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Original scientific paper

VARIATION OF SPIKE INDEX OF CEREAL AND INDEX OF PEA PODS IN MONOCROPS AND INTERCROPS SYSTEM OF CULTIVATION

Milosav GRČAK[1], Dragan GRČAK[2], Radivoje JEVTIĆ[2], Mirjana LALOŠEVIĆ[2], Danijela KONDIĆ[3], Jelica ŽIVIĆ[4], Desimir KNEŽEVIĆ[1]

[1]University of Priština, Faculty of Agriculture, Kosovska Mitrovica – Lešak, Lešak, Serbia
[2]Institute of Field and Vegetable Crops, Novi Sad, Serbia
[3]University of Banja Luka, Faculty of Agriculture Banjaluka, Banjaluka, Republika Srpska, Bosnia & Herzegovina
[4]College of Agriculture and Food Technology, Prokuplje, Serbia

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Parameters of plant productive organs (spike, pod etc.) are influenced by genotype of plant species and scientific technology farming measures as well environmental conditions. The aim of this study was to establish variability of spike harvest index for wheat, triticale, rye, oat and pea pods index, influenced by monocrops and intercrops system of cultivation. Four cereal species: wheat, triticale, rye and oat and one legume (pea) were included in investigation that carried out on field experimental conditions during one vegetation season. Each species were sown in monocrops and in intercrops wheat + pea, triticale + pea, rye + pea and oat + pea. Harvest index of spike variate between 65.2% (triticale intercrops) and 86.5% (oat solo). The values of spike weight and seed weight was different among the cereal species and higher in intercrops than in monocrop system of cultivation. However, only for rye in mixture with pea, harvest index

Corresponding author: Desimir Knežević,University of Priština, Faculty of Agriculture, Kosovska Mitrovica – Lešak, Kopaonička bb, 38219 Lešak, Kosovo and Metohia, Serbia, *deskoa@ptt.rs*

(78.8%) was higher than in monocrops of rye (77.0%). Harvest index of pod variate in ratio 50.3% (pea solo) and 69.5% (in intercrops pea + rye). The values of pod weight and seed weight pod^{-1} was different and higher in intercrops than in monocrops system of cultivation. Harvest pod index of peas was significantly higher in mixture with each small grains species genotypes than in pea's monocrops. On the base of result we can conclude that intercropping cereals + peas, have positive effect on spike and pod characteristics which values were higher in intercrops than in monocrops.

Keywords: cereals, harvest index, intercropping, pea, pod, spike

INTRODUCTION

Growing small grains in mixtures with legumes is increasingly gaining in importance. The initial reason for the formation of such mixtures was the assumption that the system consisting of two different crops in the mixture should have a positive effect on mutual weak points and improve the production (SOBKOWICZ, 2006). This cultivation system, apart from having a positive effect on yields (AZIZ *et al*., 2015), lodging (SABOLOVIĆ, 2014), and the control of weeds (SIMIĆ *et al*., 2018; GOLIJAN and MARKOVIĆ, 2018) and diseases (KINANE and LYNGKJAER, 2002; FERNÁNDEZ-APARICIO *et al*., 2010; MARKOVIĆ, 2013; ŽIVANOV *et al*., 2014), also affects the maintenance of nitrogen in the soil and consequently reduces the costs of mineral fertilizer use (ANIL *et al*., 1998, CREWS and PEOPLES, 2004). GOODDING *et al*. (2007) concluded that nitrogen concentration (g kg^{-1}) increased in soil for 8% when wheat intercropped with grain legumes (faba bean and pea). The soil protection is very important for sustainable biodiversity (VELIČKOVIĆ *et al*., 2016). Growing forage crops in mixtures leads to better utilization of production areas, improves soil fertility, produces more stable yields of crops that are more adaptable to the conditions of low temperatures and drought (MIKIĆ *et al*., 2012).

The investigation of triticale in intercropping with forage crops showed positive effect to grain quality (LESTINGI *et al*., 2010; NEFIR and TABĂRĂ, 2011). Intercropping of oats and the Egyptian clover (*Trifolium alexandrinum*) had a lower biomass, but the plants were more resistant to diseases and the crop yield was not significantly different (HOLLAND and BRUMMER, 1999). Peas are legumes widely used in mixtures with small grains. Peas represents high-quality forage which is rich in proteins and nutrients (LAUK and LAUK, 2008), and affect the accumulation of atmospheric nitrogen, which has a major impact on agricultural production. The monocrop of peas characterize good productivity. However, the tendency of peas lodging aggravates the harvest and that is the main reason of recommending intercropping system of peas with small grains cultivation. KADŽIULIENE *et al*. (2011) studied the effect of growing small grains in mixtures with peas and obtained results which showed that the productivity and quality varied depending on the genotype of small grains species. They found that small grains with legumes provides a higher yield and crude proteins than there is solo crop of small grains. An increase in the productivity of grains was found in some of them, but these results were not stable throughout the three years of research. Based on the results of an experiment in Estonia, it can be concluded that crop yields in mixtures of peas and small grains were higher than yields in monocrops, but it was also noted that the mixture of oats and peas showed better results compared to the mixture of wheat and peas (LAUK and LAUK, 2008). Other results show that grain yields in combined intercrops were comparable to grain yields of monocrops pea, but significantly greater than yield in monocrops of lupin, faba, bean and barley (HAUGGAARD-NIELSEN *et al*., 2008). In the research done by PETROVIĆ *et al*. (2000) it was shown that the

values of the spike index are in positive correlation with the weight of the grain per plant and the harvest index, and that the index of spike varies depending on the genotype and the impact of the external factor (DIMITRIJEVIĆ *et al*. , 2006). PETROVIĆ *et al*. (2002) studied the variability and stability of the spike index of 22 genetically different varieties and they concluded that spike index varied from 0.60 to 0.83 and that the most of varieties exhibited satisfactory stability of spike index.

The aim of this study was to determine the variation of the spike index for wheat, triticale, rye and oats and variation of pea pods index, based on the weight of seeds, the weight of the spikes and the weight of the pods in the conditions of monocrops and intercrops cultivation.

MATERIALS AND METHODS

The research was conducted in 2018 at the experimental field of the Institute of Field and Vegetable Crops in Novi Sad (45°33'N, 19°84'E). The trial was organized in randomized complete block system (RBCD) in 4 replications. The plot size was 5 m^2. The trial included nine treatments: wheat (*Triticum aestivum*), triticale (*Triticosecale*), rye (*Secale cereale*), oats (*Avena sativa*) and peas (*Pisum sativum*) sown as monocrops and mixed with peas+wheat, peas+triticale, peas+rye and peas+oats as intercrop. Varietiesincluded in trial were: Ilina (wheat), Odisej (triticale), Savo (rye), Jadar (oats), Kosmaj (pea). The sowing density per m^2 for monocrops of small grains were as follows: wheat 530 grains, triticale 500 grains, rye 500 grains and oats 450 grains, whereas the sowing density for the pea monocrops was 150 grains per m^2. In the mixture for sowing used 70% seeds of pea of recommended density m^{-2} and 30% of seeds of recommended density m^{-2} of small grain species, i.e. precisely, mixture sowed with 105 grains of pea + 160 grains of wheat, 105 grains of pea + 150 grains of triticale, 105 grains of pea + 150 grains of rye and 105 grains of pea + 135 grains of oat.

Samples for analysis were taken with 0.25 m^2 frame tool, in three-stage of plant developing (the first crop was taken on May 14 at the flowering stage, the second on May 24 at the early milky stage and the third on June 4, 2018 at the milky stage) for both sole crops and intercrops. The plants were dried in a glasshouse. In total 40 plants per treatment were taken for analysis (10 plants per plot). Grain weight per spike, weight of spike and weight of pod were assessed. Based on the obtained average values of the weight of the seed and spike, the spike index is calculated according to the formula:

$$Spike\ index\ (\%) = \frac{weight\ of\ seeds^{-spike}}{weight\ of\ spike}\ \text{x}\ 100$$

On the basis of the obtained average values of the weight of the pod and seeds, the pod index of pea is calculated according to the formula:

$$Pod\ index\ (\%) = \frac{weight\ of\ seeds^{-pod}}{weight\ of\ pod}\ \text{x}\ 100$$

Statistical data processing was done using the MSTAT C 5.0 version. An analysis of variance by the monofactorial system was performed and the significance of the differences was tested using the LSD test (HADŽIVUKOVIĆ, 1991).

Euclidian distance and similarity among small grains species on the base of values spike harvest index traits obtained in monocrops and intercrops with peas, and distance and similarity of peas pod index value obtained in monocrops and mixture peas + small grain species (wheat, triticale, rye and oat) analyzed by using IBM SPSS Statistics 20.

RESULTS AND DISCUSSION

The spike weight varied in the range from 1.56 g in wheat grown as sole crop to 2.88 g in triticale grown in the mixture with peas. The spike weight of triticale grown as monocrop, (2.54 g) was higher than in rye (1.93 g) and oats (1.87 g), quite significantly higher than in wheat grown as monocrop (1.56 g), and significantly higher than in wheat grown in the mixture with peas (1.61 g). Also, the value of the spike weight in triticale grown as monocrop (2.54 g) was higher than that of rye (2.36 g) and of oat (1.91) grown in the mixture with peas, but lower than in triticale (2.88 g) grown in the mixture with peas (Table 1).

Table 1. The spike characteristics of small grains genotypes in solo crops and intercrops with pea

Genotype in monocrops and intercrops cultivation	Spike weight (g)	Seed weight (g)	Harvest index of spike (%)
Wheat	1.562 d	1.183 b	75.0 cd
Triticale	2.537 ab	1.731 ab	68.0 ef
Rye	1.926 bcd	1.498 ab	77.0 bcd
Oat	1.873 bcd	1.618 ab	86.5 a
Wheat/peas	1.609 d	1.187 b	71.2 de
Triticale/peas	2.875 a	1.918 a	65.2 f
Rye/peas	2.362 abc	1.867 a	78.8 bc
Oat/peas	1.913 bcd	1.607 ab	84.0 ab
Average	**2.082**	**1.576**	**75.7**

The spike weight in triticale grown in the mixture with peas was significantly higher than that of wheat, rye and oat grown individually, and also grown in the mixture with peas (Table 1 and 2). It can be noted that the spike weight in all four types of small grains was higher when grown in the mixture than when grown as individual crops. The spike weight in rye grown in the mixture with peas (2.36 g) was significantly higher than the spike weight in wheat grown in both systems, individually (1.56 g) and in the mixture with peas (1.61 g).

The seed weight was the lowest in wheat grown as monocrop (1.18 g) and also in intercropping in wheat grown in the mixture with peas (1.19 g), while the highest seed weight was measured in triticale grown in the mixture with peas (1.92 g), and in rye in the mixture with peas (1.87 g). The seed weight in wheat (1.19 g), triticale (1.92 g) and rye (1.87 g) in the mixture with peas was higher than in sole crops. The seed weight in oats grown as sole crops (1.62 g) was slightly higher than in the mixture with peas (1.61 g). The seed weight in triticale (1.92 g) and oats (1.87 g) in the mixture with peas was significantly higher than the seed weight per spike

in wheat grown as sole crop (1.18 g) and wheat (1.18 g) grown in the mixture with peas (Table 1 and 3).

The harvest index of spike varied from 65.2% in triticale in the mixture with peas to 86.5% in oats as monocrops (Table 1). The harvest index of spike in oats monocrop (86.5%) and in intercropping of oats with peas (84.0%) was significantly higher than in wheat (75.0%), triticale (68.0%) and rye (77.0%) grown as monocrops, and also was higher than in the mixtures of wheat+peas (71.2%), triticale+peas (65.2%) and rye+peas (78.8%). The spike index in triticale grown in the mixture with peas (65.2%) was significantly lower than the harvest index of spike in wheat, rye and oats grown as sole crops and in the mixture with peas (Table 1 and 4).

Table 2. ANOVA for spike weight in small grains genotypes in solo crops and mixture with pea

Source	DF	SS	MS	F	Prob	LSD	
						0.05	0.01
Replication	3	0.614	0.205	1.3295^{ns}	0.2914	-	-
Genotype in monocrops and intercrops	7	6.027	0.861	5.5930**	0.0010	0.6562	0.9711
Error	21	3.233	0.154	-	-	-	-
Total	31	9.874	-	-	-	-	-

Table 3. ANOVA for seed weight in small grains genotypes in solo crops and mixture with pea

Source	DF	SS	MS	F	Prob	LSD	
						0.05	0.01
Replication	3	0.431	0.144	1.2414^{ns}	0.3198	-	-
Genotype in monocrops and intercrops	7	2.161	0.309	2.6663*	0.0385	0.5695	0.8428
Error	21	2.432	0.116	-	-	-	-
Total	31	5.024	-	-	-	-	-

Table 4. ANOVA for H index of spike in small grains genotypes in solo and mixture crops with pea

Source	DF	SS	MS	F	Prob	LSD	
						0.05	0.01
Replication	3	0.002	0.001	0.3985^{ns}	-	-	-
Genotype in monocrops and intercrops	7	0.154	0.022	14.1545**	0.000	7.478	11.07
Error	21	0.033	0.002	-	-	-	-
Total	31	0.189	-	-	-	-	-

The analysis of variance of the pod weight in peas (Table 5) show that the highest value of the pod weight (0.46 g) was in the intercrops of peas and rye and the lowest pod weight in peas (0.24 g) grown as monocrop. The pod weight in peas as sole crops was statistically

significantly lower than the pod weight in peas grown in the mixture pea+rye and pea+oats (Table 5 and 6).

The analysis of variance of average grain weight showed that there were statistically significant differences between the two variants of cultivation (Table 5 and 7).

Table 5. Pod characteristics of pea in solo crops and intercrops with small grains

	Pod weight (g)	Seed weight (g)	Harvest index of pod (%)
Peas	0.2442 b	0.1273 b	50.25 b
Peas/Wheat	0.3772 ab	0.2570 ab	65.25 a
Peas/Triticale	0.3787 ab	0.2677 a	68.75 a
Peas/Rye	0.4627 a	0.3428 a	.69.50 a
Peas/Oat	0.4525 a	0.3257 a	.69.00 a
Average	**0.383**	**0.264**	**64.55**

Table 6. ANOVA for Pod weight of pea in solo crops and intercrops with small grains

Source	DF	SS	MS	F	Prob	LSD	
						0.05	0.01
Replication	3	0.013	0.004	0.7467^{ns}	-	-	-
Genotype in monocrops and intercrops	4	0.122	0.030	5.1615*	0.0118	0.1521	0.2522
Error	12	0.071	0.006	-	-	-	-
Total	19	0.206	-	-	-	-	-

Table 7. ANOVA for seed weight of pod of pea in solo crops and intercrops with small grains

Source	DF	SS	MS	F	Prob	LSD	
						0.05	0.01
Replication	3	0.009	0.003	0.6264^{ns}	-	-	-
Genotype in monocrops and intercrops	4	0.115	0.029	6.2183**	0.0060	0.1388	0.2302
Error	12	0.056	0.005	-	-	-	-
Total	19	0.179	-	-	-	-	-

Table 8. ANOVA for H index of pod of pea in solo crops and intercrops with small grains

Source	DF	SS	MS	F	Prob	LSD	
						0.05	0.01
Replication	3	0.005	0.002	0.5738^{ns}	-	-	-
Genotype in monocrops and intercrops	4	0.107	0.027	8.6128**	0.0016	10.75	17.83
Error	12	0.037	0.003	-	-	-	-
Total	19	0.149	-	-	-	-	-

The pod index in peas grown as sole crops was statistically significantly different in relation to the peas grown in the mixtures with other crops, but there was no significant statistical differences between the crops in the mixtures according to the analysis of variance (Table 8).

The analysis of variance of the pod weight in peas (Table 5) showed the lowest pod weight was achieved in the mixture of peas +wheat. In terms of the pod weight, there was statistically significant difference between sole crop peas and in mixtures with rye and oats.

When it comes to the estimates of the average grain weight on the basis of the analysis of variance, there was also statistically significant difference between the two variants of cultivation (Table 7),

The pod index in monocrop of peas was significantly different in relation to the pod index of peas grown in the mixture with other crops, but for pod index there were no significant differences between the crops in the mixture (Table 8).

Based on the calculated spike index in this study, were conducted multiple comparisons among each to other of monocrops of wheat, triticale, rye, oat and mixture wheat+peas, triticale + peas, rye + peas and oat+peas.

The similarity with Euclidean distance was made and presented in dendogram (Fig 1). The least distance was estimated between rye and intercropping rye+peas as well as between oat and oat+peas intercropping. According to spike index, within cluster one the pair Rye and Rye/Peas expressed the least distance with wheat monocrop in the range of 2.5 units or expressed the highest similarity in the range of 25. This cluster one (rye, rye+peas, wheat) had the highest similarity with pair Oat and oat+peas.

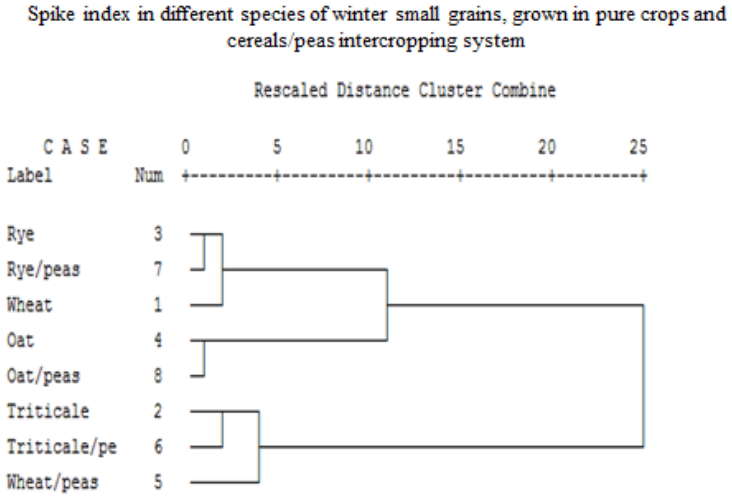

Figure 1. Dendogram for distance among winter cereal species according to value of spike index obtained in single crops system and intercropping system of growing

Within third cluster are triticale, triticale+peas and wheat+peas. The smallest distance was 2.5 units. The most similar to this pair is wheat/peas intercropping with the distance of 4 units. This third cluster had the highest distance 25 units with remain two clusters i.e. cluster 1 and cluster 2 according to spike index in winter form of cereals grown as single crop and intercropping in legume (Figure 1).

Obtained values of pod index of winter peas, grown as monocrop or mixture of peas+cereals, were compared to each other, using hierarchical methods of Euclidean distance presented on dendogram (Figure 2). Among this five samples was one cluster which contains sample with the least distance 1.0 in the range of 25.0 units. Within this cluster was intercrops peas+triticale, peas+oat, peas+rye, peas+wheat. This cluster of four intercrops had low similarity to single crop of peas with the highest distance 25.0 units in the range of 25.0 units (Figure 2.)

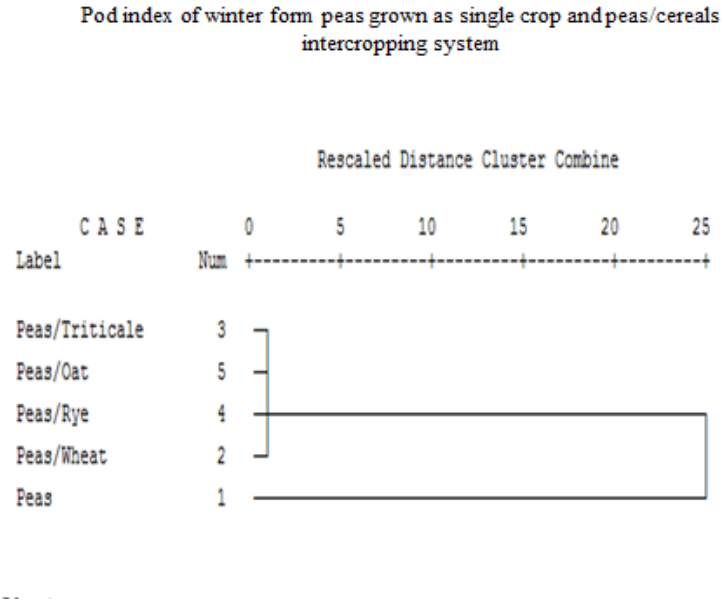

Figure 2. Dendogram for distance among winter peas according to value of pod index obtained in single crop and in intercropping system peas/small grains species

CONCLUSION

The research found that values of spike weight and seed weight spike^{-1} were significantly different among the cereal species and higher in intercrops than in monocrops system of cultivation while in the same cereal species spike weight and seed weight spike^{-1} were different but not significantly different. Harvest index of spike variate between 65.2% (triticale intercrops) and 86.5% (oat monocrops). Value of harvest index of spike was significantly different among cereal species grown in monocrops and intercrops. In the same cereal species harvest index of spike was different but not significantly different. In wheat, triticale and oat harvest index of spike was higher in monocrops than in intercrops, while only in rye was higher

in mixture with pea (78.8%) was higher than in rye monocrops (77.0%). The values of pod weight and seed weight pod^{-1} was higher in intercrops than in monocrops system of cultivation. Harvest index of pod was the least 50.3% in pea monocrop and the highest 69.5% in intercrops pea + rye. Harvest pod index of peas pod was significantly higher in mixture with each small grains species genotypes than in pea's monocrops. The intercropping have advantages due to the positive effect of intercrops of forage crops and cereals on value of pod and, spike traits values as well on the development of diseases and weeds that have been established in some other experiments. The intercropping can recommend as a system of cultivation which promising significant savings in protection products, and there will not be losses when it comes to the spike and pod indexes.

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VARIRANJE INDEKSA KLASA KOD STRNIH ŽITA I INDEKSA MAHUNE KOD GRAŠKA PRI GAJENJU U POJEDINAČNOM I ZDRUŽENOM USEVU

Milosav GRČAK[1], Dragan GRČAK[2], Radivoje JEVTIĆ[2], Mirjana LALOŠEVIĆ[2], Danijela KONDIĆ[3], Jelica ŽIVIĆ[4], Desimir KNEŽEVIĆ[1]

[1]Univerzitet u Prištini, Poljoprivredni fakultet, Kosovska Mitrovica, Lešak, Srbija
[2]Naučni institut za ratarstvo i povrtarstvo Novi Sad, Novi Sad, Srbija
[3]Univerzitet u Banja Luci, Poljoprivredni fakultet Banja luka, Banjaluka, Republika Srpska, Bosna & Hercegovina
[4]Visoka Poljoprivredno prehrambena škola u Prokuplju, Prokuplje, Srbija

Izvod

Osobine produktivnih organa (klas, mahuna itd) kod žitarica i graška variraju u zavisnosti od genotipa, tehnologije gajenja i drugih faktora spoljašnje sredine. Cilj ovog rad je da se ustanovi varijabilnost žetvenog indeksa klasa kod strnih žita i žetvenog indeksa mahune kod pasulja gajenim u pojedinačnim i združenim usevima. U istraživanjma je korišćen po jedan genotip ozimih vrsta: pšenice, triticale, raži, ovsa i graška. Eksperiment je izveden na oglednom polju Rimski Šančevi u Institutu za ratarstvo i povrtarstvo Novi Sad. Genotipovi strnih žita i graška su sejani na parcelicama 5 m^2 u 4 ponavljanja u monokulturi i u smeši pšenica + grašak, triticale + grašak, raž + grašak i ovas+grašak. U vreme pune zrelosti požnjevene biljke su korišćene za analizu osobina klasa i metlice kod strnih žita i osobina mahune kod graška. Analizirano je 40 biljaka (10 biljaka po ponavljanju) za svaki genotip u oba sistema gajenja pri setvi pojedinačno i u združenoj setvi za osobine: masa klasa, masa semena po klasu, masa mahune i masa semena po mahuni. Izračunat je žetveni indeks klasa kod pšenice, triticale, raži i ovsa kao i žetveni indeks mahune kod graška. Masa semena po klasu je varirala od 1.18 g kod pšenice u pojedinačnom usevu, do 1.92 g kod triticale gajenog u smeši sa graškom, a prosečna masa semena po klasu za sve genotipove u obe varijante gajenja je iznosila 1.57 g. Masa klasa je varirala izmedju 1.56 g kod pšenice u pojedinačnom usevu, do 2.87 g kod triticale gajenog u smeši sa graškom, a prosečna masa semena po klasu za sve genotipove u obe varijante gajenja je iznosila 2.87 g. Žetveni indeks klasa je bio najmanji 65.2% kod triticale u smeši sa graškom a najveći kod ovsa 86.5% gajenog u monokulturi. Vrednosri mase klasa i mase semena po klasu su bile različite u zavisnosti od vrste strnih žita i načina setve i gajenja useva. Masa klasa i masa semena po klasu je bila veća kod genotipova gajenih u združenoj setvi nego u pojedinačnom usevu. Medjutim, žetveni indeks klasa je bio veći, samo, kod raži u združenoj setvi sa graškom 76.8% nego u pojedinačnom usevu (77.0%). Kod graška, masa semena po mahuni je varirala od 0.13 g u pojedinačnom usevu do 0.34 g u združenoj setvi sa raži, dok je prosečna nasa semena po mahuni u oba sistema gajenja bila 0.26 g. Masa mahune je bila najmanja kod graška u solo usevu 0.24g a najveća 0.46 g u združenom usevu sa raži, a prosečna vrednost mahune u svim varijantama gajenja je iznosila 0.38 g. Žetveni indeks mahune je varirao izmedju 50.3% u pojedinačnom usevu graška i 69.5% u usevu združene setve graška i raži. Ustanovljene su značajne razlike za masu mahune, masu semena po mahuni i žetveni indeks mahune, čije vrednosi su bile značajno veće u združenom usevu graška sa svakom vrstom stnih žita, nego u pojedinačnom usevu graška.

Na osnovu dobijenih rezultata, može se zaključiti da združena setva graška i strnih žita ima pozitivan uticaj na ispoljavanje većih vrednosti osobina klasa i osobina mahune.

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