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PERFORMANCE OF MULTI-COMPONENT MIXTURES OF SPRING CEREALS. PART 1. YIELDS AND YIELD COMPONENTS

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Abstract. A single-factor field experiment was conducted in 2009-2011 on light soil to determine productivity of multi-species mixtures of barley, oat, wheat and triticale. The cereals were grown in 3- and 4-species mixtures. The objective of this study was to determine if these highly diverse cereal mixtures are more productive and yield more stable than pure stand cereals. Mixtures did not differ in grain yield and each of them yielded between the highest and the lowest yielding component grown in pure stand. All mixtures yielded more stable than pure stands of barley, oat and triticale. Oat-wheat-triticale mixture yielded more grain protein than pure stand cereals and mixtures with the exception of barley-wheat-triticale mixture. Growing cereals in mixtures caused reduction in productive tillering of barley and 1000-grain weight of oat, while increased number of grains and grain weight per spike of triticale.

Key words: mixtures, plant features, productivity, protein

INTRODUCTION

Data show that cereal mixtures are still important element of agricultural landscape in Poland. According to Statistical Yearbook of Agriculture they covered 1.0 million ha in 2013 making up 13.5% of the total area of cereals [GUS 2014]. They are grown on infertile soils and are most popular in small farms that keeps animals, in which cereal production prevails [Sulewska and Michalski 2007, Rudnicki *et al*. 2008, Leszczyńska 2010]. Mixtures usually give more stable yields than pure stands [Wanic *et al*. 1999, Szempliński and Budzyński 2011], are more tolerant to unfavorable location in crop rotation [Wanic *et al*. 2000] and are less susceptible to diseases and insect pests [Kurowski *et al*. 2007, Tratwal and Walczak 2010].

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To date, in most experiments, authors have used 2-species cereal mixtures and compared their yields with yields of pure stands. Recent research of Tobiasz-Salach *et al.* [2011] showed that among all possible pairs of spring cereals grown in mixtures the highest yielding were those of oat with wheat and oat with triticale. Both mixtures however did not significantly overyield their components grown in pure stands.

Only a few studies have been dealt with mixtures comprising more than two spring cereals but their results are inconclusive. Rudnicki and Wasilewski [1993] and Sobkowicz [2003] demonstrated no yield advantage of 3-species mixtures over 2-component ones. Buczek *et al.* [2007] found higher yield of mixture of oat, wheat and barley than yields of all components grown in pure stands, particularly when oat or wheat prevailed in composition of the mixture at seeding. In study of Klima and Łabza [2010] mixture of oat, triticale and barley performed worse than mixture of oat and spring barley. In those experiments authors grown only one multi-cereal mixture, and compared its yield with 2-species mixtures or with pure stands. There have been no experiments comparing yields of multi-cereal mixtures with themselves and with pure stands.

The first objective of the study was to assess the performance of 3-component mixtures and mixture comprising all four main spring cereals: barley, oats, wheat and triticale. It was assumed that due to high diversity of these mixtures, they would yield higher and more stable than cereals in pure stands. The second objective was to determine which traits of the cereals used in this study are affected by mixed cropping.

MATERIAL AND METHODS

Single-factor field experiment was conducted in 2009-2011 in Agricultural Experimental Station Swojec (51°07′ N; 17°08′ E) belonging to Wrocław University of Environmental and Life Sciences. Experiment was arranged according to randomized complete block design with four replicates, on 21 m^2 elementary plots. Pure stands and 3- and 4-species mixtures of barley cv. Mercada, oat cv. Cwał, wheat cv. Parabola and triticale cv. Dublet were used as plot factor. The species were grown as pure stands in recommended for agricultural practice seeding density: barley 360 grains m^{-2}, and other species 540 grains m^{-2}. Mixtures were composed using proportional substitutive design [Jolliffe 2000] with equal proportion of each cereal in relation to its seeding density in pure stand – 33% and 25% for 3- and 4-species mixture respectively.

The experiment was established on alluvial loamy sand soil of 6.4 pH. One kg of the soil sampled from plough layer contained 7.0 g C-org, 0.52 g N-total, 0.123 g P and 0.133 g K. In 2009 and 2010 winter rye and in 2011 winter triticale were grown as a preceding crop before the experiment. After harvest of the preceding crop, shallow post-harvest soil tillage was done and in November field was ploughed to a depth of 25--27 cm. Each year before sowing, the experimental field was fertilized with mineral fertilizers, at rates of: 40 kg N, 40 kg P_2O_5 and 50 kg K_2O per hectare. Phosphorus fertilization was used in spite of high P content in the soil in order to secure different requirements of the cereals for this element. Additional 40 kg $N \cdot ha^{-1}$ was applied at the end of tillering stage of the cereals. In spring soil was prepared for sowing with combined implement comprising light cultivator and tooth harrow. Cereals in pure stands and in mixtures were sown on 01.04.2009, 08.04.2010 and on 01.04.2011 using

Wintersteiger® plot seeder, with 11.5 cm row spacing. Weeds were controlled with herbicides.

Five weeks after plant emergence – at stem elongation stage (BBCH 31-32) and at full maturity (BBCH 87-89) of crops, four 1 m long consecutive rows with plants were sampled from each plot (0.46 m^2). After separation of species from mixtures plants were dried in a glasshouse for two weeks and weighted. Subsamples of plants were taken and dried in the laboratory drier at 70°C to determine dry weight. At full maturity plants and inflorescences of each species were counted and the inflorescences were threshed in the sample thresher. Based on grain samples, percentage of each species in mixture and 1000-grain weight were determined. Plots were harvested at full maturity with Wintersteiger® plot combine harvester on 08.08.2009, 12.08.2010 and 13.08.2011. Nitrogen content was determined using Kjeldahl method in treatment mean grain samples and crude protein was calculated by multiplying N by 6.25.

Analysis of variance for randomized complete block design was performed on most data using *awa* computer program package [Bartkowiak 1978]. Treatment means were compared using LSD at P=0.05 test when F test was significant. To compare yielding stability between pure stand cereals and mixtures during the three experimental years, coefficient of variation (CV) was calculated. It was calculated separately for each pure stand cereal and mixture on the basis of treatment mean grain yields obtained in experimental years (n = 3).

During the growing season of 2009 the precipitation in June was nearly two and a half times higher and with a lower air temperature than a 40-year average (Table 1). Also in July the rainfall was higher (by 60%) than the average for the long-term period. In 2010 in June the precipitation was nearly halved with the higher air temperature than a monthly long term average, but it did not affect the development of plants because of more water stored up in the soil in the previous month. Also owing to the fact that the amount of water accumulated after winter was sufficient, the slightly lower rainfall together with the higher temperature in April and May 2011 did not disrupt the emergence and the next growth stages of cereals.

Table 1. Monthly mean air temperatures and rainfall sums during the growing season of cereals at Agricultural Experimental Station Swojec in Wrocław
Tabela 1. Średnie miesięczne temperatury powietrza i sumy opadów w okresie wegetacji zbóż w Rolniczym Zakładzie Doświadczalnym Swojec we Wrocławiu

Month – Miesiąc	2009	2010	2011	1968-2008
Mean temperature – Średnia temperatura, °C				
April – kwiecień	12.0	9.3	11.8	8.4
May – maj	14.2	12.7	14.7	13.9
June – czerwiec	15.8	17.9	19.2	16.9
July – lipiec	19.5	21.4	18.3	18.6
Rainfall – Opady, mm				
April – kwiecień	30.9	45.4	27.0	37.5
May – maj	67.5	140.7	49.4	53.0
June – czerwiec	162.0	32.9	95.7	64.9
July – lipiec	134.2	78.6	170.9	83.9
Sum of rainfall (April-July) Suma opadów (kwiecień – lipiec)	394.6	297.6	343.0	239.3

RESULTS

Five weeks after plant emergence, at stem elongation stage of cereals, all mixtures yielded significantly more aboveground plant dry matter than cereals in pure stands (Table 2). The lowest yielding mixture (oat-wheat-triticale) produced 10.8% more dry matter per unit area than the highest yielding pure stand (barley). There was no difference in plant dry matter yield among mixtures and also among pure stands at this stage of growth. Yields did not differ at full maturity of cereals, however oat and triticale having higher crop growth rate between stem elongation and full maturity, tended to yield more biomass than other pure stand cereals and mixtures. Crop growth rate of above-mentioned pure stands was significantly higher than barley, wheat and barley-oat-wheat mixture. Pure stands of barely and oat, developed significantly higher number of inflorescences per unit area than other cereals and mixtures. The trait did not differ among mixtures.

Table 2. Plant dry matter yields and inflorescence number per unit area (mean for 2009-2011)
Tabela 2. Plony suchej masy roślin i liczba kwiatostanów na jednostce powierzchni (średnia z lat 2009-2011)

Species or mixture Gatunek lub mieszanka	Aboveground plant dry matter yield Plon nadziemnej suchej masy roślin			Inflorescence number per m^2 Liczba kwiatostanów na m^2
	5 weeks after plant emergence 5 tygodni po wschodach roślin (BBCH 31-32) (a)	full maturity dojrzałość pełna (BBCH 87-89) (b)	crop growth rate szybkość wzrostu łanu (b – a)	
	$g \cdot m^{-2}$	$g \cdot m^{-2}$	$g \cdot m^{-2}$	–
B	194	904	710	765
O	187	1017	831	762
W	193	936	743	581
T	182	1009	826	575
BOW	217	912	695	674
BOT	224	986	763	615
BWT	220	976	756	605
OWT	215	972	757	614
BOWT	218	979	761	664
$LSD_{0.05}$ – $NIR_{0,05}$	17	ns – ni	82	73

B – barley – jęczmień, O – oat – owies, W – wheat – pszenica, T – triticale – pszenżyto
ns – ni – not significant difference – różnica nieistotna

Cereals in pure stands and mixtures produced similar grain yield during the experimental years (Table 3). Three-year average shows that multi-species mixtures did not differ in grain yield. Barley-oat-wheat mixture was the only one that yielded significantly less grain (by 7.1%) than pure stand barley, the highest yielding cereal. The least productive in the experiment was wheat that yielded significantly less grain than other cereals and mixtures, except for mixture of barley, oat and wheat. Coefficient of variation demonstrates that there was little variability in grain yield during the experimental years. Grain yields of all 3-species mixtures were less variable than yields of corresponding pure stands and only stability of 4-component mixture was the same as pure stand wheat.

Table 3. Grain and crude protein yields
Tabela 3. Plony ziarna i białka ogólnego

Species or mixture Gatunek lub mieszanka	Grain yield – Plon ziarna					Crude protein Białko ogólne (2009-2011)	
	2009	2010	2011	2009-2011	CV	content zawartość	yield plon
	Mg·ha^{-1}	Mg·ha^{-1}	Mg·ha^{-1}	Mg·ha^{-1}	%	% dm	kg·ha^{-1}
B	5.12	4.57	4.65	4.78	6	10.6	430
O	4.86	4.33	4.49	4.56	6	11.1	431
W	4.13	4.19	4.38	4.23	3	13.5	488
T	4.82	4.35	5.04	4.74	7	12.3	495
BOW	4.41	4.45	4.45	4.44	1	12.6	475
BOT	4.78	4.61	4.53	4.64	3	12.1	476
BWT	4.68	4.73	4.55	4.66	2	12.8	505
OWT	4.59	4.59	4.68	4.62	1	13.4	528
BOWT	4.56	4.75	4.80	4.70	3	12.1	484
$LSD_{0.05}$ – $NIR_{0,05}$	ns – ni	ns – ni	ns – ni	0.31	–	–	30

B – barley – jęczmień, O – oat – owies, W – wheat – pszenica, T – triticale – pszenżyto
CV – coefficient of variation – współczynnik zmienności
dm – dry matter – sucha masa
ns – ni – not significant difference – różnica nieistotna

Grain crude protein content was higher in oat-wheat-triticale mixture than in other mixtures and the mixture yielded significantly more protein than cereals in pure stands and mixtures with the exception of barley-wheat-triticale mixture. Among pure stands wheat and triticale gave significantly higher grain crude protein yields than oat and barley owing to higher protein concentration in grain.

Each species responded differently to neighboring cereals in multi-component mixtures. Barley produced significantly less spikes per plant in mixtures than in pure stand (Table 4).

Table 4. Yield components of barley and protein content in grain (mean for 2009-2011)
Tabela 4. Komponenty plonu jęczmienia oraz zawartość białka w ziarnie (średnia z lat 2009-2011)

Species or mixture Gatunek lub mieszanka	Spike no. per plant Liczba kłosów z rośliny	1000-grain weight Masa 1000 ziarn	Grain weight per spike Masa ziarna z kłosa	Grain no. per spike Liczba ziarn w kłosie	Barley grain in mixture yield Udział ziarna jęczmienia w plonie mieszanki	Crude protein content Zawartość białka ogólnego
	–	g	g	–	%	% dm
B	1.82	46.6	0.72	15.5	–	10.6
BOW	1.44	46.9	0.70	15.1	34	11.2
BOT	1.40	45.8	0.70	15.5	27	11.6
BWT	1.41	44.8	0.64	14.4	28	11.3
BOWT	1.35	44.1	0.66	14.9	22	10.3
$LSD_{0.05}$ – $NIR_{0,05}$	0.21	ns – ni	ns – ni	ns – ni	–	–

B – barley – jęczmień, O – oat – owies, W – wheat – pszenica, T – triticale – pszenżyto
dm – dry matter – sucha masa
ns – ni – not significant difference – różnica nieistotna

The reduction of spike number per plant ranged from 20.9% in barley-oat-wheat mixture to 25.8% in 4-cereal mixture. No difference was noted in 1000-grain weight, grain weight and grain number per spike of barley. Except for barley-oat-wheat mixture, contribution of barley grain to yield of mixtures was lower than expected (lower than 33% and 25% for 3- and 4-species mixture respectively). Compared to pure stand, growing barley together with oat and triticale increased concentration of crude protein in barley grain by 1.0 percentage point.

Unlike barley, oat produced similar number of panicles per plant in pure stand and in mixtures (Table 5). The only trait of oat that was affected by mixed cropping was 1000-grain weight. It was significantly lower than in pure stand, when the species was grown in barley-oat-wheat, oat-wheat-triticale and 4-component mixture, by 11.5%, 9.9% and 8.3% respectively. Grain weight and grain number per panicle of oat did not differ in the experiment. The percentage of grain of oat in yields of 3-species mixtures was 3-7 percentage points lower from the expected value, while in 4-component mixture it was 4 percentage points lower. Growing oat with other cereals had positive influence on the crude protein content in grain of the species. Oat grown in mixture with wheat and triticale had the highest percentage of grain crude protein.

Table 5. Yield components of oat and protein content in grain (mean for 2009-2011)
Tabela 5. Komponenty plonu owsa oraz zawartość białka w ziarnie (średnia z lat 2009-2011)

Species or mixture Gatunek lub mieszanka	Panicle no. per plant Liczba wiech z rośliny	1000-grain weight Masa 1000 ziarn	Grain weight per panicle Masa ziarna z wiechy	Grain no. per panicle Liczba ziarn z wiechy	Oat grain in mixture yield Udział ziarna owsa w plonie mieszanki	Crude protein content Zawartość białka ogólnego
	–	g	g	–	%	% dm
O	1.32	25.3	0.74	28.9		11.1
BOW	1.50	22.4	0.69	28.8	30	12.4
BOT	1.34	23.5	0.79	32.7	28	12.2
OWT	1.39	22.8	0.64	27.0	26	12.9
BOWT	1.40	23.2	0.64	26.0	21	11.5
$LSD_{0.05}$ – $NIR_{0,05}$	ns – ni	2.0	ns – ni	ns – ni	–	–

B – barley – jęczmień, O – oat – owies, W – wheat – pszenica, T – triticale – pszenżyto
dm – dry matter – sucha masa
ns – ni – not significant difference – różnica nieistotna

Wheat was the only species which yield components did not change significantly due to mixed cropping (Table 6). Among 3-species mixtures, the highest contribution of wheat to grain yield was noted in barley-oat-wheat mixture. It exceeded expected value by 3 percentage points. Also in that mixture the highest protein concentration in grain of wheat was observed.

Triticale responded differently than other species to neighboring cereals in mixtures (Table 7). Among yield components, weight of grain and number of grains per spike significantly increased when triticale was grown in mixtures. Compared to values in pure stand the greatest increases in grain weight and number per spike were noted in barley-oat-triticale mixture, by 41.9% and 35.5% respectively. Number of spikes per plant and 1000-grain weight of triticale were unaffected in the experiment. Percentage of grain of triticale in mixture yield was very high ranging from 40% in oat-wheat-

-triticale mixture to 45% in barley-oat-triticale mixture. Grain of triticale constituted almost one third of the yield of 4-species mixture. The highest concentration of crude protein in grain of triticale was noted when the cereal was grown in mixture with oat and wheat.

Table 6. Yield components of wheat and protein content in grain (mean for 2009-2011)
Tabela 6. Komponenty plonu pszenicy oraz zawartość białka w ziarnie (średnia z lat 2009-2011)

Species or mixture Gatunek lub mieszanka	Spike no. per plant Liczba kłosów z rośliny	1000-grain weight Masa 1000 ziarn	Grain weight per spike Masa ziarna z kłosa	Grain no. per spike Liczba ziarn w kłosie	Wheat grain in mixture yield Udział ziarna pszenicy w plonie mieszanki	Crude protein content Zawartość białka ogólnego
	–	g	g	–	%	% dm
W	1.00	42.2	0.79	18.9		13.5
BOW	0.98	42.0	0.84	20.5	36	14.2
BWT	0.98	42.5	0.78	18.9	31	14.0
OWT	0.99	41.9	0.79	19.4	34	14.1
BOWT	0.97	42.4	0.81	19.8	26	14.1
$LSD_{0.05}$ – $NIR_{0,05}$	ns – ni	ns – ni	ns – ni	ns – ni	–	–

B – barley – jęczmień, O – oat – owies, W – wheat – pszenica, T – triticale – pszenżyto
dm – dry matter – sucha masa
ns – ni – not significant difference – różnica nieistotna

Table 7. Yield components of triticale and protein content in grain (mean for 2009-2011)
Tabela 7. Komponenty plonu pszenżyta oraz zawartość białka w ziarnie (średnia z lat 2009-2011)

Species or mixture Gatunek lub mieszanka	Spike no. per plant Liczba kłosów z rośliny	1000-grain weight Masa 1000 ziarn	Grain weight per spike Masa ziarna z kłosa	Grain no. per spike Liczba ziarn w kłosie	Triticale grain in mixture yield Udział ziarna pszenżyta w plonie mieszanki	Crude protein content Zawartość białka ogólnego
	–	g	g	–	%	% dm
T	0.99	34.7	0.86	25.1	–	12.3
BOT	0.96	36.8	1.22	34.0	45	12.4
BWT	0.97	36.8	1.11	30.8	41	12.9
OWT	0.98	35.4	1.04	29.9	40	13.2
BOWT	0.97	36.2	1.14	31.7	31	12.3
$LSD_{0.05}$ – $NIR_{0,05}$	ns – ni	ns – ni	0.17	3.5	–	–

B – barley – jęczmień, O – oat – owies, W – wheat – pszenica, T – triticale – pszenżyto
dm – dry matter – sucha masa
ns – ni – not significant difference – różnica nieistotna

DISCUSSION

The present research shows that multi-cereal mixtures promotes grain yield stability. The observation is confirmed by earlier study in which mixture of barley oat and triticale produced more stable yields during the experimental period, than their corresponding pure stands [Sobkowicz 2003]. In this study likewise in the previous one, grain yields of cereals were high and the yield variability in pure stands was small. Both research showed that multi-cereal mixtures better adapted to those relatively benign environmental conditions giving lower than pure stands variability in grain yield. This positive feature of multi-cereal mixtures should not be considered however as a rule, because in research of Rudnicki and Wasilewski [1993] conducted in unfavorable climatic conditions, barley-oat-wheat mixture with equal proportion of the components yielded more stable than only one component of the mixture grown in pure stand. This suggests that in productive environment when yields of pure stand cereals are high and different little from year to year, 3-component equal proportion mixture yield more stable because the best adapted component constituting 1/3 of such mixture is able to compensate for small yield loss made by the two worse adapted components. But when environmental conditions are severe the best adapted component is unable to compensate for considerable yield loss. Positive relationship between species richness and yield stability was noted in experiment with plants from natural habitat, in which 10-species mixtures yielded more stable than mixtures having less components [Bonin and Tracy 2012].

The assumption that highly diverse cereal mixture yields more grain than pure stand cereals was not supported by the present study. None mixture yielded more grain than its highest yielding pure stand component and only barley-oat-wheat mixture produced more grain than wheat, the lowest yielding cereal in the experiment. Existing data show that equal proportion 3-species mixtures may perform worse than those having higher initial percentage of that species that is most productive in pure stand [Buczek *et al*. 2007, Rudnicki and Wasilewski 1993]. Czarnocki *et al*. [2013] found that, among 3-species mixtures of winter cereals, only that with higher initial percentage of wheat yielded less grain than pure stands. Other results were obtained by Tratwal and Walczak [2010]. In their study conducted at different sites, mixture of spring barley, oat and wheat yielded significantly lower than the highest yielding component grown in pure stand but significantly higher than the lowest yielding component.

Stem elongation stage was the only period when all mixtures were more productive than pure stands, indicating there was complementary resource use by mixture components. Former research showed that during the same stage of growth barley-oat-triticale mixture yielded less dry matter than pure stand barley [Sobkowicz 2003]. Similar for both studies was greater growth rate of pure stand triticale than other cereals during the second part of the growing season.

Changes in different yield components of barley, oat and triticale resulting from multi-species interactions in mixtures indicate that for each of the species, competitive pressure was important at different stage of growth. Except for wheat, the change was always greater between pure stand and any mixture than between mixtures. Most surprising was the reduction of productive tillering (number of spikes per plant) of barley in mixtures, the trait that frequently increases in mixtures ensuring competitive dominance of the cereal [Noworolnik and Leszczyńska 1999, Sobkowicz 2003, Idziak and Michalski 2007]. Decrease in 1000-grain weight of oat in mixtures compared to pure stand observed in our study was also found by Zając *et al.* [2010]. However, Tobiasz-Salach *et al.* [2007] noted decrease in number of grains and grain weight per panicle of oat resulting from growing the species in mixture with spring triticale. Those two traits of oat were unchanged in the present experiment. Compared to pure stand, triticale increased number of grains and grain weight per spike in all mixtures. This result does not agree with that of Michalski [1996] and Michalski *et al.* [1997] who noted decrease in these features of triticale in 2-species mixtures with other cereals. Oleksy and Szmigiel [2001] demonstrated that changes in yield components of triticale due to mixed cropping, depend to a large degree on cultivar used.

The experiment showed superiority of oat-wheat-triticale mixture above other mixtures and pure stand cereals in terms of grain protein content and grain protein yield. Increased protein content in grain of oat and triticale when grown in the mixture contributed to this result. Higher protein concentration in grain of one or both of those species due to mixed cropping with other cereals was noted also by Jokinen [1991] and Sobkowicz and Podgórska [2006]. Higher grain protein yields of pure stand wheat and triticale than pure stand barley and oat observed in our study were also showed by Szempliński and Budzyński [1994].

CONCLUSIONS

1. Multi-species mixtures of spring cereals did not differ in grain yield and each of them yielded between the highest and the lowest yielding component grown in pure stand. All mixtures yielded more stable than pure stands of barley, oat and triticale during experimental period.
2. Compared to pure stands, growing cereals in multi-component mixtures caused reduction in productive tillering of barley and 1000-grain weight of oat but increased number of grains and grain weight per spike of triticale.
3. The use of mixtures instead of pure stands resulted in higher dry matter yield at stem elongation stage but there was no difference in dry matter yield at full maturity of cereals.
4. Oat-wheat-triticale mixture had the highest crude protein concentration in grain among mixtures and higher grain protein yield than cereals in pure stands and mixtures with the exception of barley-wheat-triticale mixture.

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WYDAJNOŚĆ WIELOSKŁADNIKOWYCH MIESZANEK ZBÓŻ JARYCH. CZĘŚĆ 1. PLONY I ELEMENTY PLONOWANIA

Streszczenie. Jednoczynnikowe doświadczenie polowe przeprowadzono w latach 2009--2011 na glebie lekkiej, w celu określenia produkcyjności wielogatunkowych mieszanek jęczmienia, owsa, pszenicy oraz pszenżyta. Zboża uprawiano w 3- i 4-gatunkowych mieszankach. Celem badań było stwierdzenie, czy tak różnorodne mieszanki są bardziej produktywne oraz stabilniejsze w plonowaniu niż zasiewy czyste zbóż. Mieszanki nie różniły się plonem ziarna, a ich plony mieściły się pomiędzy najwyższym a najniższym plonem ich komponentów z zasiewów czystych. Wszystkie mieszanki plonowały stabilniej niż zasiewy czyste jęczmienia, owsa i pszenżyta. Mieszanka owsa, pszenicy i pszenżyta odznaczała się większym plonem białka w ziarnie niż zasiewy czyste zbóż i pozostałe mieszanki z wyjątkiem mieszanki jęczmienia, pszenicy i pszenżyta. W porównaniu z zasiewami czystymi uprawa zbóż w mieszankach powodowała ograniczenie krzewienia produkcyjnego jęczmienia i MTZ owsa oraz zwiększenie liczby i masy ziarn z kłosa pszenżyta.

Słowa kluczowe: białko, cechy roślin, produktywność, uprawa współrzędna

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