NARDI FUNDULEA, ROMANIA
www.incda-fundulea.ro

ROMANIAN AGRICULTURAL RESEARCH, NO. 36, 2019
Print ISSN 1222–4227; Online ISSN 2067–5720

INFLUENCE OF PLANT DENSITIES ON SOME YIELD ELEMENTS IN SEVERAL LOCAL AND FOREIGN SOYBEAN CULTIVARS IN TRANSYLVANIA PLAIN CONDITIONS

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ABSTRACT

Soybean can play an important role in securing the European protein resources. Transylvania Plain is a very favourable area for soybean crop. To optimise the crop management in these conditions, thirteen soybean cultivars (9 created at Agricultural Research and Development Station Turda and 4 of foreign origin) were studied with different plant densities and row spacing, in the specific environment of Transylvanian Plain.

The yield increased by increasing the plant density up to 60 germinating seeds m^{-2}, after which yield declined at the highest plant density. 60 g.s. m^{-2} plant population recorded the highest positive significant differences (approximately 10%), as compared to the average of all tested plant densities.

The distance of 25 cm between rows produced a significantly higher yield as compared with the average of the trial.

The climatic conditions influenced very significantly the yield variation (55.95%) while the genotypes, plant populations, and distances between rows had a statistically significantly lower influence (8.72%, 4.42% and 1.57%) compared to the effect of climatic conditions. The interaction between genotype and plant density contributed significantly (2.26%) to grain yield per unit area, while the interaction between plant density and row spacing had a statistically not significant effect of 1.09%).

Keywords: soybean cultivars, plant population (densities), distance between rows, yield.

INTRODUCTION

Conventional soybean crop is in the foreground given the desire to develop and secure the European vegetable protein resource by increasing cultivated areas. Romania's agriculture can open new perspectives, as appropriate favourable climatic conditions are met for obtaining high yields. Romania has the highest potential for soybean crop in the European Union by the large agricultural areas available and the knowledge of the quantitative potential of existing varieties is of major importance.

Transylvania Plain is a very favourable area for soybean crop. However areas planted with soybeans varied greatly over time. Years ago, the main limiting factor of expansion of soybean areas was the long duration of the vegetation period (Mureşanu et al., 2010).

Soybean has the ability to regulate its growth and production components in response to changes in the plant density and competition. Previous studies have addressed various aspects of these problems, but there is a lack of information on how competition affects interplant plant variability, or how certain varieties respond to different densities (Mellendorf, 2011).

Given the wide diversity of climatic conditions in the area of influence of Agricultural Research and Development Station Turda, a decisive role has the choice of variety in accordance with natural conditions, based on knowledge of its behaviour in the area (Mureşanu and Mărginean, 2011).

Crop densities and distance between rows have a crucial importance in achieving high yields per area, making it possible to identify genotypes less dependent on competition between plants and use them to create

Received 6 July 2016; accepted 7 January 2019. First Online: January, 2019. DII 2067-5720 RAR 2019-84

cultivars capable of achieving high yields in a range of different culture conditions.

The objectives of this paper were: the analysis of the yielding ability and stability of several soybean cultivars developed at ARDS Turda or of foreign origin and establishing the influence of different plant densities and distances between rows.

MATERIAL AND METHODS

Yield trials were carried out in the experimental field of soybean breeding Laboratory from the Agricultural Research and Development Station Turda (46°34'15"N, 23°46'45"E) in the years 2012-2014.

The ARDS Turda area is part of the district Transylvanian Plain at the south-west limit it in the left bank of Arieş River. The soil known as the type of mold cambic chernozem, vertic horizons which have a sequence of Am – Bvy – C or Cca. There are also types of gleyed chernozems, pseudogleisated and saline. In the valleys, there are isolated halomorfe soils. Depending on the steepness of the slope and utilization, soil presents various stages of erosion.

The climate of the area, by Koppen classification, is symbolized by formula D.f.b.x., defining boreal continental climate influences with four distinct seasons. The thermic regime is characterized by air temperatures of 8.6°C as annual average, highest in July with the monthly average of 19.6° C, while the coldest of -4.4°C average monthly temperature in January. The results of experiments were influenced by certain climatic particularities of the three years of experimenting 2012-2014.

Adverse conditions in terms of temperature and precipitations (very dry) recorded in the year 2012 especially in August created less favorable conditions for grain filling, also an acceleration of the maturity period. In terms of temperatures recorded in the months of April to August the year can be described as warm (+14.3°C) and in terms of precipitations as dry year (-14.1 mm).

The year 2013 can be characterized as an unfavorable year for soybean crop in the reference area, warm and dry, amid to the evolution of temperatures in the months of July, August, in the flowering stages and pod formation.

Data concerning thermal regime and precipitation recorded in 2014 at ARDS Turda highlighted that 2014 can be characterized as quite favorable for soybean crop in the reference area.

The biological material used consisted of 13 soybean cultivars of which 9 are creations of ARDS Turda and four are of foreign origin (Table 1).

Table 1. The list of soybean cultivars studied

No.	Cultivar	Source	Maturity group	Registration year	Genealogy
1	Diamant	ARDS Turda	000	1987	HI 464 x T - 1917
2	Perla	ARDS Turda	000	1994	GS 54/145 x Norchief
3	Safir	ARDS Turda	00	2000	HL 20 x Altona
4	Eugen	ARDS Turda	00	2002	Maple Arrow x Evans
5	Onix	ARDS Turda	00	2002	Maple Presto x Evans
6	Felix	ARDS Turda	00	2005	Maple Presto x Merit
7	Darina TD	ARDS Turda	00	2011	T93- 8966 x Amurskaja
8	Cristina TD	ARDS Turda	00	2012	Zefir x Lena
9	Mălina TD	ARDS Turda	00	2012	Amurskaja x Simson
10	Dekabig	USA	I	-	-
11	Asgrow	USA	I	-	-
12	Condor	Novi Sad Serbia	0	-	-
13	Balkan	Novi Sad Serbia	00	-	-

RESULTS AND DISCUSSION

The table of variance analysis for plant height (Table 2) shows that all four factors and the interaction year x genotype had a very significant positive influence on the height of the varieties studied. The genotype x distance between rows interaction had a distinctly significant influence and the triple interaction year x genotype x densities had a significant influence on this character. The other interactions studied did not have significant influence on height variation.

The influence of climatic conditions of the three experimental years on plant height can be seen in Table 3. The third year had a significant positive influence, as compared with the trial average.

Table 2. Analysis of variation for plant height (cm) in 13 soybean genotypes (Turda, 2012-2014)

No.	Source of variation	Sum of squares	DF	s^2	F
1	Total	283942.3	623		
2	Years (Y)	209058.3	2	104529.2	83.44***
3	Plant density (D)	1161.3	3	387.1	10.51***
4	Genotype (G)	24210.3	12	2017.5	21.31***
5	Row distance (H)	569.2	1	569.2	11.25***
6	Y x D	261.8	6	43.6	1.18
7	Y x G	16162.7	24	673.4	7.11***
8	D x G	1602.1	36	44.5	1.20
9	Y x G x D	4193.7	72	58.2	1.58*
10	G x H	1547.0	12	128.9	2.54**
11	D x H	29.7	3	9.9	0.19
12	Y x G x D x H	2494.3	72	34.6	0.68
13	Error y	2505.3	2	1252.6	
14	Error d	4306.3	117	36.8	
15	Error g	3408.0	36	94.6	
16	Error h	7893.0	156	50.6	

Table 3. Influence of experimental conditions on plant height (cm) in the studied soybean cultivars (Turda, 2012-2014)

Source of variation	Plant height (cm)	Trial average (cm)	%	Difference	Significance
Year					
A_1 - 2012	86.9	81.9	106	5.03	-
A_2 - 2013	57.4	81.9	70	-24.5	0
A_3 - 2014	101.4	81.9	124	19.48	*
			LSD p 5%	14.9	
			LSD p 1%	34.5	
			LSD p 0.1%	109.7	
Plant density					
D_1 - 30 g.s. m^{-2}	80.1	81.9	98	-1.82	00
D_2 - 45 g.s. m^{-2}	81.2	81.9	99	-0.69	-
D_3 - 60 g.s. m^{-2}	82.6	81.9	101	0.74	-
D_4 - 75 g.s. m^{-2}	83.6	81.9	102	1.77	*
			LSD p 5%	1.33	
			LSD p 1%	1.80	
			LSD p 0.1%	2.32	
Distance between rows					
H_1 - 50 cm	82.8	81.9	101	0.96	-
H_2 - 25 cm	80.9	81.9	99	-0.96	-
			LSD p 5%	1.13	
			LSD p 1%	1.49	
			LSD p 0.1%	1.91	

The 75 g.s. m^{-2} plant density had a significant positive influence on plant height, compared with the density of 30 g.s. m^{-2} which had a distinctly significant negative influence. The plant densities of 45 g.s. m^{-2} and 60 g.s. m^{-2} and also the two distances between rows examined did not have significant influence on the plants height.

Suitability for mechanized harvesting is an important target for breeding soybean programs, and a high insertion of the first basal pods is a key factor in this respect. Analysis of variance for the height of insertion of the first pods of soybean genotypes studied in three experimental years is shown in Table 4. The years, genotypes, densities and distances between rows as well as the interaction of these factors significantly influenced the variation of the insertion height of the first pod in the three experimental years.

Table 4. Analysis of variation for insertion height (cm) in 13 soybean genotypes (Turda, 2012-2014)

No.	Source of variation	Sum of squares	DF	s^2	F
1	Total	8095.46	623		
2	Years (Y)	128.31	2	64.16	162.07***
3	Plant density (D)	4150.72	3	1383.57	6064.69***
4	Genotype (G)	523.52	12	43.63	302.48***
5	Row distance (H)	67.35	1	67.35	392.75***
6	Y x D	69.64	6	11.61	50.88***
7	Y x G	1157.44	24	48.23	334.37***
8	D x G	239.63	36	6.66	29.18***
9	Y x G x D	533.94	72	7.42	32.51***
10	G x H	62.05	12	5.17	30.10***
11	D x H	49.17	3	16.39	95.586***
12	Y x G x D x H	640.26	72	8.89	
13	Error y	0.79	2		
14	Error d	26.69	117		
15	Error g	5.19	36		
16	Error h	26.75	156		

Only the 60 g.s. m^{-2} and 75 g.s. m^{-2} reached a value that can be considered suitable for mechanized harvesting (more then 12 cm). The very early cultivars Diamant and Perla reached 13 cm and 15 cm at the 60 g.s. m^{-2} respectively 15 cm and 17 cm at the 75 g.s. m^{-2}, most cultivars had an insertion height over 15 cm for the 60 g.s. m^{-2} and 75 g.s. m^{-2}, reaching a value of 20 cm (Asgrow) (Figure 1).

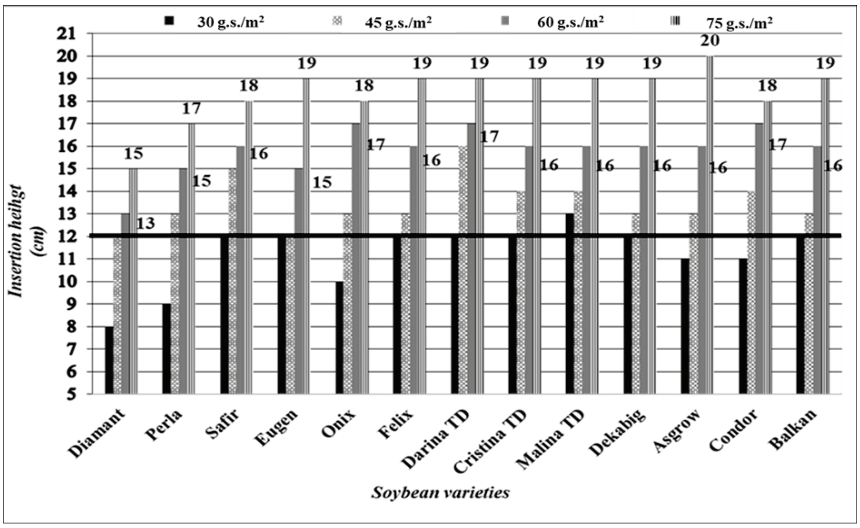

Figure 1. Influence of plant density and genotypes on insertion height in the studied soybean cultivars (Turda, 2012-2014)

The height of the first pod insertion increased directly proportional with the seeding density for all genotypes examined. First pod insertion height for mechanized harvesting with minimal losses must exceed 12 cm. In the studied cultivars this value was reached at the seeding densities of 60 g.s. m^{-2} and 75 g.s. m^{-2}.

Yielding capacity is a very complex trait, the result of a constellation of basic physiological and morphological of traits (Savatti et al., 2004). An important part of the yielding capacity is the number of pods/plant. Analysis of variance for this trait in the 13 studied soybean cultivars is presented in Table 5.

The factors: year, genotype and plant density had a very significant influence on the number of pods/plant. The interaction between genotype x plant density showed a distinctly significant influence and the interaction year x genotype indicated a significant influence on the character.

Table 5. Analysis of variation for number of pods/plant in 13 soybean cultivars (Turda, 2012-2014)

No	Source of variation	Sum of squares	DF	s^2	F
1	Total	95664.67	623		
2	Years (Y)	33380.87	2	16690.43	19.012***
3	Plant density (D)	1334.21	3	444.74	7.899***
4	Genotype (G)	5200.08	12	433.34	4.706***
5	Row distance (H)	1.25	1	1.25	0.041
6	Y x D	495.74	6	82.62	1.468
7	Y x G	3183.96	24	132.67	1.441*
8	D x G	4272.21	36	118.67	2.108**
9	Y x G x D	3806.59	72	52.87	0.939
10	G x H	185.41	12	15.45	0.510
11	D x H	121.31	3	40.43	1.335
12	Y x G x D x H	1583.75	72	21.99	0.726
13	Error y	18002.56	2	9001.28	
14	Error d	6587.25	117	56.30	
15	Error g	3314.62	36	92.07	
16	Error h	4726.00	156	30.29	

Regarding the effect of weather conditions during the experimental period on this character, from Table 6 it can be observed that the year 2014 was favourable for soybean crop, resulting in significant positive differences from the average of the three experimental years. In contrast, the second experimental year (2013) showed significant negative differences compared to the average 2012-2014.

The lowest density had a distinctly significantly positive influence on this character compared to control, while the highest plant density had a negative significant influence. The different row spacing did not influence the number of pods/plant.

Table 6. Influence of experimental conditions on the number of pods/plant in the 13 studied soybean cultivars (Turda, 2012-2014)

Source of variation	Number of pods/plant	Trial average	%	Difference	Significance
Year					
A_1 - 2012	30.2	29.7	101.9	0.56	-
A_2 - 2013	20.4	29.7	68.9	-9.22	0
A_3 - 2014	38.3	29.7	129.2	8.67	*
			LSD p 5% LSD p 1% LSD p 0.1%	4.00 9.28 19.39	
Plant density					
D_1 - 30 g.s. m^{-2}	31.7	29.7	106.8	2.01	**
D_2 - 45 g.s. m^{-2}	29.8	29.7	100.5	0.15	-
D_3 - 60 g.s. m^{-2}	29.6	29.7	99.8	-0.05	-
D_4 - 75 g.s. m^{-2}	27.5	29.7	92.9	-2.12	0
			LSD p 5% LSD p 1% LSD p 0.1%	1.68 2.00 2.87	
Distance between rows					
H_1 - 50 cm	29.71	29.67	100.2	0.04	-
H_2 - 25 cm	29.62	29.67	99.8	-0.04	-
			LSD p 5% LSD p 1% LSD p 0.1%	0.87 1.15 1.48	

An important component of yielding ability is the grain weight per plant. ANOVA for this trait is presented in Table 7.

The influence of climatic conditions of the three experimental years at ARDS Turda was very significant. A very significant influence had also the plant density and genotype factors and the interaction year x genotype, year x plant density and the triple interaction year x plant density x genotype. The other factors that involved the distance between rows did not have a significant influence on this character.

Table 8 shows a distinctly significant positive influence of the year (2014) on grain weight/plant, as well as a significant respectively a distinctly significant negative influence of the two experimental years (2012 and 2013) with unfavourable conditions for the expression of this character.

Plant densities had no significant influence on this character, except the highest density (75 g.s. m^{-2}), which had a significantly negative effect, when compared to the average of the trial.

The distance between rows did not significantly influence the grain weight per plant.

Table 7. Analysis of variation for seeds yield\plant (g) in 13 soybean cultivars (Turda, 2012-2014)

No.	Source of variation	Sum of squares	DF	s^2	F
1	Total	18724.64	623		
2	Years (Y)	11262.38	2	5631.19	1498.495***
3	Plant density (D)	94.55	3	31.52	5.828***
4	Genotype (G)	1520.07	12	126.67	17.122***
5	Row distance (H)	2.31	1	2.31	0.417
6	Y x D	370.79	6	61.80	11.428***
7	Y x G	937.82	24	39.08	5.282***
8	D x G	732.84	36	20.36	3.764***
9	Y x G x D	1183.21	72	16.43	3.039***
10	G x H	82.38	12	6.87	1.283
11	D x H	24.89	3	8.30	1.495
12	Y x G x D x H	319.13	72	4.43	0.798
13	Error y	7.52	2	3.76	
14	Error d	632.69	117	5.41	
15	Error g	266.33	36	7.39	
16	Error h	866.21	156	5.55	

Table 8. Influence of density and distance between rows on seeds yield\plant (g)
in the 13 studied soybean cultivars (Turda, 2012-2014)

Source of variation	Seed yield/plant (g./plant)	Trial average	%	Difference	Significance
Year					
A_1 - 2012	10.16	11.11	91.4	-0.95	0
A_2 - 2013	6.45	11.11	58.0	-4.66	00
A_3 - 2014	16.72	11.11	150.5	5.61	**
			LSD p 5%	0.82	
			LSD p 1%	1.89	
			LSD p 0.1%	6.01	
Plant density					
D_1 - 30 g.s. m^{-2}	11.32	11.11	101.9	0.21	-
D_2 - 45 g.s. m^{-2}	11.34	11.11	102.1	0.23	-
D_3 - 60 g.s. m^{-2}	11.34	11.11	102.1	0.23	-
D_4 - 75 g.s. m^{-2}	10.43	11.11	93.9	-0.67	0
			LSD p 5%	0.52	
			LSD p 1%	0.69	
			LSD p 0.1%	0.89	
Distance between rows					
H_1 - 50 cm	11.05	11.11	99.5	0.06	-
H_2 - 25 cm	11.17	11.11	101.1	0.12	-
			LSD p 5%	0.37	
			LSD p 1%	0.48	
			LSD p 0.1%	0.63	

The analysis of variance for grain yield/hectare of the 13 genotypes of soybean in the experimental years 2012, 2013 and 2014, four plant densities: 30, 45, 60 and 75 g.s. m^{-2} and two distances between rows: 50 and 25 cm are presented in Table 9.

The share of each factor and interaction on the variation of grain yield/ha can be seen in

Figure 2. The climatic conditions influenced very significantly (55.95%) and genotype, plant density, distance between rows had a lower but statistically significant influence (8.72%, 4.42% and 1.57%). The interaction between genotype and plant density contributed significantly (2.26%) to the grain yield variation. The interaction between plant density and row spacing had a statistically not significant effect of 1.09%.

Table 9. Analysis of variation for grain yield (kg ha^{-1}) in 13 soybean genotypes (Turda, 2012-2014)

No.	Source of variation	Sum of squares	DF	s^2	F
1	Total	182780200	623		
2	Years (Y)	102279500	2	51139760	1013.798***
3	Plant density (D)	8087693	3	2695898	80.690***
4	Genotype (G)	15941470	12	1328456	39.180***
5	Row distance (H)	2882113	1	2882113	89.333***
6	Y x D	1798798	6	299799.6	8.973***
7	Y x G	9977544	24	415731	12.261***
8	D x G	4131266	36	114757.4	3.435***
9	Y x G x D	9244075	72	128389.90	3.843***
10	G x H	1998472	12	166539.4	5.162***
11	D x H	120302.7	3	40100.89	1.243
12	Y x G x D x H	5120280	72	71114.99	2.204**
13	Error y	100887.4	2	50443.72	
14	Error d	3909031	117	33410.52	
15	Error g	1220622	36	33906.18	
16	Error h	5032961	156	32262.57	

High values of F test indicate very significant positive influences of most sources of variability for grain yield. A can be observed, the interaction of the four experimental factors had a distinctly significant influence, while the interaction plant density x distance between rows did not have a significant influence on recorded yield variation.

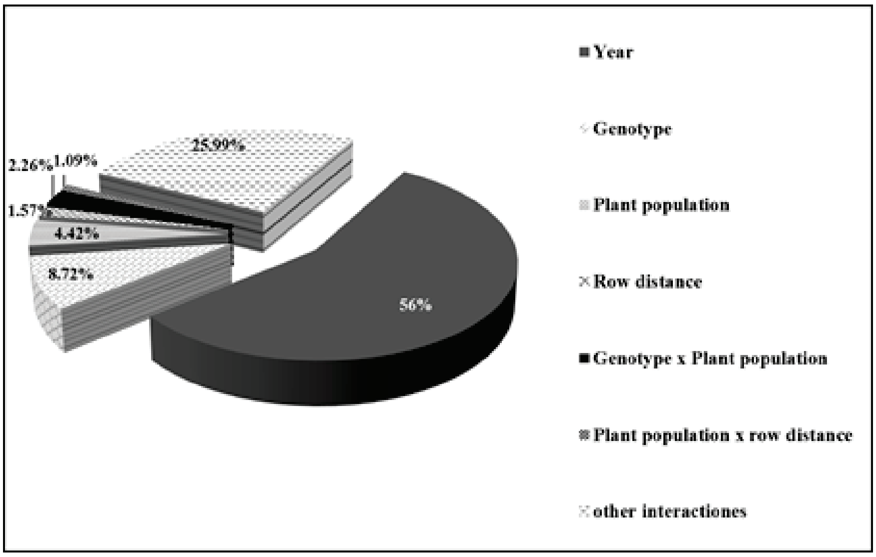

Figure 2. Factors contributing to the variation of yield (kg ha^{-1}) for the studied soybean cultivars (Turda, 2012-2014)

The third year was strongly different from the other two years, being the only one with significantly higher yield, compared with the average (Table 10).

As expected, the yield increased with increasing the plant density up to the 60 g.s. m^{-2}, but at the highest plant density a yield decline was recorded. The plant density of 60 g.s. m^{-2} produced the highest, positive significant differences compared to the trial average (approximately 10%).

Averaged on the three experimental years the distance of 25 cm between rows recorded a significantly higher yield, compared to the trial average.

The studied soybean varieties reacted differently to the four densities tested (Figure 3). The cultivar Safir that had a positive response to the highest density 70 g.s./m^{-2} with a yield of 1991 kg ha, was different from the very early cultivars like Diamant and Perla, which reacted positively to the lowest plant density (30 g.s./m^{-2}), by registering yields of 1706 kg and 1903 kg ha^{-1} respectively. The yield of variety Perla was significantly higher than the trial average. Malina TD reacted favourably to 45 g.s ha^{-1} plant density recording a high production of 2254 kg ha^{-1}, significantly higher than the trial average.

Most cultivars responded well to the plant density of 60 g.s. ha^{-1}, cultivars Felix, Onix and Asgrow, producing yields significantly higher than the average.

Table 10. Influence of experimental conditions on grain yield (kg ha^{-1}) in the studied soybean cultivars (Turda, 2012-2014)

Source of variance	Grain yield (kg ha^{-1})	Trial average (kg ha^{-1})	%	Difference	Significance
Year					
A_1 - 2012	1939	1932	100.4	6.99	-
A_2 - 2013	1433	1932	74.2	-499.3	00
A_3 - 2014	2425	1932	125.5	492.32	**
			LSD p 5%	95	
			LSD p 1%	219	
			LSD p 0.1%	696	
Plant density					
D_1 - 30 g.s. m^{-2}	1834	1932	94.9	-98.14	000
D_2 - 45 g.s. m^{-2}	1908	1932	98.7	-24.71	-
D_3 - 60 g.s. m^{-2}	2124	1932	109.9	191.92	***
D_4 - 75 g.s. m^{-2}	1863	1932	96.4	-69.06	00
			LSD p 5%	41	
			LSD p 1%	54	
			LSD p 0.1%	70	
Distance between rows					
H_1 - 50 cm	1865	1932	96.5	-67.96	000
H_2 - 25 cm	2000	1932	103.5	67.96	***
			LSD p 5%	28	
			LSD p 1%	38	
			LSD p 0.1%	49	

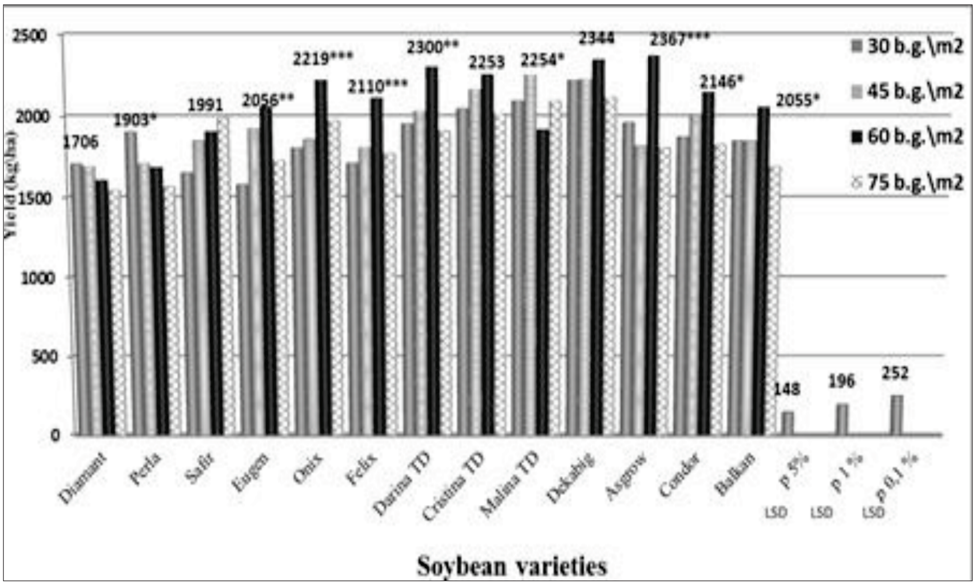

Figure 3. Influence of plant density and soybean genotypes on grain yield (kg ha^{-1})
(Turda, 2012-2014)

Numeric data represented in Figure 3 are the highest yields per unit area for each soybean variety studied.

CONCLUSIONS

The obtained results contribute to a better understanding of the response to different densities, as response to different competition between plants, in the soybean cultivars created at ARDS Turda.

Optimal seeding plant density should be determined taking into account the peculiarities of each genotype, i.e. the crop management has to be adapted for each cultivar. In the case of the soybean cultivars developed at Agricultural Research and Development Station Turda, the optimum density recommended at planting is 60 g.s. m^{-2}, to achieve a plant density at harvest of about 50 harvested plants m^{-2}. The required amount of seed is 80-100 kg ha^{-1} depending on the purity, germination and 1000 grain weight.

The A.R.D.S Turda cultivars gave good results in dense sowing (25 cm between rows). Sowing at such distance between rows is particularly recommended for weed clean land, because for this type of sowing weeds can only be done with the help of herbicides.

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