SUGAR YIELD AND TECHNOLOGICAL QUALITY OF SUGAR BEET AT DIFFERENT LEVELS OF NITROGEN FERTILIZATION

Branko MARINKOVIĆ[1], Jovan CRNOBARAC[1], Goran JAĆIMOVIĆ[1], Milorad RAJIĆ[2], Dragana LATKOVIĆ[1], Vladimir AĆIN[2]

[1] Faculty of Agriculture, Trg D. Obradovića 8., 21000 Novi Sad, Serbia,
[2] Institut of Field and Vegetable Crops, Maksima Gorkog 30., 21000 Novi Sad, Serbia
Corresponding author: branko@polj.uns.ac.rs

Abstract: *Sugar beet fertilization is more specific than other field crops, which is reflected in the fact that to achieve high sugar yield per unit area, with a high root yield is very important and its technological quality. Researches of impact of fertilization on these sugar beet traits in the period of three years are conducted in the stationary field experiment at the Institute of Field and Vegetable Crops in Novi Sad, Serbia, at Rimski Šančevi experimental station. The experiment was carried out on ten fertilization variants with increasing doses of N, P_2O_5 and K_2O, and the object of investigation was a local variety Sara. Root yield was the highest on the fertilization variants with the highest amounts of nitrogen fertilizer, but in any case, the difference in yield was not statistically significant in comparison with variants in which it was applied 100 kg N ha^{-1}. The sugar content significantly decreased, while the content of harmful nitrogen and sodium significantly increased with increasing doses of N. Refined sugar yield was the highest at the fertilization variant $N_{100}P_{50}K_{50}$.*

Key words: *sugar beet, fertilization, nitrogen, root yield, sugar yield, technological quality*

INTRODUCTION

Sugar beet synthesize a large amount of organic matter, which requires high amounts of nutrients. Fertilization of sugar beet is more specific comparing to other field crops. To obtain high sugar yield per unit area, beside achieving high yield of sugar beet root, very important property is its technological quality. The average yield of sugar beet in Serbia is low, with significant varying by years and with sugar content (digestion) lower from optimal. For this reasons, obtained sugar yield is only 5-6 t ha^{-1}. Except natural factors, which certainly have a significant impact on yield, mistakes and omissions in technology of growing are also significant (MARINKOVIC et al. 2007). According to many authors, here in the first place come omissions made during fertilization, whether low or high amounts of nutrients applied. For the agroecological conditions of Germany, FÜRSTENFELD and HORN (2003) stated that the reduction of amount of nitrogen fertilizers in the growing of sugar beet, from 200 kg ha^{-1} in 1980., to less than 100 kg ha^{-1} on average today, resulted in better quality and increased yield of sugar. The authors also emphasize the economic and ecological significance of these findings. MARINKOVIC and CRNOBARAC (2000) examined the effects of 20 different treatments of fertilizing on several varieties of sugar beet, and found equally negative effects of excess amounts or lack of three basic elements of mineral nutrition. The amounts and ratio of applied nitrogen, phosphorus and potassium, mainly depends of soil fertility, plant characteristics and the desired yield and quality (SARIC, 1977). According to the author, the use of higher amounts of fertilizer than needed is not only economic unjustified from the standpoint of direct investment, but a higher doses of nutrients can be harmfull to a great number of plant species and varieties.

Of all the elements of mineral nutrition, nitrogen has the greatest impact on yield and qualitative traits of sugar beet. Monitoring of its dynamics and the quantity in the soil reduces the possibility of over fertilization, which can have a negative impact on the yield of sugar (MARINKOVIC et al. 2003; JAĆIMOVIĆ et al. 2008).

Technological quality of roots is determined by digestion and content of non-sugar matter. Higher content non-sugar matter (organic nitrogen compounds in particular α-amino nitrogen, betaine and other organic bases, as well as minerals: K, Na, Ca, Mg, etc.) in the root causes increas of sugar content in molasses, which influence lower efficiency in the processing of sugar beet, and a lower yield of refined sugar. Determining the technological quality of sugar beet has a multiple use in the production of sugar beet (determining the expected amount of sugar per hectare, the selection of varieties, methods of fertilization and protection of, determining the time of sowing) and in the processing of sugar beet (payment to producers, feature evaluation campaign, preparing for the quality of sugar beet factory who expect), etc. (KARADZIC et al., 1990).

For these reasons the task of this research is to assess the impact of different doses of nitrogen, phosphorous and potassium fertilizers, on the technological properties of sugar beet roots, and also to determine the optimum ratio of these elements and the optimal amount of fertilizer for achieving high yields of sugar per unit area.

MATERIAL AND METHODS

Three years period research (2001-2003) have been carried out at stationary field trial in the Institute of Field and Vegetable Crops (φ 45 ° 20 N, λ 19 ° 51 E), Novi Sad, Serbia. The experiment was set up according to two-factorial (Split plot) block design in four replications, with the basic plot size of 150 m^2, and 10 different treatment combinations of doses of N, P_2O_5 and K_2O: Ø - Control (unfertilized treatment), $N_1P_1K_1$, $N_1P_2K_1$, $N_1P_2K_2$, $N_2P_1K_1$, $N_2P_2K_1$, $N_2P_2K_2$, $N_3P_1K_1$, $N_3P_2K_1$, $N_3P_2K_2$ (where: $_1$ =50, $_2$ =100, $_3$ =150 kg of pure nutrients per ha.)

The trial was set up on calcareous chernozem, with good physical and chemical properties. The soil plough (upper) layer, was in all tested treatments very well supplied with potassium (high level; 19.9-32.2 mg100g^{-1} of soil), while the content of phosphorus ranged from 7.3-25.4 mg100g^{-1} of soil, depending on the fertilization treatments.

In both years of the trial a standard technology of growing was applied. The entire amount of P_2O_5 and K_2O and half of N fertilizer were applied in autumn, before autumn ploughing, and the other half of N was applied in the spring, before sowing. Local variety of sugar beet "Sara" have been used for this trial.

After extraction of sugar beet, the average root samples from all fertilizer treatments were taken in order to determine the technological quality of sugar beet and the following parameters were determined: percentage of sugar in the root (digestion) - as the most important criterion for determining the quality of the root, the content of "harmful nitrogen" (α amino-N) and the contents of "harmful K and Na". Based on upper data, the percentage of utilization of sugar and refined sugar yield were determined. Determination of the elements of the technological quality of roots was performed by standard methods in automated laboratory for sugar beet "WENEMA" in the Institute of Field and Vegetable Crops, Novi Sad, according to the regulations valid in Serbia, which are listed in the "Methods for laboratory control of the sugar factory" *(Milic et al. 1992).*

RESULTS AND DISCUSSIONS

On all fertilized treatments, obtained yield was statistically higher compared to unfertilized treatment (Table 1). In the treatment fertilized with 50 kg ha^{-1} of nitrogen, phosphorus and potassium ($N_1P_1K_1$) obtained yield was 52.84 t ha^{-1}, or 17.24 t ha^{-1} higher comparing to control. Further increase of N by 50 kg ha^{-1} (treatment $N_2P_1K_1$) increased the yield by highly significant 8.69 t ha^{-1}, while the highest dose of nitrogen at the same levels of

P_2O_5 and K_2O ($N_3P_1K_1$) reduced the yields for 1,69 t ha^{-1} compared to the previous tretment. On the treatments fertilized with 100 kg P_2O_5 ha^{-1} and 50 kg K_2O ha-1 (P_2K_1), increasing amounts of N from 50 to 100 and further to 150 kg ha^{-1} contributed to the increase of root yield to around 2.9 t ha^{-1}. On the tretment with P_2K_2, increasing amounts of N from 50 to 100 kg ha^{-1} increased the yield by 3.46 t ha^{-1}, while the following higher dose of N resulted in its reduction by approximately 1 t ha^{-1}.

The highest yield of roots (62.47 t ha^{-1}) was obtained in the treatment $N_3P_2K_1$, however, yield difference was not statistically significant in comparison with all the treatments in which the nitrogen was applied in dose of 150 or 100 kg ha^{-1}. Fertilization with 100 kg N ha^{-1} in relation to the dose of 50 kg N increased the yield by about 5 t ha^{-1}, on average, or about 9%, while a further increase of N dose at 150 kg did not affect the yield of roots. The effect of increasing doses of N on yield of roots was accompanied by a form of quadratic regression curve (Fig. 1). Based on this regression equation, the theoretical maximum yield of 62 t ha^{-1} is achieved by fertilizing with about 116 kg of nitrogen.

Fetilization with higher amounts of N influenced a significant reduction of sugar content in root. In relation to this, the largest sugar content (15.51%) was obtained in the control tretment, and the lowest in treatments $N_3P_1K_1$ and $N_3P_2K_2$. An increase of N dose from 50 to 100 kg ha^{-1}, and a further increase to 150 kg N, reduced the sugar content in root to about 0.6% on average, in both cases.

Table. 1

The effect of different amounts of mineral fertilizers on yield, technological quality properties of roots and yield of refined sugar

Fertilizing tretments	**Root yield** *($t\ ha^{-1}$)*	**Sugar content** *(%)*	**Content of α–amino N** *($mmol\ 100\ g^{-1}$)*	**Content of K** *($mmol\ 100\ g^{-1}$)*	**Content of Na** *($mmol\ 100\ g^{-1}$)*	**% of sugar utilization**	**Rafined sugar yield** *($t\ ha^{-1}$)*
Ø	**35,60**	**15,51**	**2,20**	**2,98**	**0,48**	**14,10**	**5,08**
$N_1P_1K_1$	52,84	15,47	2,19	3,08	0,59	13,98	7,42
$N_2P_1K_1$	61,53	14,87	3,23	3,16	0,66	13,25	8,25
$N_3P_1K_1$	59,84	14,22	4,55	2,91	0,67	12,56	7,64
$N_x P_1K_1$	**58,07**	**14,85**	**3,32**	**3,05**	**0,64**	**13,26**	**7,77**
$N_1P_2K_1$	56,63	15,46	2,18	2,90	0,56	14,05	7,99
$N_2P_2K_1$	59,53	14,94	3,25	3,15	0,56	13,36	8,05
$N_3P_2K_1$	62,47	14,47	4,24	2,91	0,74	12,82	8,06
$N_x P_2K_1$	**59,54**	**14,96**	**3,22**	**2,99**	**0,62**	**13,41**	**8,03**
$N_1P_2K_2$	55,81	15,52	2,19	3,23	0,58	13,99	7,85
$N_2P_2K_2$	59,27	14,92	3,22	3,30	0,65	13,26	7,96
$N_3P_2K_2$	58,19	14,28	4,63	3,14	0,65	12,54	7,35
$N_x P_2K_2$	**57,76**	**14,91**	**3,34**	**3,22**	**0,62**	**13,26**	**7,72**
Average for N_1 treatments	55,09	15,48	2,19	3,07	0,58	14,01	7,76
Average for N_2 treatments	60,11	14,91	3,23	3,20	0,62	13,29	8,09
Average for N_3 treatments	60,17	14,32	4,47	2,99	0,68	12,64	7,68
$LSD_{0,05}$	5,08	0,54	0,77	0,20	0,16	0,59	0,70
$LSD_{0,01}$	8,19	0,74	1,06	0,28	0,21	0,81	1,14

Increasing doses of N at the same amounts of P and K have resulted in a significant, almost linear increase of harmful N and Na in the root. Harmful nitrogen is undesirable ingredient in beet, as one part of it prevents the crystallization of 25-40 parts of sugar and increases sugar losses in sugar beet processing. It is known that, of all agricultural practices, use of nitrogen fertilizers has the greatest influence on the content of α-amino nitrogen in the root. According to our research, the content of harmful N was the lowest in the control treatment and in all tretments with the lower dose of N (50 kg ha^{-1}). Similar data for Croatian conditions, according to POSPIŠIL *(2004)*, indicate that if the dose of nitrogen fertilizer substantially exceeds the optimal dose, a decrease in sugar content and a drastic increase in alpha-amino N occurs, so that a large part of the sugar goes straight into the molasses.

For the maximum utilization of sugar from the beet, very important property is the content of "harmful K and Na." Potassium and sodium compounds, along with chlorine compounds in the refinement process turns to the solution and like the "harmful nitrogen" reduce the crystallization of the sugar and increase sugar losses in molasses. This set of minerals in the technology of processing sugar beet is known as "soluble ash." The most significant influence on the content of harmful potassium in the root of sugar beet had the potassium fertilization, whereas the effect of increased dose of N was not significant.

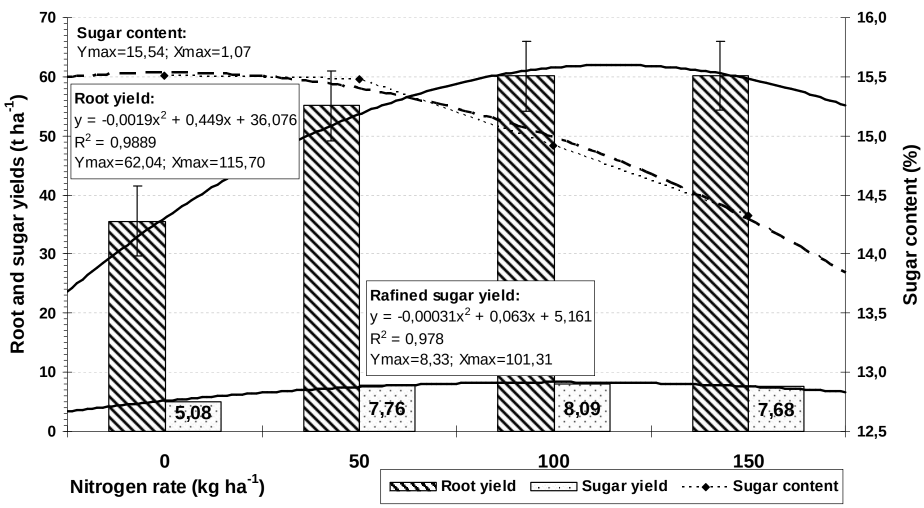

Fig. 1: Dependence of root and sugar yield of the applied amount of nitrogen

As a result of these complex impacts of elements of the technological quality of roots, the highest yield of refined sugar (8.25 t ha^{-1}) was obtained in the treatment $N_2P_1K_1$, and was approximately 62% higher in comparation with the control treatment. On average, increasing dose of N fertilizer from 50 to 100 kg ha^{-1} increased the sugar yield by 330 kg ha^{-1} (4.25%), while a further increase of N dose at 150 kg reduced the yield by 410 kg ha^{-1}; or about 5%. Dependence of the yield of refined sugar from the applied amount of nitrogen had a form of quadratic regression curve (Fig. 1), where the theoretical maximum yield (8.33 t ha^{-1}) is realized when fertilizing with 100 kg N ha^{-1}. Similar to our results, ŠOLTYSOVA (2003) revealed that the highest amount of nitrogen fertilizer reduced the digestion and yield of refined sugar significantly, by 0.33% and 0.38%, respectively. The negative effects of nitrogen on the technological properties of sugar beet is supported by studies of many foreign authors, REINIEFELD and BAUMGARTEN (1975), CAMPBELL (2002), HANAČKOVA (2003), etc. Smaller dose of nitrogen, however, increase the digestion or it remains on the level of unfertilized treatment (DRAYCOTT et al. 1974), which increase the sugar yield significantly by increasing the yield of roots. Many local authors point out that amounts of NPK over 100 kg ha^{-1} almost regularly lead to the reduction of sugar content in root and its efficiency, and rarely increase the yield of sugar beet root (STANAĆEV et al. 1983, NENADIC et al. 2003, MARINKOVIC and alL. 2004 and 2008).

CONCLUSIONS

The highest yield was obtained in the treatment $N_{150}P_{100}K_{50}$, however, yield difference was not statistically significant compared with all the fertilizing treatments in which the nitrogen was applied in dose of 150 or 100 kg ha^{-1}. Fertilization with 100 kg N ha^{-1} in relation to the dose of 50 kg N increased the yield approximately by 9%, while a further increase of N dose on 150 kg did not affect the yield of roots.

On average, an increase of N dose from 50 to 100 kg ha^{-1}, and a further increase to 150 kg N, reduced the sugar content in root for about 0.6% in both cases. Increasing N doses at the same levels of P and K have resulted in an almost linear increase of harmful N and Na in the root.

Increasing amounts of N-fertilizer from 50 to 100 kg ha^{-1} increased the yield of sugar to 4.25%, on average, while a further increase of N to 150 kg reduced the yield by 5%, approximately. Dependence of the yield of refined sugar from the applied amount of nitrogen had a form of quadratic regression curve, where the theoretical maximum yield achieved when fertilizing with 100 kg N ha^{-1}.

BIBLIOGRAPHY

1. CAMPBELL, L. G. (2002): Sugar beet quality improvement. Journal of Crop Production, Vol. 5, No. 1/2, 395-413.
2. DRAYCOTT, A. P., DURANT, M. J., LAST, P. Z. (1974): Effect of Fertilizers on Sugar Beet Quality. International Sugar Journal, 76, London, 335-338.
3. FÜRSTENFELD, F., HORN, D. (2003): Nutrient menagement in quality sugar beet cultivation- 20 years soil testing fertilisation advice. IIRB-ASBT Congres, 683-684.
4. HANAČKOVA, E. (2003): Zmeny anorganickeho dusika v pode a ich vplyv na urodu a kvalitu repy cukrovej. V celoslovenska vedecka reparska konferencia, Nitra, Zbornik vedeckej konferencie z medzinarodnou učastou, 176-179.
5. JAĆIMOVIĆ, G., MARINKOVIĆ, B., CRNOBARAC, J., BOGDANOVIĆ, D., KOVAČEV, L., DANOJEVIĆ, D. (2008): Influence of fertilization and nitrate-nitrogen position in soil profile on the sugar beet root yield and quality. Journal of Agricultural Sciences, Vol. 53, No 2, 83-90.
6. KARADŽIĆ, V., GRBIĆ, J., ĐURA, J. (1990): Ocena tehnološkog kvaliteta šećerne repe na bazi podataka koji se određuju na automatskim repno-analitičkim linijama. Prehrambena industrija, vol. 1, br. 3-4, str. 59-64.
7. MARINKOVIĆ B., CRNOBARAC J., JAĆIMOVIĆ G. (2004): Đubrenje šećerne repe azotom, fosforom i kalijumom u funkciji prinosa i kvaliteta. »Zbornik radova«, Naučni institut za ratarstvo i povrtarstvo, Novi Sad, Sveska 40, str. 373-378.
8. MARINKOVIĆ, B. CRNOBARAC, J., JAĆIMOVIĆ, G., MARINKOVIĆ, D., MIRCOV, D. V., RAJIĆ, M. (2008): Importance of increasing amounts of NPK nutrients on sugar beet yield. International Symposium "Trends in European Agriculture Development", Timisoara, May 15-16, 2008, Scientific papers, vol. 40 (2). 99-104.
9. MARINKOVIĆ, B., CRNOBARAC, J., JAĆIMOVIĆ, G., LATKOVIĆ, DRAGANA, MRĐA, JELENA, HABAN, M. (2007): Effect of fertilizing systems on sugar beet yield and quality. International Symposium "Trends in European Agriculture Development", May 24-25, 2007, Scientifical papers XXXIX, part I, 3-6.
10. MARINKOVIĆ, B., CRNOBARAC, J. (2000): Zavisnost kvaliteta i prinosa šećerne repe od primene NPK hraniva. Acta Periodica Technologica, Vol. 31, 345-350.
11. MARINKOVIĆ, B., STARČEVIĆ, LJ., CRNOBARAC, J., JAĆIMOVIĆ, G., JANKOVIĆ SNEŽANA, LATKOVIĆ DRAGANA (2003): The yield and quality of sugar beet root depending on the quantity

and the position of easily approachable N. Practical Solutions for Managing Optimum C and N Content in Agricultural Soils, II International Workshop, Czech University of Agriculture, Prague, Czech Republic, pg. 138-143.
12. MILIĆ MIRJANA, KARADŽIĆ VERA, OBRADOVIĆ SMILJKA (1992): Metode za laboratorijsku kontrolu procesa proizvodnje fabrike šećera. Tehnološki fakultet-Zavod za tehnologiju šećera, Novi Sad.
13. NENADIĆ, N., NEDIĆ, M., ŽIVANOVIĆ, LJ., KOLARIĆ, LJ., GUJANIČIĆ, T. (2003): Effect of genotype on Sugar Beet Yield and Quality. Journal of Agricultural Sciences, Vol. 48. No. 1, 1-9.
14. REINIEFELD, E., BAUMGARTEN, G. (1975): Verarbeitungseigenschaften der Zuckerube in Abhagigkeit vom Sticksoffangebot. Zucker, 2, 61-65.
15. SARIĆ, M. (1977): Zavisnost efekta upotrebljenih mineralnih đubriva od biljne vrste. Bilten za kontrolu plodnosti zemljišta i upotrebu đubriva, Novi Sad, br.1, 67-71.
16. STANAĆEV, S., MILOŠEVIĆ, R., STEFANOVIĆ, D. (1983): Uticaj različitog đubrenja na prinos i kvalitet šećerne repe u intenzivnoj kulturi. Zbornik radova, Institut za ratarstvo i povrtarstvo, Novi Sad, Sv. 13, 71-81.
17. ŠOLTYSOVA, B. (2003): Učinok hnojenia na zmeny kvantitativnych a kvalitativnych parametrov repy cukrovej. V celoslovenska vedecka reparska konferencia, Nitra, Zbornik vedeckej konferencie z medzinarodnou učastou, 162-166.