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Original scientific paper

AGRONOMIC PERFORMANCE AND STABILITY OF SEED, PROTEIN AND OIL YIELDS OF SEVEN SOYBEAN CULTIVARS DETERMINED IN FIELD EXPERIMENTS IN SLOVENIA

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The environment can have a crucial influence on soybean production in particular regions, even more so when production environments are different from breeding environments. Therefore, soybean cultivars must be evaluated in field trials at various locations in order to explore the duration of the growing period and capacity of yield, which is based on interactions between genotype and environment. Seven soybean cultivars originating from five European countries were evaluated for thousand-seed weight, seed, protein and oil yields and protein and oil contents in five environments in Slovenia. Yield stability of seed, protein and oil was determined in order to select best genotype. Results showed that cultivar and environment had a significant impact on all measured variables. In almost all tested environments the best seed, protein and oil yielding cultivars were ES Mentor (3425–5628 kg seed/ha, 1280–2192 kg protein/ha, 640.8–918.9 kg oil/ha) and NS Mercury (3468–5342 kg seed/ha, 1266–2071 kg protein/ha, 618.6–880.7 kg oil/ha). The highest average protein content was found in NS Favorit (41.0% of DW). Volma had the highest average oil content (20.2%). Three yield

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stability indices were used to assess yield stability; in terms of Shukla's variance (σ_i^2) and S square Wricke's ecovalence (W_i^2), Josefine turned out to have most stable seed and oil yields, while ES Mentor had most stable protein yields. Regarding Kang's yield stability (YS_i), which makes simultaneous selection for mean yield and stability and is therefore most relevant for practical usage, ES Mentor, NS Mercury and NS Favorit were selected as superior genotypes regarding stability of seed, protein and oil in this study. Correlation analysis of some chosen traits showed different interdependence between measured variables depending on the environment. As expected, protein and oil contents were negatively correlated, yet this was only significant in one environment.

The results of this study pointed out that among the seven tested cultivars, ES Mentor, NS Mercury and NS Favorit were best genotypes and are highly recommended for usage in soybean production in Slovenia.

Keywords: soybean, content of proteins and oil, yield of seed, protein and oil, yield stability indices, correlation

INTRODUCTION

Soybean (*Glycine max* (L.) Merr.) is one of the most important sources of plant proteins and oils in the world. However, in Europe it is mostly regarded as a protein crop (KURASCH *et al*., 2017a). Sufficient yield of proteins is crucial for the selection of soybean cultivar for production, since oilseed rape and sunflower are more important oil crops than soybean. The most important breeding goals and goals of new variety introduction, besides yield of seed and proteins (SATO *et al.*, 2014), are early maturing (precocity), rapid juvenile development, resistance to lodging, cool and drought tolerance and disease resistance (MILADINOVIĆ *et al.*, 2015; KURASCH *et al.*, 2017a). The selection of suitable cultivars that give optimum and stable yields in a given environment and that also reach full maturity at the appropriate time is even more demanding for soybean due to its high photoperiod sensitivity, which has a strong influence on the length of the growing season. Furthermore, the growing season of soybean is also highly dependent on temperature conditions (KURASCH *et al.*, 2017b).

In all seed crops, flowering is a major factor that determines the production of seed dry matter and the yield potential (JUNG and MÜLLER, 2009) and photoperiod has a key role in flowering induction (HOWELL, 1998). At least 10 homologs of the *Flowering Locus T (FT)* gene, which is part of the 'florigen' signal (ZEEVAART, 2006), have been discovered in soybean; some of these homologs were found to control flowering behaviour and consequently may enable the high adaptability of this crop (LIU *et al.*, 2017). Nevertheless, different soybean cultivars can only truly fulfil their full yield potential within the narrow range of latitudes they are specifically adapted to (WATANABE *et al.*, 2012).

Selection of the best cultivars would be straightforward if there were no genotype-by-environment (GE) interactions (YAN *et al.*, 2010). GE interaction investigations deal with the phenomenon in which cultivars often do not perform in a similar manner and rank differently when tested in multiple environments (VOLTAS *et al.*, 2005). Soybean multi-environment trials (MET) are conducted annually worldwide in order to determine superior genotypes for specific growing regions and to help growers select the most promising cultivars (YAN *et al.*, 2000). The aim of the MET studies is also to obtain cultivars, which would maximise the economic income. Ideal cultivars should have high yielding ability and high stability, which means that they consistently display high performance over several environments (ASHRAF *et al.*, 2010).

Two concepts are crucial for any crop plant improvement program: i) knowledge of the genetic variability of a used plant material, and ii) evaluation of the adaptability of genotypes to a wide range of environments (ALGHAMDI, 2004). Adaptability, which is a prerequisite for stability, is usually measured by different stability statistics. One of the most widely used method for stability analysis is the univariate stability model, which is based on variance estimates and indices that measure stability statistics and encompass Shukla's variance (σ_i^2), S square Wricke's ecovalence (W_i^2) and Kang's yield stability (YS_i) (DIA *et al.*, 2017). YS_i performs simultaneous selection for mean yield and stability and therefore is the most relevant selection index that can be used in various plant breeding programs (KANG, 1993).

Soybean sensitivity to photoperiodism determines the growth season length for each cultivar and hinders the wide usage of the same cultivars at different latitudes. The most important cultivar parameters that determine economically justified production are an appropriate maturity group (number of days to full maturity) and a stable yield performance. The aim of this study was to evaluate the agronomic characteristics of seven cultivars of soybean grown in five environments in Slovenia and to determine superior genotypes in terms of seed, protein and oil yield stability.

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MATERIALS AND METHODS

Field experiments

In field experiments, seven soybean cultivars from five European countries were used. Cultivars belonged to the maturity groups 000, 00 (both very early) or I (medium). None of the cultivars originated in Slovenia. Four cultivars were developed at higher latitudes and three at lower latitudes comparable to the experimental sites in Slovenia (Table 1). Field experiments were conducted over three years (2014–2016) at the following locations: Jablje, Rakičan and the Biotechnical faculty (latitude, longitude and altitude of experimental sites are given in Table 1), but not every year at each location. The experiments in Jablje and Rakičan took place only in 2014 and at the Biotechnical faculty in the years 2014, 2015 and 2016. Therefore, we formed environments on the basis of year-by-location combinations and we established five year-by-location environments (YLEs); Jablje 2014 was denoted as E1, Rakičan 2014 as E2 and the Biotechnical faculty between 2014–2016 as E3, E4 and E5, respectively.

The Jablje (YLE E1) location had deep and hydromorphic soil. Planting was done on the 26th of April and harvest occured on the 7th of October. Fifty-five seeds per m^2 were sown on 30 cm rows spaced on an experimental plot of 6 m^2. The previous crop was buckwheat. At the Rakičan (YLE E2) location, there was eutric brown soil. Soybeans were sown on the 7th of May and harvested on the 13th of October. The plant density was 55 seeds per m^2, and row spacing was 45 cm with an experimental plot size of 6 m^2. The previous crop here was also buckwheat. The experimental field at the Biotechnical faculty (YLEs E3, E4 and E5) locations had hydromeliorated medium deep silty-clay soil. Soybean cultivars were sown on the 9th, and two times on 19th of May and harvested on the 29th and 30th of September and the 6th of October at E3, E4 and E5, respectively. At this location, the experimental plot size was 7.65 m^2, with a plant density of 60 seeds per m^2 and row spacing of 25 cm. The previous crops were sunflower (at E3), potato (at E4) and winter wheat (at E5). Fertilisation was made only at E1 and E2, with 28/80/120 kg NPK per ha and 28/83/165 kg $N:P_2O_5:K_2O$ per ha, respectively, based on the results of soil analysis. Otherwise, the soybean was grown by conventional technology and procedures.

Table 1. Characteristics of soybean cultivars and location data of experimental locations

Cultivar	Maturity group*	Country of origin	Location of origin				Breeder/holder/maintainer
				Latitude	Longitude	Altitude	
NS Mercury	00	Serbia	Novi Sad, province of Vojvodina	45°16′N	19°50′E	80 m	Institute of Field and Vegetable Crops (Novi Sad)
NS Favorit	000	Serbia	Novi Sad, province of Vojvodina	45°16′N	19°50′E	80 m	Institute of Field and Vegetable Crops (Novi Sad)
ES Mentor	00	France	Mondonville, Toulouse	43°40'N	1°17'E	180 m	Euralis Semences
Josefine	00	Austria	Gleisdorf, Weiz district	47°6'N	15°42'E	362 m	Saatzucht Gleisdorf GmbH
Smuglyanka	00	Ukraine	Kirovograd, central Ukr.	48°30'N	32°15'E	124 m	AgeSoya
Ros	I	Belarus	Luninets, Brest region	52°16′N	26° 46'E	136 m	Soya-North Co. Ltd.
Volma	00	Belarus	Luninets, Brest region	52°16′N	26° 46'E	136 m	Soya-North Co. Ltd.
Experimental locations							
Jablje				46°7′N	14°34′E	302 m	
Rakičan				46°39′N	16°12′E	186 m	
Biotechnical faculty				46°3′N	14°11′E	295 m	

*Declared by the breeder

At each YLE, a randomised complete block experiment was done; four replications were carried out at E1 and E2 and three replications at E3, E4 and E5. Six response variables were analysed: 1000-seed weight (TSW) (g) (at E1 and E2, 1000-seed weight was determined only for a composite sample for each cultivar and therefore no standard error was calculated), seed yield (kg/ha at 9% seed moisture), content of protein and oil expressed on a dry weight basis expressed as percentage (%) and yield of protein and oil (kg/ha). TSW was determined according to the International Seed Testing Association (ISTA) protocol (ISTA, 2005). Yield of protein/oil was calculated as a product of seed yield (dry weight) and protein/oil content (% of dry weight). Content of protein and oil was determined by a non-destructive method of near infrared spectroscopy with a NIRSystems 6500 Monochromator (Foss NIRSystem, Silver Spring, MD).

Statistical analysis consisted of three paths. In the first path, a mixed model was determined for each response variable; YLE and cultivar were considered as fixed and crossed factors and blocks as random factors. In the statistical software programme R (R CORE TEAM, 2016), the 'nlme' package was used for this analysis. In the second path, stability indices were calculated using the 'agricolae' package. The stability of yields is presented with Shukla's variance (σ_i^2), S square Wricke's ecovalence (W_i^2) and Kang's yield stability index (YS_i). In the third path, correlations between response variables were calculated using the 'agricolae' package.

Weather conditions

Regarding the growth season of soybean plants, weather conditions were most favourable at E1 and E3, where moderate precipitation in May and June (91 mm and 177 mm at E1 and 94 mm and 131 mm at E3) allowed plants to maintain a good vegetative phase. Favourable temperatures during summer with no lack of precipitation and a not-uncommonly wet and warm September (226 mm/14.9°C at E1 and 204 mm/16.2°C at E3) allowed good ripening and no delay in harvesting. E2 had a lack of precipitation in June (67 mm), but a very excessive amount of rain in September (310 mm). Otherwise, the temperature profile was favourable at E2. In July, August and September, out of all the environments, E4 and E5 had the highest temperatures (24.3°C and 23.2°C for July; 22.3°C and 20.6°C for August; and 16.5°C and 18.3°C for September) and the lowest precipitation (118 mm and 86 for July; 96 mm and 90 mm for August; and 152 mm and 47 mm for September). At E5, there was high precipitation in May and June (157 mm and 175 mm) (Figure 1).

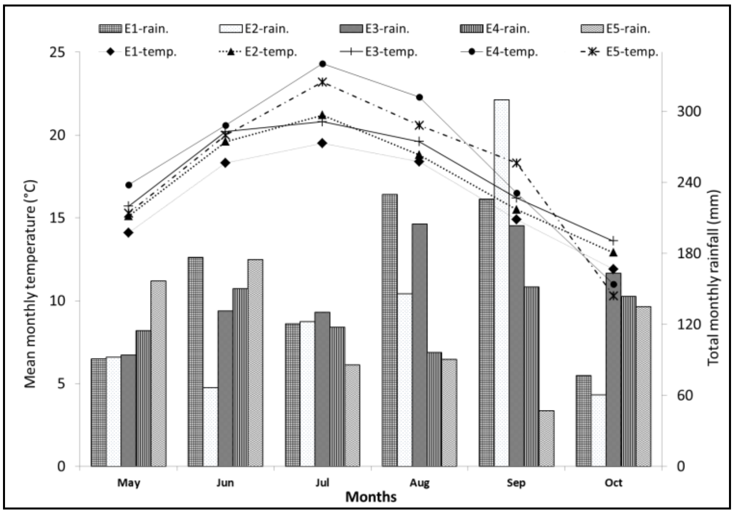

Figure 1. Mean monthly temperature and total monthly precipitation from May to October for the field experiments at all five year-by-location environments (YLEs) (E1 - Jablje 2014; E2 - Rakičan 2014; E3 - Biotechnical faculty 2014; E4 - Biotechnical faculty 2015; E5 - Biotechnical faculty 2016)

RESULTS

Analysis of variance

All the models exhibited that YLE and cultivar were the main sources of variation and were highly significant (Table 2). The interaction term, though always significant, had much lower F-values, which suggest the possible existence of some stable cultivar groups across the YLE. Due to highly significant YLE-by-cultivar interactions for all investigated traits, we did not perform multiple comparisons of the sets of means to distribute average values by YLE or by cultivars, but we showed this mean in results tables anyway, which served for informative purposes only and was not statistically analysed, as already explained. We only performed multiple comparisons for the interaction, but up to 16 statistical groups appeared (results not shown). They would not add any practical value to result interpretation; therefore, for each cultivar at each YLE, we presented only the means of replications ± standard error.

Table 2. Analysis of variance for thousand-seed weight (TSW), seed yield, protein content, protein yield, oil content and oil yield of soybean cultivars

Source of variation	df	TSW	Seed yield	Protein content	Protein yield	Oil content	Oil yield
Year-by-location environment (YLE)	4	24.33***	35.72***	17.5***	34.53***	374.9***	28.82***
Cultivar (C)	6	17.39***	28.58***	36.7***	32.85***	54.3***	23.67***
YLE x C	24	4.45***	2.41**	8.5***	3.10***	43.6***	2.27**

Significance codes: 0 '***' 0.001 '**' 0.01

Maturity group

Maturity group, declared by the breeder, is given in Table 1. However in our field experiments, we observed that cultivars had different maturity groups and we assigned cultivars to their appropriate group, namely Josefine and Smuglyanka to group 0, NS Favorit and Ros to group 00 and Volma to group 000. We assigned ES Mentor and NS Mercury to the same maturity group as the breeder (00).

1000-seed weight

The absolute highest TSW reached was in cultivar Ros at E3 (248.6 g) and the lowest in Smuglyanka at E4 (154.9 g). The same cultivars had also the highest and the lowest average TSWs (Ros with 216.2 g and Smuglyanka with 177.7 g, respectively). Average TSWs in terms of environment ranged between 173.3 g (E4) and 225.1 g (E2) (Figure 2).

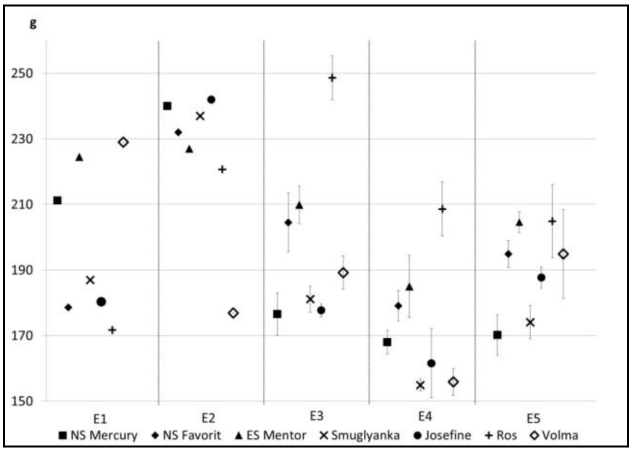

Figure 2. Comparison of the 1000-seed weight (g) of soybean cultivars at five year-by-location environments (YLEs) (E1 - Jablje 2014; E2 - Rakičan 2014; E3 - Biotechnical faculty 2014; E4 - Biotechnical faculty 2015; E5 - Biotechnical faculty 2016)

Seed yield

ES Mentor was the best yielding cultivar, with yields ranging from 3425 kg/ha at E5 to 5628 kg/ha at E1 (average yield 4600 kg/ha), followed by NS Mercury (3468 kg/ha at E2 to 5342 kg/ha at E1; average 4556 kg/ha), Smuglyanka (3077 kg/ha at E5 to 4544 kg/ha at E1; average 3964 kg/ha), NS Favorit (2825 kg/ha at E2 to 5054 kg/ha at E3; average 3846 kg/ha), Josefine (2948 kg/ha at E5 to 4300 kg/ha at E3; average 3658 kg/ha) and Ros (2143 kg/ha at E5 to 4802 kg/ha at E3; average 3276 kg/ha). The lowest average seed yield was determined for the Volma cultivar (average yield 2587 kg/ha, at E5 1236 kg/ha) (Figure 3). Cultivars reached the lowest average seed yield (2824 kg/ha) at E5 and the highest at E3 (4591 kg/ha). The average seed yield at E1 was 4316 kg/ha, at E2 3276 kg/ha and at E4 3903 kg/ha.

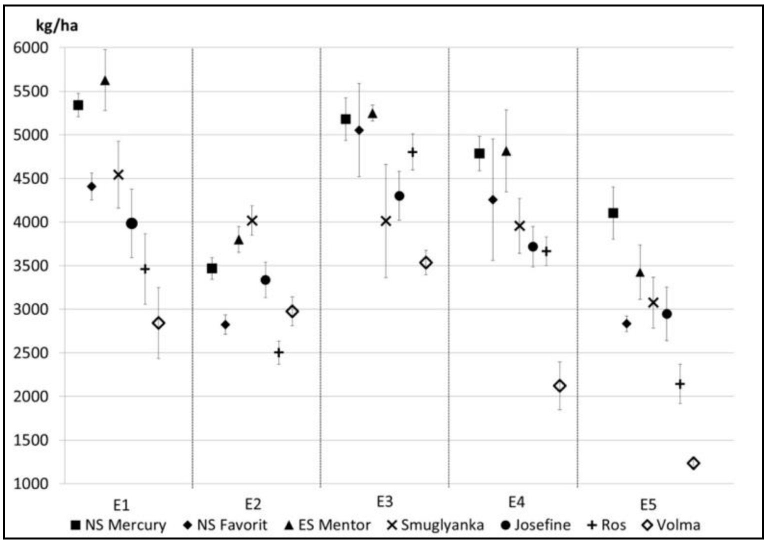

Figure 3. Comparison of seed yield (kg/ha) in soybean cultivars at five year-by-location environments (YLEs) (E1 - Jablje 2014; E2 - Rakičan 2014; E3 - Biotechnical faculty 2014; E4 - Biotechnical faculty 2015; E5 - Biotechnical faculty 2016)

Protein content and protein yield

The average protein content ranged from 38.7% (Volma) to 41.0% (NS Favorit) (Table 3). The absolute highest protein content was determined in cultivar ES Mentor (42.8%) at E1, which also achieved the highest average yield of protein (1710 kg/ha), followed by NS Mercury (1689 kg/ha) and NS Favorit (1437 kg/ha). The lowest protein content was determined for Smuglyanka at E5 (37.7%), but the cultivar with the lowest average yield of protein was Volma (909 kg/ha). E3 had the most favourable conditions for soybean protein production, since the average protein content was the second highest at 40.1% (the highest protein content was at E1 with 40.6%), but the protein yield was the highest in this YLE (1684 kg/ha). The lowest average protein yield was determined at E5 (1028 kg/ha) (Table 3).

Table 3. Content (C, in %) and yield (Y, in kg/ha) of protein

Cultivar	YLE										Average	
	E1		E2		E3		E4		E5			
	C %	Y kg/ha	C %	Y kg/ha	C %	Y kg/ha	C %	Y kg/ha	C %	Y kg/ha	C %	Y kg/ha
NS Mercury	42.6	2071	40.1	1266	40.0	1882	39.4	1717	40.8	1526	40.7	1689
NS Favorit	41.0	1645	41.0	1054	42.0	1935	40.1	1559	40.8	1052	41.0	1437
ES Mentor	42.8	2192	39.5	1366	40.4	1933	39.5	1732	41.0	1280	40.7	1710
Smuglyanka	39.7	1641	40.1	1466	39.1	1425	37.8	1364	37.7	1057	39.0	1410
Josefine	40.0	1451	40.7	1236	38.7	1511	38.3	1297	40.3	1078	39.7	1318
Ros	40.0	1260	40.3	918	41.3	1846	39.0	1302	38.8	757	39.9	1202
Volma	38.2	989	38.3	1038	38.9	1258	38.3	742	40.0	450	38.7	909
Average	40.6	1607	40.0	1192	40.1	1684	38.9	1388	39.9	1028		

Oil content and oil yield

Cultivars were very close regarding average oil content, which ranged from 19.0% (NS Mercury) to 20.2% (Volma) (Table 4). Even though Volma had the highest average oil content, it had the lowest average yield of oil (475.4 kg/ha). The highest yield of oil was reached by ES Mentor (640.8 kg/ha at E5 to 918.9 kg/ha at E3; average 799.6 kg/ha) followed by NS Mercury (618.6 kg/ha at E2 to 880.7 kg/ha at E3; average 780.5 kg/ha), Smuglyanka (585.3 kg/ha at E5 to 743.4 kg/ha at E4; average 685.0 kg/ha) and NS Favorit (457.6 kg/ha at E2 to 889.3 kg/ha at E3; average 674.7 kg/ha). The absolute lowest oil content was determined for Josefine and Smuglyanka (17.6%) at E1, where the average oil content was the lowest found (18.2%). The highest average oil content was determined at E4 (20.8%), but the highest average yield of oil was observed at E3 (804 kg/ha), where ES Mentor stands out with 918.9 kg/ha. The lowest yield of oil was determined at E5 (530.0 kg/ha), where Volma reached only 223.4 kg/ha in oil yield (Table 4).

Table 4. Content (C, in %) and yield (Y, in kg/ha) of oil

Cultivar	YLE										Average	
	E1		E2		E3		E4		E5			
	C %	Y kg/ha	C %	Y kg/ha	C %	Y kg/ha	C %	Y kg/ha	C %	Y kg/ha	C %	Y kg/ha
NS Mercury	16.8	816.7	19.6	618.6	18.7	880.7	20.2	879.5	20.1	748.9	19.0	780.5
NS Favorit	18.4	738.3	17.8	457.6	19.4	889.3	21.0	810.4	20.5	529.3	19.2	674.7
ES Mentor	16.7	855.3	19.8	684.9	19.2	918.9	20.9	918.0	20.6	640.8	19.3	799.6
Smuglyanka	17.6	727.7	18.4	672.7	18.8	685.9	20.7	743.4	20.9	585.3	19.1	685.0
Josefine	17.6	638.5	19.3	586.0	20.7	810.8	22.1	748.9	22.1	594.2	20.1	668.2
Ros	19.1	601.7	18.3	417.0	18.8	795.5	20.0	665.3	19.9	387.7	19.2	565.9
Volma	21.4	553.8	18.9	512.0	20.2	647.0	20.8	402.4	19.9	223.4	20.2	475.4
Average	18.2	704.6	18.9	564.1	19.3	804.0	20.8	738.3	20.6	530.0		

Yield stability indices

Shukla's variance (σ_i^2) and S square Wricke's ecovalence (W_i^2) measure the contribution of a genotype to the genotype-by-environment interactions and error term, meaning that a genotype with low σ_i^2 or W_i^2 is regarded as stable. Kang's yield stability (YS_i) emphasises both the mean yield (M) and stability variance (σ_i^2) for a selected trait and gives equal weight to M and σ_i^2. By this method, genotypes with a YS_i greater than the mean YS_i are considered stable.

Regarding the stability of seed yield, Shukla's variance and Wricke's ecovalence pointed out Josefine to be the most stable cultivar, followed by ES Mentor, NS Favorit and NS Mercury. Volma turned out to have most unstable seed yield. Regarding Kang's stability index, ES Mentor was selected as the best genotype in terms of seed yield stability, followed by NS Mercury and NS Favorit. For protein yield stability, Josefine had lowest σ_i^2 and W_i^2, followed by NS Mercury and ES Mentor. By YS_i index, NS Mercury, ES Mentor, NS Favorit and Josefine were the best chosen cultivars in terms of protein yield stability in this study. The highest oil yield stability was observed in ES Mentor, Josefine and Ros, whereas Volma had the least stable oil yield. Kang's YS_i selected ES Mentor, NS Mercury, NS Favorit and Josefine to be leading genotypes in this investigation regarding oil yield (Table 5).

Table 5. Yield stability indices in seven cultivars for stability of seed, protein and oil yields. Values for Shukla's variance (σ_i^2) and S square Wricke's ecovalence (W_i^2) are given in 10.000's

Cultivar	Seed yield				Protein yield				Oil yield			
	σ_i^2	W_i^2	YS_i		σ_i^2	W_i^2	YS_i		σ_i^2	W_i^2	YS_i	
			V	S			V	S			V	S
NS Mercury	61.4	210.3	7	+	6.2	27.4	8	+	1.4	4.9	9	+
NS Favorit	41.1	152.3	5	+	52.3	159.0	2	+	2.1	7.0	4	+
ES Mentor	30.8	122.8	10	+	10.2	38.8	5	+	0.0	1.0	10	+
Smuglyanka	83.0	272.0	2		13.0	46.7	-1		2.6	8.5	1	
Josefine	5.6	50.8	2		0.0	9.5	2	+	0.6	2.7	4	+
Ros	71.9	240.3	-2		17.7	60.2	-8		1.0	3.9	0	
Volma	133.4	415.9	-10		19.6	65.6	-10		5.5	16.8	-10	
Average			2				-0.3				2.6	

σ_i^2 – Shukla's variance; W_i^2 – S square Wricke's ecovalence; YS_i – Kang's yield stability; V – value of YS_i; S – selected genotypes based on YS_i value

Correlation analyses

YLE had great influence on the coefficients of correlation between some of the investigated traits. There was no correlation between yield of seed and TSW. We found positive correlation between yield of seed and protein content (significant at E1 and E4) and in most cases, negative correlation between yield of seed and oil content, yet only significantly at E1. There were clear negative correlations between protein and oil content in all environments (highly significant at E1 and near significant at E3; $p = 0.108$). Protein content was positively correlated with protein yield (significant at E1 and E4), whereas oil content showed one positive (at E3) and one negative (at E1) statistically significant connection to the yield of oil. Yield of seed and yield of protein/oil was highly positively and significantly correlated in all environments. The same goes for the correlation between yield of protein and yield of oil (Table 6).

Table 6. Simple correlations (Pearson's r) between pairs of investigated traits over five year-by-location environments (YLE's) (E1 - Jablje 2014; E2 - Rakičan 2014; E3 - Biotechnical faculty 2014; E4 - Biotechnical faculty 2015; E5 - Biotechnical faculty 2016)

Correlation pair	E1	E2	E3	E4	E5
Yield of seed, TSW	0.16^{ns}	0.34^{ns}	0.30^{ns}	0.34^{ns}	-0.20^{ns}
Yield of seed, protein content	0.78***	-0.09^{ns}	0.39^{ns}	0.60*	0.25^{ns}
Yield of seed, oil content	-0.77***	0.45^{ns}	-0.25^{ns}	-0.17^{ns}	0.24^{ns}
Protein content, oil content	-0.83***	-0.36^{ns}	-0.56^{ns}	-0.34^{ns}	-0.19^{ns}
Protein content, protein yield	0.83***	0.02^{ns}	0.54^{ns}	0.66*	0.34^{ns}
Oil content, oil yield	-0.61**	0.60**	-0.04^{ns}	-0.04^{ns}	0.35^{ns}
Seed yield, protein yield	0.99***	0.99***	0.9820***	0.99***	0.99***
Seed yield, oil yield	0.97***	0.98***	0.9683***	0.99***	0.99***
Protein yield, oil yield	0.95***	0.97***	0.9258***	0.99***	0.98***

Significance codes: ***' 0.001 '**' 0.01 '*' 0.05; ns – not significant

DISCUSSION

In the European Union (EU), the average soybean seed yield in 2016 was 2928 kg/ha (FAOSTAT, 2018). This means that all tested cultivars from our study (except Volma) achieved average seed yields above the EU average yield. Particularly high yielding cultivars included ES Mentor (3425–5628 kg seed/ha; average yield 4600 kg/ha) and NS Mercury (3468–5342 kg seed/ha; average yield 4556 kg/ha) (Figure 3). The yield of NS Mercury (maturity group 00) is comparable to POPOVIĆ *et al.* (2012), who also tested varieties bred in Novi Sad, although those varieties belong to slightly later maturity groups (0 and I; seed yields for two years for all varieties were from 4547 kg/ha to 4984 kg/ha calculated at 9% seed moisture). Cultivar NS Favorit (000), which belongs to a very early maturity group, had a lower average seed yield (average 3846 kg/ha; spanning from 2825 kg/ha to 5054 kg/ha) in this study – the reason for this difference could be in the length of the growing season, as cultivars with shorter growing seasons have lower average yields in favourable years (RAO *et al.*, 2002).

Thousand-seed weight (TSW) is one of the most important components of the yield. In our study, however, no significant correlation was found between seed yield and TSW, although seed yield was moderately positively correlated with thousand-seed weight in almost all environments. This means that high-yielding cultivars could have smaller seeds and, vice versa, cultivars with low yield could have bigger seeds. For example, Ros had very low seed yield (3276 kg/ha), even though it was the leading cultivar with the highest TSW (216.2 g) (Figure 2). Similar phenomena were also observed elsewhere (MILADINOVIĆ *et al.*, 2006; MALIK *et al.*, 2007; KURASCH *et al.*, 2017a). Significantly negative or/and positive correlations between seed yield and TSW were further determined by MILADINOVIĆ *et al.*, 2006; POPOVIĆ *et al.*, 2012; EL-MOHSEN *et al.*, 2013; AL-HADI *et al.*, 2017; KURASCH *et al.*, 2017a.

There have been reports of protein content in soybean ranging from 34.1 to 56.8% and oil content ranging between 8.3 and 27.9% (WILCOX and SHIBLES, 2001). MLAKAR *et al.* (2016) tested the influence of different production systems on protein and fat content in the cultivars ES

Mentor and Aligator. In ES Mentor, they determined relatively similar values for average protein content (41.5% vs. 40.7% in our study) and lower values for average oil content (17.3% vs. 19.3% in our study) as found in this investigation. POPOVIĆ *et al.* (2012) determined significantly lower values for protein content and considerably higher values for oil content in their four NS soybean varieties (average for two years in all varieties was 37.15% for protein content and 21.08% for oil content) compared to our experiment, where varieties from Novi Sad, NS Mercury and NS Favorit, reached 40.7% of protein with 19.0% of oil and 41.0% of protein with 19.2% of oil, respectively. Numerous studies showed that, besides genetic variation (genotype), content of protein and oil in soybean seeds is heavily influenced by agronomic management practice, e.g. planting dates (TREMBLAY *et al.*, 2006; MUHAMMAD *et al.*, 2009; BELLALOUI *et al.*, 2015; MATSUO *et al.*, 2016) and environmental factors, such as temperature (ROTUNDO and WESTGATE, 2009; MOURTZINIS *et al.*, 2017) and water conditions (EGLI and BRUENING, 2004; TURNER *et al.*, 2005). Therefore, even if the same variety is grown every year at the same location, oscillations in protein/oil content are highly expected due to changing weather conditions and/or agronomic practice.

Negative correlation between oil and protein content is long known and well documented (YAKLICH *et al.*, 2002; MILADINOVIĆ *et al.*, 2006; POPOVIĆ *et al.*, 2012; KURASCH *et al.*, 2017a). Negative correlation between protein and oil content was also observed in our study in all environments, yet only at E1 was this correlation significant (Table 6). The best yielding cultivars in all yield parameters (seed, protein and oil) were ES Mentor and NS Mercury. However, none of them had the highest protein or oil content, which indicates that the yield of protein and oil is more dependent on seed yield than on protein and oil content. This was clearly confirmed by correlation analysis, where different, but mainly low and not significant correlations between protein/oil yield and protein/oil contents were observed. On the other hand, the yield of seed was both positively and highly significantly correlated with yields of protein and oil in all environments. This finding poses much higher relevance to grain yield than to protein or oil content, when the primary goal of soybean cultivation is to obtain high yields of protein and oil. This hypothesis corroborates the results of KURASCH *et al.* (2017a), which came to the same conclusion. Furthermore, the strategy of soybean breeding for obtaining high protein/oil content or high protein/oil yields should also be dependent on the intended end-use of the bred soybean cultivar (KURASCH *et al.*, 2017a).

According to MILADINOVIĆ *et al.* (2006), successful cultivars are spreading across localities on the basis of their adaptability, where photoperiod plays a major role. Therefore, cultivar performance must be evaluated in field trials at various locations, particularly where cultivation will occur outside the breeding environments (MEKBIB, 2003). No cultivars in this investigation originate from this region and their maturity group was declared in their environment of origin (Table 1). This means that when some cultivars are cultivated in environments at different latitudes, their maturity group can change (MOURTZINIS *et al.*, 2017). KURASCH *et al.* (2017b), who conducted field experiments with 75 European soybean cultivars from five different maturity groups (000, 00, 0, I and II) at 22 locations across Europe and providing the first assessment of potential mega-environments within Europe, noticed that when cultivars were moved towards higher latitudes, they reached full maturity later and flowered and matured earlier when grown at a lower latitudes. These findings are similar to those of the present study, where all cultivars were officially declared to be very early (00 or 000), except for Ros, which had maturity group of I (medium) (Table 1). During field trials we noticed that at this cultivation latitude, Josefine (00), NS Favorit (000) and Smuglyanka (00) turned out to ripen later and should be declared as 0, 00 and 0, respectively. On the other hand, cultivars Ros (I) and Volma (00) matured earlier in our environments and should be declared as 00 and 000, respectively. Intriguingly, only ES Mentor and NS Mercury with a maturity group of 00, turned out to fit perfectly into our environments with no deviation from the maturation period. At first glance, this could be one of the main reasons for the highest average yield of seed, proteins and oils in these two cultivars in all environments in this study.

In experiments, where interactions between two independent variables (e.g. location and year, different storage parameters, etc.) are statistically confirmed, the combination of independent variables can be legitimately taken as the environment and used for calculations in stability analyses (SUDARIĆ *et al.*, 2006; MURPHY *et al.*, 2009; RAK *et al.*, 2013; SOOD *et al.*, 2015; DIA *et al.*, 2016a, b; FLAJŠMAN *et al.*, 2018). Regarding BECKER and LEON (1988), stability describes a predictable response to environments, and genotype is considered stable if it performs exactly to a predictable response with no deviation from this response. By Kang's yield stability index, which takes into account mean yield and stability variance, ES Mentor, NS Mercury and NS Favorit were brought to the forefront among all studied soybean cultivars regarding yields of seed, proteins and oils. Kang's yield stability index also has a very practical value since farmers would desire using cultivars, which are high-yielding and perform consistently from season to season or year to year (MEKBIB, 2003). Notably, the most stable genotypes, in terms of stability indices only, were Josefine for seed and protein yield and ES Mentor for oil yield. However, the stability indices *per se* are not informative enough for selection of the most suitable cultivar, since high yield performance is randomly or even rarely positively correlated with high yield stability (MOHAMMADI and AMRI, 2008). Therefore, selection of the best genotype based on Kang's stability index is the most justified and reliable in terms of selecting stable and high yielding cultivars.

Stability analysis of soybean cultivars is taking place worldwide in order to select appropriate genotypes for each particular growing region. Numerous authors use different yield-stability statistics to evaluate performance of tested genotypes (YAN and RAJCAN, 2003), e.g. GGE biplot (ZHANG *et al.*, 2005; MATEI *et al.*, 2018), Wricke's ecovalence (SILVA *et al.*, 2016), regression (b), determination (R^2) and deviation of the linear regression (σ^2) coefficients (LIMA *et al.*, 2000), regression coefficient (*b*) (YAN *et al.*, 2010), coefficients of variation (CV) (POPOVIĆ *et al.*, 2012), amongst others. Interestingly, however, all stability indices are relative to each study and determine the best genotype among tested cultivars. Therefore direct comparison between different studies by the same index is inadequate.

Stable agronomic performance is a cultivar characteristic that derives from complex traits, controlled by large number of genomic regions, where each gene adds a very small part to the end result; however, environment strongly directs a large proportion of allelic contribution (DES MARAIS *et al.*, 2013). One of the main reasons for the phenotypic variation of quantitative traits are genotype-by-environment interactions, when statistical models confirming their significance (COOPER *et al.*, 1996). Genotype-by-environment interactions are in an "omic" era, investigated on the genomic scale at the quantitative trait locus level, which poses opportunities for marker-assisted selection for improving trait stability (MALOSETTI *et al.*, 2013). XAVIER *et al.* (2018) evaluated the multi-parental soybean population and identified six chromosomal regions that were associated with the grain yield and its response to the influence of environment. Furthermore, they were able to link one chromosomal region to grain yield stability (XAVIER *et* *al.*, 2018). These findings enable the understanding of the genetic and molecular basis of yield stability in relation to interactions with environmental factors and may open the door to genomic assisted breeding for both higher yield performance and more stable yield. In addition, localisation and functional characterisation of such genes can lead to design scenarios where genes can be exploited for more efficient and faster achievement of breeding goals.

CONCLUSION

One of the main European objectives for ensuring food security is to improve protein self-sufficiency. Therefore, the production of high yielding and stable soybean genotypes, which are acquired through evaluation in field trials at various locations, is of paramount importance for every country aiming to attain objective. In this study, genotype-by-environment interactions had a crucial influence on soybean cultivar performance and yield stability. In the view of seed, protein and oil yield stability, the superior genotype in this study was the cultivar ES Mentor, followed by both Novi Sad's cultivars, NS Mercury and NS Favorit. Fortunately, ES Mentor is widespread in Slovenian soybean production. Furthermore, because of high yield performance and yield stability, we also recommend NS Mercury and NS Favorit for wider use in soybean production in our area and regions with similar photoperiod and pedo-climatic conditions, regardless of what soybean seed is used.

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REFERENCES

ALGHAMDI, S.S. (2004): Yield stability of some soybean genotypes across diverse environments. Pak. J. Bot., *12*: 2109-2114.

AL-HADI, M.A.G., M.R., ISLAM, M.A., KARIM, M.T., ISLAM (2017): Morpho-physiological characterization of soybean genotypes under subtropical environment. Genetika, *49* (1): 297-311.

ASHRAF, M., Z., IQBAL, M., ARSHAD, A., WAHEED, M.A., GLUFRAN, Z., CHAUDHRY, D., BAIG (2010): Multi-environment response in seed yield of soybean [*Glycine max* (L.) Merrill], genotypes through GGE biplot technique. Pak. J. Bot., *42* (6): 3899-3905.

BECKER, H.C. and J., LEON (1988): Stability analysis in plant breeding. Plant Breed., *101* (1): 1-23.

BELLALOUI, N., H.A., BRUNS, H.K., ABBAS, A., MENGISTU, D.K., FISHER, K.N., REDDY (2015): Agricultural practices altered soybean seed protein, oil, fatty acids, sugars, and minerals in the Midsouth USA. Front. Plant Sci., *6*: 31.

COOPER, M., P.S., BRENNAN, J.A., SHEPPARD (1996): A Strategy for Yield Improvement of Wheat Which Accommodates Large Genotype by Environment Interactions. M., Cooper, G.L., Hammer (Eds.) Plant Adaptation and Crop Improvement: CAB International, Wallingford, Oxfordshire: 487-512.

DES MARAIS, D.L., K.M., HERNANDEZ, T.E., JUENGER (2013): Genotype-by environment interaction and plasticity: exploring genomic responses of plants to the abiotic environment. Annu. Rev. Ecol. Evol. Syst., *44:* 5-29.

DIA, M., T.C., WEHNER, R., HASSELL, D.S., PRICE, G.E., BOYHAN, S., OLSON, S., KING, A.R., DAVIS, G.E., TOLLA (2016a): Genotype × environment interaction and stability analysis for watermelon fruit yield in the United States. Crop Sci., *56* (4): 1645-1661.

DIA, M., T.C., WEHNER, P., PERKINS-VEAZIE, R., HASSELL, D.S., PRICE, G.E., BOYHAN, S.M., OLSON, S.R., KING, A.R., DAVIS, G.E., TOLLA, J., BERNIER, B., JUAREZ (2016b): Stability of fruit quality traits in diverse watermelon cultivars tested in multiple environments. Hort. Res., *3*: 16066.

DIA, M., T.C., WEHNER, C., ARELLANO (2017): RGxE: an r program for genotype x environment interaction analysis. Am. J. Plant Sci., *8*(7): 1672.

EGLI, D.B. and W.P., BRUENING (2004): Water stress, photosynthesis, seed sucrose levels and seed growth in soybean. J. Agr. Sci., *14* (2): 1-8.

EL-MOHSEN, A.A.A., G.O., MAHMOUD, S.A., SAFINA (2013): Agronomical evaluation of six soybean cultivars using correlation and regression analysis under different irrigation regime conditions. J. Plant Breed. Crop Sci., *5*(5): 91-102.

FAOSTAT (2018): Food and Agriculture Organization of the United Nations. Website http://faostat.fao.org/default.aspx (Accessed 2018-4-10)

FLAJŠMAN, M., N., ŠTAJNER, D.K., AČKO (2018): Genetic diversity and agronomic performance of Slovenian landraces of proso millet (*Panicum miliaceum* L.). Turk. J. Bot., *43* (2): 185-195.

HOWELL, S.H. (1998): Molecular genetics of plant development. Cambridge University Press, pp. 365.

ISTA (2005): International Rules for Seed Testing. Edition 2005. International Seed Testing Association, Bassersdorf, Switzerland.

JUNG, C. and A.E., MÜLLER (2009): Flowering time control and applications in plant breeding. Trends Plant Sci., *14* (10): 563-573.

KANG, M.S. (1993): Simultaneous selection for yield and stability in crop performance trials: Consequences for growers. Agron. J., *85*(3): 754-757.

KURASCH, A.K., V., HAHN, W.L., LEISER, N., STARCK, T., WÜRSCHUM (2017a): Phenotypic analysis of major agronomic traits in 1008 RILs from a diallel of early European soybean varieties. Crop Sci., *57*(2): 726-738.

KURASCH, A.K., V., HAHN, W.L., LEISER, J., VOLLMANN, A., SCHORI, C.A., BÉTRIX, ... & A., SUDARIĆ (2017b): Identification of mega-environments in Europe and effect of allelic variation at maturity E loci on adaptation of European soybean. Plant Cell Environ., *40* (5): 765-778.

LIMA, W.F., J.F.F.D., TOLEDO, C.A.A., ARIAS, M.F.D., OLIVEIRA (2000): Stability of soybean yield through different sowing periods. Pesq. Agropec. Bras., *35* (11): 2181-2189.

LIU, W., B., JIANG, L., MA, S., ZHANG, H., ZHAI, X., XU, W., HOU, Z., XIA, C., WU, S., SUN, T., WU, L., CHEN, T., HAN (2017): Functional diversification of Flowering Locus T homologs in soybean: GmFT1a and GmFT2a/5a have opposite roles in controlling flowering and maturation. New Phytol., *217*(3): 1335-1345.

MALIK, M.F.A., M., ASHRAF, A.S., QURESHI, A., GHAFOOR (2007): Assessment of genetic variability, correlation and path analyses for yield and its components in soybean. Pak. J. Bot., *39* (2): 405-413.

MALOSETTI, M., J.M., RIBAUT, F.A., VAN EEUWIJK (2013): The statistical analysis of multi-environment data: modelling genotype-by-environment interaction and its genetic basis. Front. Physiol., *4*: 44.

MATEI, G., C., MENEGUZZI, L.G., WOYANN, M.H., TODESCHINI, D.M., TREVIZAN, J., CONTE, A.H., BOZI, G., BENIN (2018): Oil, protein and fatty acid profiles of Brazilian soybean cultivars in multi-environmental trials. Aust. J. Crop Sci., *12* (5): 686-698.

MATSUO, N., K., FUKAMI, S., TSUCHIYA (2016): Effects of early planting and cultivars on the yield and agronomic traits of soybeans grown in southwestern Japan. Plant Prod. Sci., *19*, (3): 370-380.

MEKBIB, F. (2003): Yield stability in common bean (*Phaseolus vulgaris* L.) genotypes. Euphytica, *130* (2): 147-153.

MILADINOVIĆ, J., H., KUROSAKI, J., W., BURTON, M., HRUSTIĆ, D., MILADINOVIĆ (2006): The adaptability of short-season soybean genotypes to varying longitudinal regions. Eur. J. Agron., *25:* 243-249.

MILADINOVIĆ, J., M., VIDIĆ, V., ĐORĐEVIĆ, S., BALEŠEVIĆ-TUBIĆ (2015): New trends in plant breeding–example of soybean. Genetika, *47*(1): 131-142.

MLAKAR, S.G., M.B., SOLAROV, M., BAVEC, M., ROBAČER, M., JAKOP, T., VUKMANIČ, F., BAVEC (2016): Protein and fat content of soybean from different production systems. J., Lević (Ed.). Proceedings of the III International Congress on Food Technology, Quality and Safety, University of Novi Sad, Institute of Food Technology, Serbia: 642-645.

MOHAMMADI, R. and A., AMRI (2008): Comparison of parametric and non-parametric methods for selecting stable and adapted durum wheat genotypes in variable environments. Euphytica, *159*: 419-432.

MOURTZINIS, S., A.P., GASPAR, S.L., NAEVE, S.P., CONLEY (2017): Planting date, maturity, and temperature effects on soybean seed yield and composition. Agron. J., *109* (5): 2040-2049.

MUHAMMAD, A., S.K., KHALIL, K.B., MARWAT, A.Z., KHAN, I.H., KHALIL, AMANULLAH, S., ARIFULLAH (2009): Nutritional quality and production of soybean land races and improved varieties as affected by planting dates. Pak. J. Bot., *41*: 683-689.

MURPHY, S.E., E.A., LEE, L., WOODROW, P., SEGUIN, J., KUMAR, I., RAJCAN, G.R., ABLETT (2009): Genotype × environment interaction and stability for isoflavone content in soybean. Crop Sci., *49*: 1313-1321.

POPOVIĆ, V., M., VIDIĆ, Đ., JOCKOVIĆ, J., IKANOVIĆ, S., JAKSIĆ, G., CVIJANOVIĆ (2012): Variability and correlations between yield components of soybean [*Glycine max* (L.) Merr.]. Genetika, *44* (1): 33-45.

R CORE TEAM (2016): R: A Language and Environment for Statistical Computing. Vienna, Austria: R Foundation for Statistical Computing. URL: https://www.R-project.org/ (Accessed 2018-3-19)

RAK, K., F.M., NAVARRO, J.P., PALTA (2013): Genotype × storage environment interaction and stability of potato chip color: Implications in breeding for cold storage chip quality. Crop Sci., *53* (5): 1944-1952.

RAO, M.S.S., B.G., MULLINIX, M., RANGAPPA, E., CEBERT, A.S., BHAGSARI, V.T., SAPRA, J.M., JOSHI, R.B., DADSON (2002): Genotype × environment interactions and yield stability of food-grade soybean genotypes. Agron. J., *94*: 72-80.

ROTUNDO, J.L. and M.E., WESTGATE (2009): Meta-analysis of environmental effects on soybean seed composition. Field Crops Res., *110*: 147-156.

SATO, T., M., VAN SCHOOTE, H., WAGENTRISTL, J., VOLLMANN (2014): Effects of divergent selection for seed protein content in high-protein vs. food-grade populations of early maturity soybean. Plant Breed., *133* (1): 74-79.

SILVA, K.B., A.T., BRUZI, A.M., ZUFFO, E.V., ZAMBIAZZI, I.O., SOARES, P.M., DE REZENDE, V., FRONZA, G.D.L., VILELA, F.B.S., BOTELHO, C.M., TEIXEIRA, M.A.O., COELHO (2016). Adaptability and phenotypic stability of soybean cultivars for grain yield and oil content. Genet. Mol. Res., *15* (2): pp 11.

SOOD, S., A.G.L., KANT, A., PATTANAYAK (2015): Assessment of parametric and non-parametric methods for selecting stable and adapted finger millet (*Eleusine coracana* (L.) Gaertn.) genotypes in sub-mountainous Himalayan region. Int. J. Basic Appl. Agri. Res., *13*: 283-288.

SUDARIĆ, A., D., ŠIMIĆ, M., VRATARIĆ (2006): Characterization of genotype by environment interactions in soybean breeding programmes of southeast Europe. Plant Breed., *125* (2): 191-194.

TREMBLAY, G.J., J.M., BEAUSOLEIL, P., FILION, M., SAULNIER (2006): Response of three soybean cultivars to seeding date. Can. J. Plant Sci., *86*: 1071-1078.

TURNER, N.C., S.L., DAVIES, J.A., PLUMMER, K.H.M., SIDDIQUE (2005): Seed filling in grain legumes under water deficits, with emphasis on chickpeas. Adv. Agron., *87*: 211-250.

VOLTAS, J., H., LOPEZ-CORCOLES, G., BORRAS (2005): Use of biplot analysis and factorial regression for the investigation of superior genotypes in multi-environment trials. Eur. J. Agron., *22* (3): 309-324.

WATANABE, S., K., HARADA, J., ABE (2012): Genetic and molecular bases of photoperiod responses of flowering in soybean. Breed. Sci., *61* (5): 531-543.

WILCOX, J.R. and R.M., SHIBLES (2001): Interrelationships among seed quality attributes in soybean. Crop Sci., *41*, 1: 11-14.

XAVIER, A., D., JARQUIN, R., HOWARD, V., RAMASUBRAMANIAN, J.E., SPECHT, G.L., GRAEF, … & K.M., RAINEY (2018): Genome-Wide analysis of grain yield stability and environmental interactions in a multiparental soybean population. G3: Genes, Genomes, Genetics, *8*: 519–529.

YAKLICH, R.W., B., VINYARD, M., CAMP, S., DOUGLASS (2002): Analysis of seed protein and oil from soybean northern and southern region uniform tests. Crop Sci., *42*: 1504-1515.

YAN, W. and I., RAJCAN (2003): Prediction of cultivar performance based on single-versus multiple-year tests in soybean. Crop Sci., *43* (2): 549-555.

YAN, W., L.A., HUNT, Q., SHENG, Z., SZLAVNICS (2000): Cultivar evaluation and mega-environment investigation based on the GGE biplot. Crop Sci., *40* (3): 597-605.

YAN, Z., J.G., LAUER, R., BORGES, N., LEON (2010): Effects of genotype × environment interaction on agronomic traits in soybean. Crop Sci., *50* (2): 696-702.

ZEEVAART, J.A. (2006): Florigen coming of age after 70 years. Plant Cell, *18* (8): 1783-1789.

ZHANG, M., M.S., KANG, P.F., REESE, J., HARBANS, L., BHARDWAJ (2005): Soybean cultivar evaluation via GGE biplot analysis. J. New Seeds, *7*: 37-50.

AGRONOMSKE PERFORMANSE I STABILNOST PRINOSA SEMENA, PROTEINA I ULJA KOD SEDAM SORTI SOJE U POLJSKIM OGLEDIMA U SLOVENIJI

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Izvod

Životna sredina ima ključni uticaj na proizvodnju soje u određenom regionu, čak i više kada se proizvodne spoljašnje sredine razlikuju od sredina u kojima se vrši oplemenjivanje. Sedam sorata soje poreklom iz pet evropskih zemalja ocenjeno je za apsolutnu težinu semena, prinos zrna, proteina i ulja na pet lokaliteta u Sloveniji. Za odabir najboljeg genotipa za gajenje utvrđena je stabilnost prinosa zrna, proteina i ulja. Rezultati pokazuju da sorta i životna sredina imaju značajan uticaj na sve izmerene osobine. U gotovo svim ispitivanim lokalitetima najveće prinose zrna, proteina in ulja dale su sorte ES Mentor (3425 - 5628 kg zrna/ha, 1280 - 2192 kg proteina/ha, 640,8 – 918,9 kg ulja/ha) i NS Mercury (3468 - 5342 kg zrna/ha, 1266 - 2071 kg proteina/ha, 618,6 - 880,7 kg ulja/ha). Najviši prosečan sadržaj proteina utvrđen je kod sorte NS Favorit (41,0% suve materije-ST). Za procenu stabilnosti prinosa korišćeni su tri indeksa stabilnosti prinosa; po Shuklovoj varijansi (σ_i^2) i S kvadratnoj Vrickeov-oj ekovalentnosti (W_i^2), sorta Josefine je pokazala najstabilniji prinos zrna i ulja, a ES Mentor najstabilniji prinos proteina. Što se tiče Kangove stabilnosti prinosa (YS_i), ES Mentor, NS Mercury i NS Favorit su o ovoj studiji izabrani kao superiorni genotipovi. Kao što se očekivalo u korelacionoj analizi, sadržaji proteina i ulja bili su negativno korelisani, ali samo u jednom lokalitetu statistički značajno. Rezultati ove studije ističu da su među sedam ispitanih sorti ES Mentor, NS Mercury i NS Favorit najpogodnije za korišćenje u proizvodnji soje u Sloveniji.

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