INFLUENCE OF STAND DENSITY ON YIELD AND QUALITY OF NS SUNFLOWER CONFECTIONARY HYBRIDS

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Abstract: *A two year field plot was conducted on experimental fields of Institute of field and vegetable crops in Novi Sad. The effect of stand density on seed yield, protein content and mass of 1000 seeds were researched. Old and new perspective confectionary sunflower hybrids of NS Seed Company were used. There were six stand densities, from 20000-70000 plants per hectare with increasing step of 10000. There were significant differences between hybrids and in both years the highest yield had new hybrid NS-H-6485. In average, for all 6 hybrids maximal seed yield in both years were at stand density between 40000-50000 plants per hectare. Protein content was higher in old hybrids (Vranac and Cepko) and gradually decreases with increasing stand density. Mass of 1000 seed, which is an important quality parameter, was higher in all new hybrids and in average for all stand density in both years was higher than 100 g. Hybrid NS-Goliat had especially large seed, even more than 150 g. Stand density had high influence on 1000 seed mass, and seed mass at the highest stand density was for approximately 50 % lower than at the lowest stand density in both years.*

Key word: *sunflower, confectionary hybrids, yield, protein content, seed mass*

INTRODUCTION

Non-oil type or confectionary sunflower seed is distinguished of standard oil type by bigger size of plants and seed, higher protein and lower oil content, better seed hullability because of thicker hull loosely connected to the kernel, as well as by different shell color and seed shape.. The most important criteria for production of confectionary hybrids are seed yield, protein content and 1000 seed mass. Larger size of seeds is desirable because they have higher market value. Unfortunately, production and research of confectionary sunflower in Serbia is very low. ZUBRISKI AND ZIMMERMAN (1974) found that seed yield of nonoil sunflower increased with increase in plant density from 28200 to 47800 plants ha^{-1}. ROBINSON et al. (1980) found that the minimum plant density required for maximum yield of nonoil sunflower ranged from 25 000 to 62 000 plants ha^{-1}, depending on location. They attributed the differing effects of plant density on yield among the six locations to soil, temperature and rainfall. Also optimum plant density is influenced by sunflower ability to compensate different plant densities through the number of seeds per head and seed weight. ROBINSON et al. (1980) found that nonoil and oilseed sunflower generally required the same plant densities for maximum yield, while ZUBRISKI AND ZIMMERMAN (1974) found that plant density for maximum yield of oilseed sunflower was greater than for nonoil sunflower. In deciding on an optimum plant density for nonoil sunflower, both seed yield and size must be considered. Since seed size decreases as plant density increases, it is desirable to aim for the plant density that will produce enough large seed without severely reducing overall yield (GUBBELS AND DEDIO, 1986).

According to BARROS et al (2004) for oil type sunflower the lowest plant density increased significantly the 1000 seed mass and seed yield was the highest with the medium plant density. Maximum seed yield and oil content at four oil sunflower hybrids were at 60000 plants ha^{-1} (CRNOBARAC et al., 2007). The aim of this study was to research hybrid specificity

of confectionery sunflower to plant density and to determine if plant densities could be reduced to increase seed size without reducing seed yield.

MATERIALS AND METHODS

Field plots were conducted in 2011-2012 on experimental field of Institute of field and vegetable crops in Novi Sad. The effect of plant density on seed yield, protein content and 1000 seed mass were researched on six NS-seed hybrids of confectionary sunflower. (NS-goliat, NS-slatki, NS-gricko, NS-H-6485, NS-vranac, NS-cepko). The hybrids were sown on six plant densities, from 20000-70000 plants per hectare with increasing step of 10000. Design of trial was a split plot, where hybrids were on whole plot and density on subplot level. Plots consisted of six rows 10 m long with70 cm between rows. Two-three seeds per hill were seeded and after emergence the seedlings were thinned to the appropriate stands. The two center rows were used for data collection. After harvest, the moisture was measured and yield calculated at 9 % moisture. Data was processed by ANOVA and regression analysis.

RESULTS AND DISCUSSION

The influence of year on all traits was high significant ($p<0.01$) and accounted from 5.6-54.9% of total variability (Table 1). The lowest part of variability was on 1000 seed mass and the highest on protein content. The influence of genotype on all traits also was highly significant and accounted from 19.2-60.5% of total variability. The lowest influence of genotype was on seed yield and the highest on 1000 seed mass. The influence of plant density also was highly significant for all traits, but partitioning in total variability was lower than year or genotype. The lowest influence of density was on protein content (8.5%) and the highest on 1000 seed mass (29.4%). All double interaction in all traits were significant, but the highest partition in total variability, above 10% had interactions Y x G and D x G in seed yield. Triple interactions were significant in protein content and 1000 seed mass, while in seed yield triple interaction was nonsignificant.

Table 1.

Partitioning of the treatment sums of squares and significances derived from the ANOVA

Source of variation	df	Planting dates trial		
		Seed yield	Protein content	Mass of 1000 seed
Year (Y)	1	32.7**	54.9**	5.6**
Genotype (G)	5	19.2**	26.9**	60.5**
Y x G	5	10.1**	0.7**	1.5**
Plant density (D)	5	15.1**	8.5**	29.4**
D x Y	5	1.9*	0.3**	0.2**
D x G	25	17.0**	5.4**	2.2**
D x G x Y	25	3.9ns	3.2**	0.5**

** Indicates significance at $p < 0.01$ * Indicates significance at $p < 0.05$ ns - nonsignificant.

In average for all others treatments if we look only year, in 2012 was significantly higher yield than in 2011, difference was 0.57 tha^{-1}(Tab.2). In average for all others treatments if we look only hybrid, hybrids NS-H-6485 and NS-gricko had significantly higher yield than all other hybrids, which had very similar yield. In both year the highest yield had hybrid NS-H-6485 and second was hybrid NS-gricko, which only in 2012 had significantly lower yield than former.

In average for all others treatments if we look only plant density yield significantly increase with plant density till to 40000 plants per hectare. The highest yield (4.21 tha^{-1}) was at 50000 plants per hectare and after that yield start to decrease and on density of 70000 plants

seed yield was even significantly lower than on 40000 plants per hectare. Similar influence of plant density was in both researched year. In 2011 significantly lower yield was only at minimal and maximal plant density, while between 30000-60000 plants there were no significant differences. In 2012 the highest yield was at 50000 plants which were significantly higher than yield at 20000 and 30000 plants. Between plant densities from 40000 to 70000 plants per hectare there were no significant differences. For agronomists is very interesting to monitor the impact of density for each hybrid, based on average for two or more years. In this research hybrid NS-goliat significantly increase yield till to plant density of 60000 plants per hectare. Hybrid NS-gricko till to 50000, and hybrids NS-slatki, NS-H-6485 and NS-vranac till to 40000 plants per hectare. Opposite to other, hybrid NS-cepko not significantly increasing yield with increasing plant density.

Table 2.

The effect of plant density and hybrids in two years, on seed yield of confectionery sunflower

Year (Y)	Hibryds (H)	Plant density (D)						Average Y*H	Average Y
		20	30	40	50	60	70		
2011	NS-goliat	2.94	4.02	3.70	4.04	4.12	3.75	**3.76**	**3.72**
	NS-slatki	2.77	3.13	3.50	3.70	3.39	2.93	**3.24**	
	NS-gricko	3.74	3.97	4.18	4.53	3.90	3.29	**3.93**	
	NS-H-6485	3.32	3.90	4.39	4.09	4.38	4.11	**4.03**	
	NS-vranac	3.65	3.80	4.11	3.25	3.23	3.23	**3.55**	
	NS-cepko	3.74	3.77	3.86	3.90	3.94	3.54	**3.79**	
	Average Y*D	**3.36**	**3.77**	**3.96**	**3.92**	**3.83**	**3.47**		
2012	NS-goliat	3.49	3.60	4.21	4.24	4.33	4.26	**4.02**	**4.29**
	NS-slatki	3.79	4.19	4.53	4.56	4.57	4.41	**4.34**	
	NS-gricko	4.31	4.48	4.24	4.84	4.38	4.31	**4.43**	
	NS-H-6485	3.94	4.69	4.88	5.16	4.93	5.05	**4.77**	
	NS-vranac	4.18	4.42	4.39	3.99	4.10	4.14	**4.20**	
	NS-cepko	3.75	4.12	3.88	4.19	4.03	3.71	**3.95**	
	Average Y*D	**3.91**	**4.25**	**4.35**	**4.50**	**4.39**	**4.31**	**Average H**	
Average H*D	NS-goliat	3.21	3.81	3.95	4.14	4.22	4.00	**3.89**	
	NS-slatki	3.28	3.66	4.01	4.13	3.98	3.67	**3.79**	
	NS-gricko	4.03	4.22	4.21	4.68	4.14	3.80	**4.18**	
	NS-H-6485	3.63	4.29	4.63	4.62	4.66	4.58	**4.40**	
	NS-vranac	3.91	4.11	4.25	3.62	3.66	3.68	**3.87**	
	NS-cepko	3.74	3.95	3.87	4.04	3.99	3.62	**3.87**	
	Average D	**3.63**	**4.01**	**4.16**	**4.21**	**4.11**	**3.89**		

LSD	Y	H	D	Y*H	Y*D	H*D	Y*D*D
1%	0.18	0.32	0.16	0.45	0.27	0.46	0.66
5%	0.14	0.24	0.12	0.33	0.20	0.35	0.50

Like oil content for common oil type of sunflower, for confectionery sunflower protein content is main quality indicator. In average for all other treatments if we look only year, in 2011 was significantly higher protein content than in 2012, difference was 3.29% (Tab.3) and it was opposite to seed yield. In average for all others treatments if we look only hybrid, old hybrids NS-cepko and NS-vranac had significantly higher protein content than all other new hybrids. The lowest content of 15.25% and 15.29% had hybrids NS-goliat and NS-H-6485, respectively, while hybrids NS-slatki and NS-gricko were between these two groups. In both investigated year order of hybrids was the same like on average.

In average for all others treatments if we look only plant density protein content significantly decrease with increasing plant density till to 60000 plants per hectare. At 20000

plants per hectare was 17.85% and at 60000 plants only 16.01%. There were strong linear regression (r = 0.94) and protein content regularly decrease 0.35% for each increasing density for 10000 plants. Similar influence of plant density was in both researched year, but protein content significantly decreased only to 50000 plants per hectare. In two way interactions of density and hybrid, there were no so obviously dependence of protein content and plant density like in other interaction. Mainly the lowest protein content was at higher plant density, with exception of hybrid NS-vranac where with increasing plant density not changed protein content.

Table 3.

The effect of plant density and hybrids in two years, on protein content of confectionery sunflower

Year (Y)	Hibryds (H)	Plant density (D)						Average Y*H	Average Y
		20	**30**	**40**	**50**	**60**	**70**		
2011	NS-goliat	17.58	18.02	16.91	17.49	16.18	17.57	**17.29**	**18.31**
	NS-slatki	17.99	18.65	20.09	18.27	16.66	17.83	**18.25**	
	NS-gricko	20.78	19.16	17.63	17.12	17.67	17.67	**18.34**	
	NS-H-6485	18.70	18.11	17.25	16.43	16.09	15.03	**16.93**	
	NS-vranac	19.12	18.37	19.99	18.60	19.96	18.97	**19.17**	
	NS-cepko	22.59	18.52	21.02	19.38	19.24	18.71	**19.91**	
	Average Y*D	**19.46**	**18.47**	**18.81**	**17.88**	**17.63**	**17.63**		
	NS-goliat	14.08	13.11	13.33	13.03	12.76	12.91	**13.20**	**15.02**
	NS-slatki	16.39	16.24	14.82	15.11	13.34	14.08	**15.00**	
	NS-gricko	16.98	15.47	15.46	14.57	14.38	14.61	**15.24**	
	NS-H-6485	15.37	14.32	13.42	12.72	13.11	12.93	**13.64**	
	NS-vranac	16.71	16.46	15.87	15.85	15.99	15.82	**16.11**	
	NS-cepko	17.92	17.10	16.92	16.55	16.77	16.40	**16.94**	
	Average Y*D	**16.24**	**15.45**	**14.97**	**14.64**	**14.39**	**14.46**	**Average H**	
Average H*D	NS-goliat	15.83	15.57	15.12	15.26	14.47	15.24	**15.25**	
	NS-slatki	17.19	17.45	17.45	16.69	15.00	15.95	**16.62**	
	NS-gricko	18.88	17.31	16.54	15.85	16.02	16.14	**16.79**	
	NS-H-6485	17.03	16.21	15.33	14.57	14.60	13.98	**15.29**	
	NS-vranac	17.91	17.42	17.93	17.22	17.98	17.39	**17.64**	
	NS-cepko	20.25	17.81	18.97	17.96	18.01	17.56	**18.43**	
Average D		**17.85**	**16.96**	**16.89**	**16.26**	**16.01**	**16.04**		

LSD	Y	H	D	Y*H	Y*D	H*D	Y*D*D
1%	0.15	0.26	0.25	0.37	0.35	0.60	0.85
5%	0.11	0.20	0.19	0.28	0.26	0.46	0.65

In average for all others treatments if we look only year, in 2011 was significantly higher seed mass than in 2012, difference was 11,18g (Tab.4) and it was opposite to seed yield. In average for all others treatments if we look only hybrid, all new hybrids had average 1000 seed mass higher than 110g and even hybrid NS-goliat had 126,5g. Old hybrids were billow 100g, NS-cepko and NS- vranac had 82.86 and 77.85g, respectively. In both years the biggest seed had hybrid NS-goliat and all other new hybrid even in 2012 year had seed mass near 110g. Old hybrids in 2011 had seed mass from 80-90 and in 2012 from 70-80g.

In average for all others treatments if we look only plant density seed mass significantly and regularly decrease with increasing plant density. The biggest seed of 127.35g was at 20000 plants per hectare and the lowest of only 90.65 was at the highest plant density of 70000 plants. There were strong linear regression (r = 0.98) and regression coefficient was 7.33, it means that seed mass regularly decrease 7.33g for each increasing density for 10000 plants. Similar influence of plant density was in both researched year. In 2011 significantly

lower yield was only to the 60000 plant per hectare, while in 2012 the seed mass regularly decreased till to maximum plant density of 70000 plants per hectare. In two way interactions of density and hybrid, also new hybrids separate from old. For new hybrids significant decreasing of seed mass with increasing plant density were till to 60000 plants and for old hybrids only to 40000 or 50000 plants per hectare. It means that new or hybrids with bigger seed are more sensitive to higher plant density, but hybrids NS-goliat and NS-gricko had market requested seed mass over 100g even at the highest plant density of 70000 plants per hectare.

Table 4.

The effect of plant density and hybrids in two years, on 1000 seed mass of confectionery sunflower

Year (Y)	Hibryds (H)	Plant density (D)						Average Y*H	Average Y
		20	30	40	50	60	70		
2011	NS-goliat	158.71	147.50	136.25	128.74	116.90	116.13	**134.04**	**111.07**
	NS-slatki	145.38	133.54	124.63	116.98	103.00	103.00	**121.09**	
	NS-gricko	157.65	142.49	123.80	119.64	112.13	111.09	**127.80**	
	NS-H-6485	141.38	127.14	116.28	105.18	96.13	94.15	**113.37**	
	NS-vranac	94.24	88.23	82.25	76.84	78.25	78.34	**83.02**	
	NS-cepko	108.40	97.53	86.90	79.79	77.39	72.58	**87.10**	
	Average Y*D	**134.29**	**122.74**	**111.68**	**104.53**	**97.30**	**95.88**		
2012	NS-goliat	143.37	126.56	119.93	111.27	109.13	102.89	**118.86**	**99.89**
	NS-slatki	133.39	118.00	115.03	105.74	94.17	90.66	**109.50**	
	NS-gricko	126.57	116.07	113.40	100.10	96.47	94.34	**107.82**	
	NS-H-6485	139.84	125.68	109.70	105.66	98.59	92.82	**112.05**	
	NS-vranac	86.15	76.30	73.31	69.01	66.72	64.62	**72.68**	
	NS-cepko	93.09	86.30	78.03	74.33	71.62	67.19	**78.43**	
	Average Y*D	**120.40**	**108.15**	**101.57**	**94.35**	**89.45**	**85.42**	**Average H**	
Average H*D	NS-goliat	151.04	137.03	128.09	120.00	113.02	109.51	**126.45**	
	NS-slatki	139.38	125.77	119.83	111.36	98.59	96.83	**115.29**	
	NS-gricko	142.11	129.28	118.60	109.87	104.30	102.71	**117.81**	
	NS-H-6485	140.61	126.41	112.99	105.42	97.36	93.48	**112.71**	
	NS-vranac	90.19	82.26	77.78	72.92	72.49	71.48	**77.85**	
	NS-cepko	100.75	91.91	82.47	77.06	74.50	69.88	**82.76**	
Average D		**127.35**	**115.44**	**106.63**	**99.44**	**93.37**	**90.65**		

LSD	Y	H	D	Y*H	Y*D	H*D	Y*D*D
1%	2.27	3.94	2.08	5.57	3.45	5.97	8.44
5%	1.69	2.92	1.57	4.13	2.61	4.52	6.39

CONCLUSIONS

According to yield and quality of confectionery sunflower in Serbia,

New NS confectionery hybrids have higher yield and 1000 seed mass, but lower protein content than old hybrids.

Seed yield follow quadratic curve, increase with increasing plant density till to maximum and after that decrease.

Protein content and 1000 seed mass linearly decrease with increasing plant density. With increasing density for each 10000 plant decreases were 0.35% and 7.33g, respectively.

The highest influences on seed yield and protein content had year, while genotype had on 1000 seed mass. Plant density had the highest influence on 1000 seed mass.

NS confectionery sunflower hybrid had high specificity to plant density. According to simultaneously influence on yield and quality (protein content and seed size) it could made next recommendations. Optimal density for old hybrids is around 30000-40000 plants per acre,

with yield of around 4 tha^{-1} and protein content of 17-18%, but low 1000 seed mass (80-90g). For new hybrids optimal densities are higher around 50000 plants with yield of around 4.4 tha^{-1} and 1000 seed mass above 110 g, but lower protein content of 16-17%.

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