EFFECTS OF NPK RATES AND RATIO ON SUGAR BEET YIELD AND QUALITY

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ABSTRACT: Small plot trials were conducted at the experimental fields of the Institute Tamis, Pancevo, on the lime chernozem soil type over the period 1998-2003. There were 19 variants in the trial in addition to the control. The NPK amounts ranged from 50 to 130 kg/ha and were used in various ratios. The highest average sugar beet yield was obtained using 100 kg/ha of NPK (59,97 t/ha). The increase amounted to 47,9% compared with the control variant. The average sugar content in the root ranged from 13,67 ($N_{130}P_{50}K_{50}$) to 14,45% ($N_0P_0K_{100}$) and sugar use from 11,05 ($N_{130}P_{50}K_{50}$) to 12,09% ($N_{50}P_{100}K_{100}$). The highest average consumable sugar yield was registered using the following fertilizer variant N_{100} $P_{100}K_{100}$ (6.98 t/ha) and $N_{100}P_{100}K_{50}$ (6.81 t/ha). Root yield and consumable sugar yield were greatly affected by the humidity during the sugar beet vegetation period.

***Key words**:* sugar beet, NPK, root yield, sugar digestion, sugar use, consumable sugar.

INTRODUCTION

Determining optimal mineral nutrient amounts in order to obtain high and economically justified yields of high-quality sugar beet roots is as topical today as ever.

It is well-know that the main components of mineral nutrition (NPK) affect not only sugar beet plant productivity but its technological characteristics as well. When developing a fertilization system for sugar beet, particular attention must be devoted to fertilizer rate as well as to nutrient ratios and application time.

According to *Stanaćev* (1979) and *Stanaćev and Stefanović* (1974), higher nitrogen rates decrease sugar content and utilization percentage, and particularly high, harmful nitrogen levels may often reduce leaf yield as well. Root yield, however, either remains the same or decreases. The same authors argue that the optimum nitrogen rates (those providing the highest sugar yield and utilization percentage) on chernozem in Vojvodina are in the 60-120 kg/ha range, with the precise amount depending on the level of soil fertility. In the Srem region of the Vojvodina Province, according to *Milovanović* (1977), nitrogen rates above 100 kg/ha will not increase root yields but will reduce root sugar content. Other authors found that N rates above 150 kg/ha almost as a rule decrease root

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sugar content and sugar use level but rarely increase root yield (*Radenović and Dobrodoljani*, 1988; *Sarić,* 1988; *Nenadić et al.*, 1990; *Milošević and Stefanović*, 1984; *Škrbić*, 1994, etc.).

Root sugar content is also influenced by the balance of NPK rates *(Nenadić and Tomić*, 2000). Application of larger potassium fertilizer rates increases sugar content (*Jocić*, 1992).

Sugar beet yield and quality depends a lot on weather conditions (most importantly moisture) during the growing season as well. (*Gujaničić,* 1996; *Nenadić and Tomić*, 2000). A lot of authors point out that white sugar yield depends more root yield than on sugar content and sugar utilization (*Nenadić et al.*, 1990 and 2003; *Gujaničić*, 1996).

Since there are a lot of differing opinions in the literaure about NPK effects on sugar beet yield and quality, we have decided to try to make a contribution to the resolution of these issues.

MATERIALS AND METHODS

A series of small-scale field trials on calcareous chernozem were carried out during 1998-2003 to study the effects of NPK fertilizers on sugar beet yield and quality. The experiments were carried out on the experiment field of the Tamiš Institute in Pančevo using a randomized block design with five replications. The sugar beet cultivar Rama was used.

The study involved 19 fertilization treatments and an unfertilized check:

– check treatment (no fertilization), $N_{100}P_0K_0$, $N_0P_{100}K_0$, $N_0P_0K_{100}$, $N_{100}P_{100}K_0$, $N_{100}P_0K_{100}$, $N_0P_{100}K_{100}$, $N_{50}P_{50}K_{50}$, $N_{50}P_{100}K_{50}$, $N_{50}P_{100}K_{100}$, $N_{100}P_{50}K_{50}$, $N_{100}P_{100}K_{50}$, $N_{100}P_{100}K_{100}$, $N_{100}P_{130}K_{50}$, $N_{100}P_{130}K_{130}$, $N_{130}P_{50}K_{50}$, $N_{130}P_{100}K_{50}$, $N_{130}P_{100}K_{100}$ and $N_{130}P_{130}K_{130}$ kg/ha.

Soil fertilization for sugar beet was carried out so that the entire phosphorus and potassium amounts were incorporated in the autumn after deep plowing, while the nitrogen was applied in the spring before seedbed preparation.

Winter wheat was the preceding crop in all study years. Soil tillage was of the standard type used for sugar beet preceded by wheat. Sowing was done using special pneumatic planters in the second half of March (on different dates depending on the conditions), while plant density was 80,000 plants per hectare. The usual crop tending measures were used during the growing season. Sugar beet roots were lifted by hand in October. Root mass was measured on the trial field itself and root samples for analysis were taken there as well.

Root sugar content was determined polarimetrically by the cold digestion method. Sugar use percentage was calculated according to *Reinefeld*, 1974. White sugar yield was calculated by multiplying the sugar utilization and root yield values.

The results were statistically processed and the degree of correlation among the values of the parameters studied was expressed via correlation coefficients.

METEOROLOGICAL CONDITIONS

Meteorological conditions varied significantly according to year during our study, especially with respect to moisture.

The total amount of precipitation during the sugar beet growing season (April-September) ranged between 195.2 in 2000 and 648.3 mm in 2001 (Tab. 1). Besides 2001, higher precipitation amounts were also recorded in 1999 (603.4 mm) and 2002 (373.0 mm). Total precipitation in these three years was at or above the long-term average level of 373.0 mm. The years 1998, 2003 and, especially, 2000, on the other hand, had significantly less total precipitation, ranging from 195.2 to 303.5 mm.

Such moisture conditions were a major reason for the large differences found among the study years in terms of root yield and the other parameters.

The mean growing season temperatures ranged between 18.2 and 21.4 ^{0}C (Tab. 1.) and were for the most part inversely proportional to total precipitation.

Tab.1. Amount of rainfall (mm) and average air temperatures (^{0}C) during sugar beet growing season (IV-IX) in Pančevo

Year	1998	1999	2000	2001	2002	2003	Višeg. prosek Average
Temperature	19,5	19,5	21,4	19,3	18,2	21,1	18,2
Precipitation	303,5	603,4	195,2	648,3	373,0	245,0	373,0

Calcareous chernozem is characterized by slightly alkaline soil reaction (pH=7.21), an excellent supply of phosphorus (19.2 mg/100 g soil), a medium supply of potassium (16 mg/100g zemljišta), and a relatively high humus content (4.35%).

RESULTS AND DISCUSSION

Fertilizer application had very significant influence on sugar beet root yield, both overall and in individual study years. All fertilization treatments had a positive effect on root yield. Thus, the average increase of yield in all the treatments taken together was 33.15% relative to the unfertilized check (Tab. 2).

However, the individual elements of mineral nutrition and their combinations had different effects on root yield values. Overall, the highest average root yield was found in treatments with 100 kg/ha of N, P and K each (59.97 t/ha), tab. 2.

Somewhat lower yields (by approximately 1.0-2.5 t/ha) were obtained in treatments with $N_{100}P_{100}K_{50}$, $N_{130}P_{100}K_{50}$ and $N_{100}P_{130}K_{50}$. In this regard, our results are quite similar to those of *Stanaćev* (1979*), Stanaćev and Stefanović* (1974*),* and *Milovanović* (1977), who reported that root yields of sugar beet were not increased either by nitrogen rates above 100 kg/ha or by phosphorus and potassium ones above that level.

NPK effects on root yield by study year were of similar character to the overall average.

It is important to note that root yield depended greatly on moisture conditions in a given year. The highest average root yield was obtained in the year 2001 (78.71 t/ha), which had no less than 648.3 mm of rainfall during the growing season of sugar beet

(Tab. 1.). The next highest yield was recorded in 1999 (60.93 t/ha) with its 604.3 mm of rainfall. Much lower yields were produced in 2000 (47.50 t/ha) and 2003 (23.46 t/ha) with very low total precipitation (between 195.2 and 245.0 mm). Such root yield response to moisture conditions has also been reported by *Gujaničić* (1996*), Nenadić and Tomić* (2000) and others.

Tab.2. Influence of NPK rates and ratios on sugar beet yield (t/ha)

Fertilization treatment	Year						Average	Rank
	1998	1999	2000	2001	2002	2003		
$N_0P_0K_0$	44,72	38,66	38,97	55,24	47,38	18,25	40,54	20
$N_{100}P_OK_0$	49,17	44,58	39,15	63,62	54,78	19,99	45,21	18
$N_0P_{100}K_0$	49,05	58,80	44,20	73,18	50,34	21,89	49,58	15
$N_0P_0K_{100}$	47,72	45,46	37,35	61,64	50,86	20,63	43,94	19
$N_{100}P_{100}K_0$	53,22	60,19	45,96	82,53	55,74	27,16	54,13	13
$N_{100}P_0K_{100}$	48,50	57,29	38,40	68,78	52,16	20,73	47,64	17
$N_0P_{100}K_{100}$	47,67	53,45	48,31	73,44	50,92	19,08	48,81	16
$N_{50}P_{50}K_{50}$	52,61	64,22	44,44	82,93	55,58	23,23	53,83	14
$N_{50}P_{100}K_{50}$	54,28	63,90	48,62	84,89	52,58	27,89	55,36	12
$N_{50}P_{100}K_{100}$	56,55	62,08	52,76	84,69	53,98	22,20	55,38	11
$N_{100}P_{50}K_{50}$	54,39	69,82	44,67	83,58	56,54	26,15	55,86	10
$N_{100}P_{100}K_{50}$	56,68	73,03	52,71	85,00	62,56	23,11	58,85	2
$N_{100}P_{100}K_{100}$	58,39	76,18	54,47	83,60	64,32	22,84	59,97	1
$N_{100}P_{130}K_{50}$	58,72	68,88	51,84	87,62	55,74	22,59	57,56	4
$N_{100}P_{130}K_{130}$	57,11	72,15	45,13	82,62	52,96	27,08	56,18	8
$N_{130}P_{50}K_{50}$	58,50	62,96	44,93	83,96	58,10	27,79	56,04	9
$N_{130}P_{100}K_{50}$	58,83	68,63	53,33	83,33	57,76	25,08	57,83	3
$N_{130}P_{100}K_{100}$	57,44	64,85	55,24	87,64	53,42	22,37	56,83	5
$N_{130}P_{130}K_{100}$	62,33	53,77	56,55	81,96	56,96	25,95	56,25	7
$N_{130}P_{130}K_{130}$	62,00	59,69	52,89	84,00	54,80	25,11	56,41	6
Average	54,39	60,93	47,50	78,71	54,87	23,46	53,31	–

Root sugar content (digestion) and polarimeter sugar use also depended to a certain extent on nutrient and nutrient rate. The average sugar content ranged between 13.67 and 14.45% (Tab.3.), which is not a significant difference. However, higher sugar contents were obtained in treatments with potassium only (K_{100}, 14.45%), potassium and phosphorus ($P_{100}K_{100}$, 14.11%) and potassium, phosphorus and some nitrogen ($N_{50}P_{100}K_{100}$, 14.40%). Therefore, potassium and potassium combined with phosphorus increase the root sugar content of sugar beet. These fertilization treatments practically had the highest polarimeter sugar use percentage as well (tab.3.), ranging from 12.05 to

12.09%. The lowest values of this parameter (11.05-11.40%) were obtained with N rates of 100 and 130 kg/ha, both individually and in combination with small potassium and phosphorus rates. Similar results were obtained by *Jocić* (1992*), Stanaćev* (1979*), Milovanović* (1977*), Nenadić and Tomić* (2000*), Škrbić* (1994*), Nenadić et al.* (1990), etc.

Interestingly, sugar content and polarimeter sugar use percentage were mostly inversely proportional to root yield, particularly on a by-year basis.

A very high correlation was observed between sugar content and polarimeter sugar use (r=0.904), Tab.4.

On the other hand, no significant correlation was found either between root yield and sugar content or between root yield and sugar utilization. The correlation coefficients in these cases were very low (r=0.144 and 0.170).

White sugar yield (Tab.3.) depended directly on root yield, both overall and by year. These two parameters were highly correlated (r=0.971). The strong dependence of white sugar yield on root yield has also been reported by *Nenadić et al.* (1990 and 2003) and *Gujaničić* (1996). Our results showed a very low correlation between white sugar yield and root sugar content (r=0.121) and white sugar yield and polarimeter sugar use (r=0.176).

The highest average yields of white sugar (around 6.90 t/ha) were recorded in fertilization treatments that produced the highest root yields as well ($N_{100}P_{100}K_{100}$ and $N_{100}P_{100}K_{50}$). Also noteworthy were treatments $N_{50}P_{100}K_{100}$ and $N_{100}P_{50}K_{50}$ with their white sugar yields of 6.57 t/ha. High sugar yields (over 6.0 t/ha) were also produced by more than 100 kg/ha of nitrogen, phosphorus or potassium, but these treatments are cost-ineffective compared to those with smaller nutrient rates.

Tab. 3. Influence of NPK rates and ratios on sugar digestion, sugar use and white sugar yield (1998-2003 average)

Fertilization treatment	Digestion (%)		Sugar use (%)		White sugar (t/ha)	
	Average	Rank	Average	Rank	Average	Rank
$N_0P_0K_0$	13,71	19	11,44	15	4,58	20
$N_{100}P_0K_0$	13,80	16	11,39	18	5,04	19
$N_0P_{100}K_0$	14,00	6	11,83	4	5,79	15
$N_0P_0K_{100}$	14,45	1	12,08	2	5,21	18
$N_{100}P_{100}K_0$	13,84	10	11,65	9	6,18	12
$N_{100}P_0K_{100}$	13,81	14	11,51	13	5,38	17
$N_0P_{100}K_{100}$	14,11	3	12,05	3	5,71	16
$N_{50}P_{50}K_{50}$	13,83	12	11,59	11	6,08	13
$N_{50}P_{100}K_{50}$	13,97	7	11,70	8	6,30	9
$N_{50}P_{100}K_{100}$	14,40	2	12,09	1	6,57	3
$N_{100}P_{50}K_{50}$	14,04	5	11,82	5	6,56	4
$N_{100}P_{100}K_{50}$	13,94	8	11,82	6	6,81	2
$N_{100}P_{100}K_{100}$	14,06	4	11,80	7	6,98	1
$N_{100}P_{130}K_{50}$	13,84	11	11,38	19	6,29	10
$N_{100}P_{130}K_{130}$	13,77	18	11,40	16	6,26	11
$N_{130}P_{50}K_{50}$	13,67	20	11,05	20	6,06	14
$N_{130}P_{100}K_{50}$	13,81	15	11,46	14	6,47	5
$N_{130}P_{100}K_{100}$	13,82	13	11,55	12	6,34	7
$N_{130}P_{130}K_{100}$	13,79	17	11,40	17	6,33	8
$N_{130}P_{130}K_{130}$	13,92	9	11,63	10	6,42	6
Average	13,93	–	11,63	–	6,07	–

Tab.4. Correlation coefficients between parameters studied

Parameter	1	2	3	4
Root yield (t/ha)	–	0,144	0,170	0,971**
Sugar content (%)		–	0,904**	0,121
Sugar utilization (%)			–	0,176
White sugar yield (%)				–

CONCLUSION

Our results and their analysis lead to the following conclusions:

- Fertilization of soil for sugar beet production had very significant effects on yield and quality of this crop. The average increase of root yield relative to control was 33.15%;
- The highest average root yield (59.97 t/ha) was found in the treatment with 100 kg/ha of NPK each, followed by $N_{100}P_{100}K_{50}$ (58.85 t/ha);
- These treatments also produced the highest average white sugar yields (oko 6.90 t/ha). Root yield and white sugar yield were highly correlated (r=0.971);
- Root yield (and, hence, white sugar yield) depended greatly on moisture conditions during sugar beet growing season. The highest average root yields were obtained in the years 2001 and 1999 (78.71 and 60.93 t/ha, respectively), which had the best moisture conditions for sugar beet development;
- Sugar content and polarimeter sugar use depended little on fertilization, with the average values ranging from 13.67 to 14.45% and from 11.05 to 12.09%, respectively. Potassium had a particularly positive effect on the values of these parameters, which were also highly correlated (r=0.904);
- Very low correlations were found between root content and white sugar yield, on the one hand, and sugar content and polarimeter sugar use, on the other.

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