
W 60% + G 40%	4.39	4.10	4.77	4.18	4.20	4.88	4.42
W 80% + G 20%	4.42	4.17	5.10	4.29	4.54	4.85	4.56
Mean	4.33	4.05	4.75	4.11	4.34	4.68	
$LSD_{0.05}$ values: Y = 0.147; SM = 0.283; CM = 0.147							

**Y = years; SM = sowing method; CM = cultivation method: m* = mechanical; m-ch* = mechanical-chemical; ch* = chemical.

Table 3. Number of ears of spring triticale before harvest (1 m^2)

SM	2007	2008	2009	CM			Mean
				m*	m-ch*	ch*	
W	608	581	634	589	596	639	608
G	574	540	626	526	597	616	580
W 20% + G 80%	579	557	612	550	577	622	583
W 40% + G 60%	632	545	625	574	598	629	600
W 50% + G 50%	582	585	657	591	609	624	608
W 60% + G 40%	590	559	617	557	592	617	589
W 80% + G 20%	595	586	647	587	618	623	609
Mean	594	565	631	568	598	624	
$LSD_{0.05}$ values: Y= 11.8; SM = 22.9; CM = 11.8							

**– legend as in Table 2.

Grain number per ear and grain weight per ear in the spring triticale crop was significantly dependent on meteorological conditions in particular seasons. The sowing methods and crop protection methods used in the spring triticale plots interacted only with years in their effect on these traits (Tabs 4 and 5). On average, the highest number of grains per ear, but the lowest weight (1.51 g), was found in 2007 – 45.2 pieces. In the next years of the study, the value of both the number and weight of grains per ear changed relative to the first year of the experiment. Despite the lack of significant differences, each of the cultivar mixtures was characterised by higher grain weight than the sole cropping of the cultivars.

Table 4. Number of grains in ear of spring triticale

SM	2007	2008	2009	CM			Mean
				m*	m-ch*	ch*	
W	44.7	45.2	45.7	46.2	44.1	45.2	45.2
G	45.7	44.5	44.1	43.3	45.2	45.8	44.8
W 20% + G 80%	45.6	44.0	45.8	44.9	47.8	42.7	45.1
W 40% + G 60%	45.5	38.5	44.9	41.0	43.9	44.1	43.0
W 50% + G 50%	45.1	45.8	42.9	45.2	44.3	44.2	44.6
W 60% + G 40%	45.1	42.3	45.3	44.6	45.6	42.6	44.3
W 80% + G 20%	44.9	43.8	45.4	44.6	44.8	44.6	44.7
Mean	45.2	43.4	44.9	44.3	45.1	44.2	
$LSD_{0.05}$ values: Y = 1.46; Y × SM = 5.91							

**– legend as in Table 2.

Table 5. Weight of grains of spring triticale per ear (g)

SM	2007	2008	2009	CM			Mean
				m*	m-ch*	ch*	
W	1.45	1.47	1.58	1.56	1.53	1.42	1.50
G	1.50	1.53	1.62	1.46	1.59	1.60	1.55
W 20% + G 80%	1.52	1.64	1.69	1.72	1.59	1.54	1.62
W 40% + G 60%	1.54	1.61	1.68	1.54	1.67	1.62	1.61
W 50% + G 50%	1.57	1.65	1.52	1.55	1.64	1.55	1.58
W 60% + G 40%	1.49	1.61	1.57	1.60	1.63	1.45	1.56
W 80% + Ga 20%	1.48	1.67	1.63	1.59	1.54	1.64	1.59
Mean	1.51	1.60	1.61	1.57	1.60	1.55	
$LSD_{0.05}$ values: Y = 0.063; SM × CM = 0.256; Y × SM × CM = 0.512							

**– legend as in Table 2.

Thousand grain weight (TGW) was independent of the experimental factors. It was changed significantly only by the years and the interaction of the experimental factors with years (Tab. 6). On average, grains in 2008 were characterised by the lowest size and TGW was 37.7 g. In the other seasons of the study, the character in question was significantly higher and it was at least 38.7 g. Taking into account all study years, the spring triticale grain in 2008 was found to have by far the lowest weight in the plots sown with the cultivar mixture at a proportion of 50:50 and mechanically weeded – 34.7 g. In turn, sole croppings of cv. 'Wanad' in 2009, in which mechanical or chemical crop protection was used, were found to have significantly the highest grain weight – 42 g.

Table 6. 1000 grains weight of spring triticale (g)

SM	2007	2008	2009	CM			Mean
				m*	m-ch*	ch*	
W	38.9	37.8	40.7	38.7	38.4	40.2	39.1
G	38.2	38.0	38.2	39.1	37.7	37.6	38.1
W 20% + G 80%	38.0	37.6	40.6	39.3	38.7	38.2	38.7
W 40% + G 60%	38.2	38.6	38.7	39.1	38.0	38.4	38.5
W 50% + G 50%	38.9	37.1	36.9	36.9	37.8	38.2	37.6
W 60% + G 40%	39.1	37.3	39.1	39.3	37.8	38.4	38.5
W 80% + G 20%	39.3	37.6	39.8	39.3	38.9	38.5	38.9
Mean	38.7	37.7	39.1	38.8	38.2	38.5	
$LSD_{0.05}$ values: Y = 0.95; Y × SM × CM = 7.66							

**– legend as in Table 2.

All the experimental factors differentiated spring triticale lodging, as measured using a 9-point scale (Tab. 7). This trait was mostly dependent on the weather pattern in particular years (ratings between 4.3 and 8.2), less dependent on the crop protection method (ratings between 4.4 and 7.7) and the least dependent on sowing technique (ratings between 5.9 and 6.9). The year 2008 was the most conducive to crop lodging. In that year, the average lodging rate was 4.3, whereas in the mechanically treated plot it was only 4.4. This means that plants in this treatment were strongly bent and at places even twisted. Totally different plants were found in the latter mentioned treatment in the years 2007 and 2009, since in those years triticale stems were only slightly bent at the most (the rate ranged 7.6-7.7).

Table 7. Lodging of spring triticale (9 step scale)

SM	2007	2008	2009	CM			Mean
				m*	m-ch*	ch*	
W	8.7	4.6	6.9	4.7	7.7	7.1	6.5
G	6.9	3.7	6.6	2.1	7.7	7.3	5.7
W 20% + G 80%	8.1	4.5	7.4	4.4	7.9	7.7	6.7
W 40% + G 60%	8.7	4.6	7.4	5.0	7.8	7.8	6.9
W 50% + G 50%	8.0	4.6	7.0	4.2	7.5	7.9	6.5
W 60% + G 40%	8.7	4.4	7.7	5.4	7.6	7.8	6.9
W 80% + G 20%	8.4	3.9	7.9	5.2	7.1	7.9	6.7
Mean	8.2	4.3	7.3	4.4	7.6	7.7	
$LSD_{0.05}$ values: Y= 0.30; SM = 0.59; CM = 0.30							

**– legend as in Table 2.

DISCUSSION

The correlation of yield performance of spring cereals with the weather conditions, in particular with the amount and distribution of rainfall during the growing season, is confirmed by other research (Dmowski *et al.* 2001, Emam *et al.* 2007, Asseng *et al.* 2008, Högy *et al.* 2013). In the opinion of Artyszak (1994) and Podlaska *et al*. (1993), mixed crops of cereals are less susceptible to adverse weather conditions during the growing season. The results of their research show that higher and more reliable yields are obtained in mixed crops than in sole cropping, in particular in fields with significantly varying trophic conditions and on poorer soils. In the present study, spring triticale productivity was also greatly dependent on weather conditions during the growing season and these varied significantly between the years. The second year (2008) was the least favourable for plant growth; in that year, too high rainfall and low air temperatures in May could have affected negatively the initial growth and, subsequently, lodging of spring triticale. The year 2009 proved to be the most favourable for yield performance of the studied plant, since the highest grain yields were then obtained during the entire three-year study period.

This research shows that cereal productivity was dependent not only on the weather pattern, but also on the method of sowing and crop protection. Mixed cropping of these cultivars, in particular of the cultivar mixture with a predominance of cv. ‘Wanad’ which, according to cereal growers, produces very high yields at the normal level of agronomic practices, had an effect on increasing spring triticale yield. In the opinion of Cowger and Weisz (2008) as well as Dai *et al.* (2011), mixtures composed of cultivars with the highest yielding ability in sole cropping give the highest yields.

On the basis of the existing field studies, it can be concluded that increased ear density per unit area contributes to a reduced number of grains per ear (Pisulewska *et al.* 2004). The above cited authors found an average 12% decline in the number of grains per ear after the seeding rate was increased from 400 to 500 seeds per 1 m^2. In the present study, a seeding rate of 420 seeds per 1 m^2 was used. Grain number per ear was significantly determined by weather conditions during the growing seasons and an average number of 44.5 grains per ear was obtained over the three-year study period.

The present experiment found higher grain weight per ear in mixed crops compared to sole crops of the investigated spring triticale cultivars. Kotwica and Rudnicki (2004) claim that mixed crops give a higher value of this trait only under water deficit conditions. According to them, ears of sole cropped plants are larger when there is a sufficient amount of rainfall.

Thousand grain weight is a varietal feature. It is modified by the habitat and agronomic factors (Pisulewska *et al*. 2004, Högy *et al.* 2013). Tested spring triticale cultivars were characterised by similar 1000 grains weight values in the years 2007 and 2009. A significant decrease in the number of grains and 1000 grains weight was recorded only in 2008. Mixed sowings of spring triticale cultivars did not increase the weight of 1000 grains in relation to the sowing of pure varieties of Wanad and Gabo.

CONCLUSIONS

1. To sum up the present study, it should be stressed that in composing cultivar mixtures of spring triticale one should know the yielding ability of their individual components.

2. The introduction of mixed cropping of spring triticale cultivars had a beneficial effect on most of the yield traits investigated.

3. Spring triticale grain yield was significantly differentiated by crop protection methods. The highest grain yield was obtained in the chemically treated plot (4.68 t ha^{-1}), the treatment with chemical and mechanical crop protection produced a significantly lower yield (4.34 t ha^{-1}), whereas grain yield was the lowest in the case of mechanical crop protection (4.11 t ha^{-1}).

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PLONOWANIE MIESZANEK MIĘDZYODMIANOWYCH PSZENŻYTA JAREGO

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Streszczenie. W doświadczeniu z mieszanką zbożową dwóch odmian pszenżyta jarego Gabo i Wanad uwzględniono dwa czynniki: I. Sposób siewu odmian pszenżyta jarego A. siew czysty odmiany Wanad, B. siew czysty odmiany Gabo, C–G. – siewy mieszane odmian Wanad i Gabo; II. Sposób pielęgnowania łanu pszenżyta jarego: a) mechaniczny – bronowanie posiewne oraz w fazie szpilkowania i w fazie 4-5 liści pszenżyta jarego, b) mechaniczno-chemiczny – bronowanie posiewne oraz w fazie szpilkowania i w fazie 4-5 liści pszenżyta jarego, a także dodatkowo stosowanie herbicydu, retardanta i fungicydu, c) chemiczny – aplikacja środków ochrony roślin. Siewy mieszane odmian pszenżyta jarego – Wanad i Gabo plonowały istotnie wyżej niż w uprawie jednoodmianowej Najkorzystniej plonowały mieszanki odmian złożone co najmniej w 50% z odmiany Wanad. Łączna uprawa odmian pszenżyta jarego korzystnie wpłynęła na kształtowanie się takich parametrów łanu i kłosa badanej rośliny uprawnej, jak: masa ziaren w kłosie, liczba kłosów na 1 m^2 i wyleganie roślin. Plon ziarna pszenżyta jarego istotnie różnicowały również metody pielęgnowania zasiewów. Największy plon ziarna uzyskano na obiekcie pielęgnowanym metodą chemiczną (4,68 $t \cdot ha^{-1}$), istotnie mniejszy w warunkach pielęgnacji mechaniczno-chemicznej (4,34 $t \cdot ha^{-1}$), a najmniejszy w przypadku pielęgnacji mechanicznej (4,11 $t \cdot ha^{-1}$).

Słowa kluczowe: mieszanka zbożowa, sposób pielęgnowania, sposób siewu, plon, elementy plonu