Journal of Agricultural Sciences
Vol. 45, No 1, 2000
Pages 19-27

UDC: 633.63:632.3
Original scientific paper

EFFECTS OF CROP DENSITY ON ROOT YIELD AND QUALITY OF SUGAR BEET CULTIVARS GROWN ON THE SOIL INFESTED AND UNINFESTED BY RHIZOMANIA

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Abstract: During a two-year period (1996-1997) we conducted studies on the effects of crop density on root yield and quality of sugar beet cultivars, susceptible and tolerant to rhizomania, grown on the soil infested and uninfested by this pathogen. The results obtained are of importance for both agricultural science and practice. The highest difference in sugar beet studied characteristics was achieved between infested and uninfested soil, between tolerant and susceptible cultivars, and the lowest between crop densities.

On the soil infested by rhizomania, on average, root yield was lower by 22.84 t/ha, sugar content by 2.49%, crystal sugar yield by 4.64 t/ha per cultivar and crop density.

Tolerant cultivar KWS rama produced higher root and sugar yields on both infested and uninfested soil. However, susceptible cultivars Al omona and Delta, grown on uninfested soil, had higher sugar content in sugar beet root by 0.53%.

Increased crop density resulted in higher root and sugar yields, however, considerably higher in the tolerant cultivar and on soil infested by rhizomania.

Key words: sugar beet, cultivar, rhizomania, crop density, root yield, sugar content, crystal sugar yield.

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Introduction

The effects of crop density on sugar beet yield and quality have been studied by many authors worldwide and in this country. Throughout the history of this plant growing, crop density was substantially changed. In the beginning, when sugar beet was grown for industrial procesing, it was thought that optimal density should be 200,000 - 250,000 plants per hectare. During the 1880s as animals replaced manual work, the number of plants per hectare was reduced to approximately one half. Crop density was further decreased after the introduction of new cultivars, modern farm machinery and cultural practices. In his detailed studies, Stanaćev (1979) emphasized that 60,000 plants per hectare is the lowest possible crop density. Safe yield will be obtained if crop density is 80,000-100,000 plants/ha at the time of sugar beet harvest (Lüdecke, 1953; Brykczynska, 1960; Maksimović et al. 1994).

The effects of crop density are largely dependent on soil fertility, climate conditions, amounts of precipitation in particular, time and quality of sowing. In fertile soils, where cultural practicies were applied, root yield slightly differed in crop densities ranging from 60,000-75,000 plants/ha, or was even higher than that obtained at variants with greater crop density (Haendschke, 1962). During dry seasons sugar beet produced higher root yield at greater crop densities and, conversely, under wet and irrigation conditions variants with lower crop density produced higher root yield (Hoble, 1952; Nenadić, 1994; Maksimović et al. 1994). According to data reported by Schulz et al. (1962), in Germany higher root yield was achieved by a combination of lower crop density (65,000 plants/ha), but only at early sowing dates. Lower crop density is also advantageous when equidistance between plants in a row is achieved (Kovačević et al., 1963; Sarić and Nenadić, 1983; Sarić, 1985; Nenadić et al., 1990).

All the above mentioned data about the effects of crop density on sugar beet productivity pertained to the results achieved when there was no occurence of rhizomania during sugar beet cultivation. With us very few data are available on the effects of crop density on sugar beet yield and quality, grown on the soils infested by rhizomania. However, the occurrence of rhizomania one of the most destructive sugar beet diseases, caused reduced production of this plant. Sugar beet was sown on smaller areas, and average root yield and sugar content, thereby sugar yield, were reduced. Rhizomania does a lot of harm to sugar beet: it reduces root yield by 50-80%, sugar content by 3-4 and more per cent, crystal sugar yield by 37-50 and more per cent (Šutić, et al. 1978; Rožić, 1984; Milovanović, 1989; Škrbić, 1994; Gujančić, 1996; Nenadić et al., 1996), and according to some data (Veselinović et al., 1987) it may completely destroy sugar beet crop.

On infested soils in the Srem region (Škrbić, 1994; Milovanović, 1995) and southern Banat region (Nenadić et al., 1998) root yield varied from 17.3 - 26.2 t/ha in susceptible cultivars and from 57.6 - 77.1 t/ha in tolerant ones.

The aforementioned data indicate that sugar beet can be grown succesfully

in our country, even under conditions of infection by rhizomania, however, only tolerant cultivars should be sown. All other measures are less effective.

Material and Method

Studies on the effects of crop density on root yield and quality of sugar beet cultivars (susceptible and tolerant to rhizomania) were conducted during two-year period (1996-1997) in Sremska Mitrovica on the soil infested and uninfested by rhizomania. In both cases the soil was of carbonated chernozem type. Its properties at a 0-60-cm depth were as follows: pH (in KCl) 7.1 - 7.7; $CaCO_3$ content 4.5 - 8.8%; humus content 2.0 - 3.0%; P_2O_2 12.8 - 20.7 mg and K_2O 19.2 - 30.3 mg, respectively , per 100 g of soil.

Our studies comprised three factors:

I. Crop density	II. Cultivar	III. Soil
1. 60,000 plants/ha	1. A1 omona and Delta (susceptible to rhizomania)	1. Infested by rhizomania
2. 80,000 plants/ha	2. KWS rama (tolerant to rhizomania)	2. Uninfested by rhizomania
3. 100,000 plants/ha		

Wheat was a previous crop. Basic and pre-sowing soil tillage as well as the care of the crop was performed in a standard manner as employed for regular sugar beet production. The following amounts of fertilizers were applied: 100 kg P_2O_2 per hectare, 150 kg K_2O per hectare and 50-150 kg N per hectare (average results for three variants of N fertilization were used in the present paper). Seeds were planted in late March with a pneumatic drill in rows spaced 50 cm apart, the distance between seeds in a row being 6 cm. Three crop densities were formed by thinning after seeds sprouted.

Field micro-trials were conducted using a randomized block system design in four replicates. The size of the main plot was 20 m^2 (10 x 2 m).

Meteorological conditions during study years

The basic meteorological data show that during study years conditions of heat and humidity differed a little throughout sugar beet vegetative period. In addition, during study years, heat conditions were also slightly different from those in a several years' period. However, the amounts of precipitation during study years, particularly in June and July, were lower than several years average.

Tab. 1. - Mean monthly air temperature and amounts of precipitation during sugar beet vegetative period in Sremska Mitrovica

Year	Months							
	IV	V	VI	VII	VIII	IX	X	
	Temperatures, °C							Average
1966	11.3	18.0	20.6	19.6	20.8	12.9	11.6	16.1
1997	7.3	17.4	20.8	20.7	20.9	16.6	9.8	16.2
Average	9.3	17.7	20.7	20.1	20.8	14.7	10.7	
1948-1986	11.5	16.4	19.5	20.8	20.4	16.6	11.2	16.6
	Amount of precipitation, mm							Sum
1996	32	54	62	18	68	97	39	370
1997	63	31	39	56	44	20	100	353
Average	47.5	42.5	50.5	37	56	58.5	69.5	
1948-1986	51	61	89	66	53	42	42	404

Results and Discussion

Studies were conducted on the effects of crop density on root yield and quality of sugar beet cultivars on the soil where *Rhizomania* persisted for a number of years. Studies were also cunducted on the soil where *Rhizomania* was not found prior to the establishment of the trial because sugar beet had not been grown on it before. The effects of the said factors on root yield, sugar content and crystal sugar yield were studied.

Root yield

Table 2. shows that the factors studied greatly affected root yield level as evidenced in our earlier studies (Škrbić, 1994; Nenadić et al., 1998) and reports by the authors (Milovanović, 1995; Gujančić, 1996). On the soil infested by rhizomania, root yield was, on average, lower by 22.84 t/ha in both cultivar groups and crop density variants than on the soil free from rhizomania infection.

On infested soil, root yield was reduced by 30.94 t/ha in cultivars (Al omona nad Delta) susceptible to rhizomania, while that in the tolerant cultivar KWS rama was lower by 14.73 t/ha.

On both infested and uninfested soil tolerant cultivar KWS rama produced higher root yield than susceptible cultivars. On average, cultivar KWS rama produced higher root yield by 27.23% on both soils and in both variants of crop density.

In combination of the greatest crop density (100,000 plants/ha) a considerably higher root yield was achieved. In the said crop density root yield was, on average, higher by 10.98% on both soils: in cultivar KWS rama it was higher by 19.66% and in susceptible cultivars by 1.05% compared with the lowest crop density. Accordingly, there was a stronger response to crop density increase in the tolerant cultivar than in susceptible ones.

Tab. 2. - Effects of crop density on sugar beet root yield (t/ha) during 1996-1997

A	B	C			A*B		A	
Cultivar	Soil and rhizomania	Crop density in 000 plants 60	80	100	Average	Index	Average	Index
Al omona and Delta	Uninfested	65,03	67,16	68,88	67.02	100.00	51.55	100,00
	Infested	37,47	36,06	34,70	36.08	53.83		
Average A*C		51,25	51,61	51,79				
Index		100,00	100,70	101,05				
KWS rama	Uninfested	71,68	72,72	74,49	72.96	100.00	65.59	127.23
	Infested	45,18	64,14	65,36	58.23	79.81		
Average A*C		58,43	68,43	69,92				
Index		100,00	117,11	119,66			Average B	
Average B*C	Uninfested	68,35	69,94	71,68		69.99		100.00
	Infested	41,32	50,10	50,03		47.15		69.37
Average C		54,83	60,02	60,85				
Index		100,00	109,46	110,98				

LSD	A	B	C	A*B	A*C	B*C	A*B*C
0.05	1.40	1.65	2.25	1.68	2.46	2.87	4.08
0.01	1.87	2.21	3.02	2.25	3.29	3.84	5.47

Sugar content

The results of studies on the effects of the examined factors on sugar per cent in sugar beet root are given in Tab. 3. The data show that crop density did not have any considerable effect on this property of sugar beet as evidenced by many earlier studies (Sarić and Nenadić, 1983; Sarić, 1985; Nenadić et al., 1990; Škrbić 1994). Cultivar KWS rama, tolerant to rhizomania, achieved in both soils, on average, higher sugar content by 1.77 index points than susceptible cultivars. In addition, this cultivar had higher sugar content by 1.10% on infested soil and per average crop density, and sugar content lower by 0.53% on uninfested soil compared with susceptible cultivars Al omona and Delta.

Rhizomania had the highest effect on sugar content in sugar beet root. On the soil infested by this pathogen, sugar content was lower by 2.49% per average crop density and cultivar. In tolerant cultivar KWS rama sugar content was lower by 1.68% and by 3.31% in susceptible cultivars Al omona and Delta. Identical or even higher differences were reported by many authors (Škrbić, 1994; Milovanović, 1995; Gujaničić, 1996, Nenadić et al., 1998).

Tab. 3. - Effects of crop density on sugar content (%) in sugar beet root during 1996-1997

A	B	C			A*B		A	
Cultivar	Soil and rhizomania	Crop density in 000/ha plants 60	80	100	Average	Index	Average	Index
A1 omona	Uninfested	17,72	18,05	18,28	18.02	100.00	16.36	100.00
and Delta	Infested	14,57	14,97	14,60	14.71	81.63		
Average A*C		16.14	16,51	16.44				
Index		100,00	102,29	101,86				
KWS	Uninfested	17,58	17,43	17,46	17.49	100.00	16.65	101.77
rama	Infested	15,57	15,83	16,02	15.81	90.39		
Average A*C		16,57	16,63	16,74				
Index		100,00	100,36	101,02		Average B		
Average	Uninfested	17,65	17,74	17,87		17.75	100.00	
B*C	Infested	15,07	15,40	15,31		15.26	85.97	
Average C		16,36	16,57	16,57				
Index		100,00	101,28	101,28				

LSD	A	B	C	A*B	A*C	B*C	A*B*C
0.05	0.16	0.23	0.32	0.21	0.28	0.41	0.53
0.01	0.21	0.31	0.43	0.28	0.37	0.55	0.71

Crystal sugar yield

It is evident from Tab. 4. that crystal sugar yield varied per variant of crop density, cultivar and soil like root yield did. On the soil infested by rhizomania, root yield was lower by 4.64 t/ha per average variant of crop density and cultivar. In the tolerant cultivar it was lower by 3.21 t/ha and in susceptible cultivars by 6.07 t/ha than on rhizomania-free soil.

Tolerant cultivar KWS rama produced higher crystal sugar yield on both infested and uninfested soil. In this cultivar average crystal sugar yield was higher by 26.03% than in susceptible cultivars. In addition, it should be pointed out that crop density highly affected crystal sugar yield increase in cultivar KWS rama. Namely, in this cultivar, in combinations of the greatest crop density (100,000 plants/ha) sugar yield was higher by 19.74% than in the variant of the lowest crop density (60,000 plants/ha). In susceptible cultivars sugar yield increase amounted to 2.02% as effected by crop density.

In combinations of crop density ranging from 80,000-100,000 plants/ha average crystal sugar yield (average per cultivar and both soils) was higher by 10.11 - 10.87% at the lowest crop density (60,000 plants/ha).

Tab. 4. - Effects of crop density on crystal sugar yield (t/ha) during 1996-1997

A	B	C			A*B		A	
Cultivar	Soil and rhizomania	Crop density in 000 plants 60	80	100	Average	Index	Average	Index
A1 omona and Delta	Uninfested	10,32	10,55	10,71	10.53	100.00	7.49	100.00
	Infested	4,53	4,59	4,25	4.46	42.35		
Average A*C		7,42	7,57	7,48				
Index		100,00	102,02	100,81				
KWS rama	Uninfested	10,87	11,03	11,26	11.05	100.00	9.44	126.03
	Infested	5,95	8,68	8,89	7.84	70.95		
Average A*C		8,41	9,85	10,07				
Index		100,00	117,12	119,74		Average B		
Average B*C	Uninfested	10,59	10,79	10,98		10.79	100.00	
	Infested	5,24	6,63	6,57		6.15	56.99	
Average C		7,91	8,71	8,77				
Index		100,00	110,11	110,87				

LSD	A	B	C	A*B	A*C	B*C	A*B*C
0.05	0.24	0.27	0.40	0.27	0.38	0.50	0.67
0.01	0.32	0.36	0.54	0.36	0.50	0.67	0.89

Conclusion

The results of studies on the effects of crop density on root yield and quailty of sugar beet cultivars grown on the soils infested and uninfested by rhizomania lead to the conclusions as follows:

Soil, i.e. the presence of rhizomania in it, had the highest effects on root yield, sugar content and crystal sugar yield. In infested soil, susceptible cultivars (A1 omona and Delta) produced root yield lower by 30.94% t/ha, sugar content by 3.31% and crystal sugar yield by 6.07%. In this soil, root yield lower by 22.84 t/ha, sugar content by 2.495, crystal sugar yield by 4.64 t/ha was achieved per average cultivar and crop density.

Tolerant cultivar KWS rama produced higher root and sugar yields on both infested and uninfested soil. However, susceptible cultivars A1 omona and Delta grown on uninfested soil had higher sugar content in root by 0,53%.

With increased crop density root and sugar yields were increased, the differences being also considerably higher in the tolerant cultivar on the soil infested by rhizomania.

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Received March 23, 2000
Accepted April 24, 2000

UTICAJ GUSTINE USEVA NA PRINOS I KVALITET KORENA SORATA ŠEĆERNE REPE GAJENIH NA ZARAŽENOM I NEZARAŽENOM ZEMLJIŠTU RIZOMANIJOM

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Rezime

U dvogodišnjem periodu (1996-1997) vršena su istraživanja uticaja gustine useva na prinos i kvalitet korena sorata šećerne repe, osetljivih i tolerantnih na rizomaniju, gajenih na zemljištu zaraženom i nezaraženom rizomanijom. Ogledi su izvedeni u Sremskoj Mitrovici na zemljištu tipa karbonatni černozem.

U ovim istraživanjima su proučavana tri faktora i to: (A) sorta (Al omona i Delta - osetljive na rizomaniju i KWS rama tolerantna na ovu bolest); (B) zemljište (zaraženo i nezaraženo rizomanijom) i (C) gustina useva (60, 80 i 100 hiljada biljaka po hektaru).

U istraživanjima su postignuti sledeći važniji rezultati:

Najveći uticaj na prinos korena, sadržaj šećera i prinos kristalnog šećera ispoljilo je zemljište, odnosno prisustvo u njemu patogena rizomanije. Na ovakvom zemljištu prinos korena, osetljivih sorata (Al omona i Delta), bio je manji za 30,94 t/ha; sadržaj šećera u korenu za 3,31% a prinos kristalnog šećera za 6,07 t/ha.

Tolerantna sorta KWS rama postigla je veći prinos korena i šećera kako na zaraženom tako i nezaraženom zemljištu. Međutim, osetljive sorte Al omona i Delta imale su za 0,53% veći sadržaj šećera u korenu repe gajene na nezaraženom zemljištu.

Sa povećanjem gustine useva povećan je prinos i korena i šećera, ali znatno više kod tolerantne sorte kao i na zemljištu zaraženom rizomanijom.

Primljeno 23. marta 2000.
Odobreno 24. aprila 2000.

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