The effect of nitrogen fertilization and anti-fungal plant protection on sugar beet yielding

M. Pytlarz-Kozicka

Department of Crop Production, Agricultural University of Wroclaw, Poland

ABSTRACT

Sugar beet yielding and, thus, the profitability of its cultivation depends on various conditions. These are mainly a dose of nitrogen fertilizing and anti-fungal plant protection. Based on the research carried out in a private-owned farm in Biała commune, Opole province, Poland, it was observed that the most important factors influencing plant development and root yield of sugar beets (var. Kassandra and Cortina) were genetic features of the investigated varieties and fungal control. They increased considerably root yield and sugar content. The doubled nitrogen dose from 90 to 180 kg N/ha enhanced a slight, statistically insignificant, root yield increase and a lower sugar content in beet roots. The three-year research showed that weather conditions during the vegetation period had a decisive effect on sugar beet plants development and fungal infestation. The variety Cortina was characterized with a significantly higher yield and a higher content of treacle forming compounds in the roots. The increase of N rate from 90 to 180 kg N/ha caused a significant increase of average root mass, leaves and dry matter yield and potassium and N-αNH_2 in roots, but it also lowered sugar content. In the years with favorable conditions for fungal infestation, the use of fungicides helped to obtain a higher leaf/root ratio, higher root mass, higher root and leaf yield and higher dry matter and sugar yields. However, it did not have an effect on the content of chemical compounds producing treacle in sugar beet roots.

Keywords: sugar beet; nitrogen fertilization; anti-fungal plant protection; variety

Sugar beets are one of the more important crops in Poland. Their production aims to obtain a product with high sugar content and high technological value. The final effect of the crop production depends on many factors. These include weather and soil conditions during the vegetation period, tillage technology and genetic features of the beetroot varieties. Nitrogen content is a factor that has the most considerable effect on sugar beet yielding. Thus, it is vital to determine an optimal N rate. The insufficient N fertilization has a negative effect on yields, while overrated N application decreases technological value of sugar beetroots, which has been proved in various investigations (Kalinowska-Zdun et al. 1986, Marcussen 1991, Gutmański and Nowakowski 1992, Grzebisz and Barłóg 2002). Fungal diseases have become a real problem in sugar beet plantation for the last few years (Kositorna 2004). From the economical point of view the most dangerous is *Cercospora beticola*. Now this disease has spread in the whole country and has led to the highest yield losses on sugar beet plantations. The highest infestation with *Cercospora beticola* occurs in hot and wet years during sugar beet vegetation. High pathogen stresses destroy beetroot leaves, which considerably lowers root and sugar yield. It is possible to control fungal diseases by breeding resistant varieties. In case of *Cercospora beticola* it is difficult because plant resistance to this pathogen is encoded in several genes (Szreder 2004). Moreover, fungicides may be applied. The aim of the present paper is to determine the effect of differentiated N fertilization and anti-fungal plant protection on root yield and root quality of two sugar beet varieties.

MATERIAL AND METHODS

The filed experiments were carried out in 2001–2003 in a private-owned farm in Biała commune, Opole province, Poland. The area is located within a Pleistocenic high plain of Głubczyce Plateau. Mild winters and quite wet summers characterize the climate here. Mean yearly temperature is 8.4°C, and a yearly precipitation sum is ca. 700 mm.

The three-factor split-plot experiment was set in 3 replications. The investigated factors were:
I. varieties – Kassandra and Cortina
II. N fertilization – 90 and 180 kg N/ha
III. fungal control – K = control without plant protection, A = application of a fungicide Alert 375 SC, D = application of a fungicide Duett 250 SC.

Characteristics of sugar beet varieties according to The List of Agricultural Plant Varieties, COBORU 2000:

Cortina – triploid variety of normal sugar type. Yielding of roots – medium; high sugar content and yielding, good technological value of sugar; low content of harmful nitrogen. Low susceptibility to foliar disease *Cercospora beticola*; foliage-quite plentiful.

Kassandra – triploid variety of normal sugar type. Yielding of roots – medium-high; medium-high sugar content and yielding, low sodium and potassium content. Medium susceptibility to foliar disease *Cercospora beticola*; foliage-relatively little.

The experiment was set on a very good wheat soil, of a Polish quality class II and III a. Soil fertility and nutrients content were determined in autumn before organic fertilization; soil pH was 6.5–6.8. Phosphorus content was from medium to high and potassium and magnesium contents were very high. As a forecrop to sugar beet, winter wheat was used. The experiment was set in 45 cm × 18 cm rows. The size of the plots was 6 rows × 45 cm × 10 m = 27 m^2.

In the vegetation period, plant, weed infestation and agrofags occurrence were observed. On the plots with plant protection treatment, two sprays with fungicides: Alert 375 and Duett 250 SC were applied as assumed in the experiment methodology. During harvest roots of each plot were counted and roots and leaved were weighed. Moreover, 10 roots were isolated from each plot and presumed for further investigation. Biometric measurements of the roots were carried out, the roots were chopped and 3 × 100 g of roots were analyzed in the laboratory. The following data was determined: content of dry matter, sugar, sodium, potassium and N-αNH_2 with generally applied laboratory methods. Root yields, and leaves, dry matter, sugar yields, and plant density per 1 ha, as well as mass of 1 root and K, Na and N-αNH_2 contents were calculated statistically with variance analysis method for three-factor experiments.

RESULTS AND DISCUSSION

In the investigated years, the weather conditions in the vegetation period were not so favorable for sugar beet growth and yielding. The weather was characterized with a higher mean temperature than a multiyear temperature, and periodically high precipitations, which led to fungal infestation. Mean germination capacity for Cortina in the investigated years was 98%, and field emergence capacity was 71%, for Kassandra these values were 94% and 77%, respectively. Despite a lower field emergence, plant density was still high after emergence and at sugar beet harvest (Table 1). Plant density depended mainly on the field emergence capacity of the investigated varieties, and it was much higher with Kassandra. However, N fertilization and fungal disease control had no effect on plant density. All the investigated factors influenced leaf/root ratio, the highest ratio was obtained with Kassandra and with a higher nitrogen rate. More leaves were observed in roots, beet grown with fungal control, with use of Duett 50 SC in particular. The average root mass was much higher with Cortina, a higher N rate, plant protection with fungicides also led to increased root mass (Table 1).

Table 1. Plant density (1000 plants/ha), leaf/root ratio and one root average mass (g) (2001–2003)

Variety	N fertilization (kg/ha)	Plant protection	Plant density after emergence	Plant density of harvest before	Leaf/root ratio	Root average mass
Kassandra	–	–	95.1	93.7	0.74	764
Cortina	–	–	93.6	89.3	0.62	921
NIR ($\alpha_{0.05}$)			1.2	3.2	0.1	44.5
–	90	–	94.2	90.5	0.61	792
–	180	–	94.5	92.4	0.75	893
NIR ($\alpha_{0.05}$)			r.n.	r.n.	0.1	35.0
–	–	control	94.3	90.7	0.66	793
–	–	Alert 375 SC	94.4	91.8	0.70	859
–	–	Duett 250 SC	94.4	92.1	0.74	875
NIR ($\alpha_{0.05}$)			r.n.	r.n.	0.04	31.1

Table 2. Root and leaves yields and a total yield (t/ha) (2001–2003)

Variety	N fertilization (kg/ha)	Plant protection	Root yield	Leaves yield	Total yield
Kassandra	–	–	66.7	51.1	117.8
Cortina	–	–	73.6	49.4	123.0
NIR ($\alpha_{0.05}$)			2.2	r.n.	5.1
–	90	–	68.3	47.0	115.3
–	180	–	72.0	53.5	125.5
NIR ($\alpha_{0.05}$)			r.n.	3.3	9.5
–	–	control	65.5	46.4	111.9
–	–	Alert 375 SC	71.9	51.7	123.6
–	–	Duett 250 SC	73.1	52.6	125.7
NIR ($\alpha_{0.05}$)			2.6	2.5	7.3

Mean root yields obtained in the experiment were high (Table 2). Higher yields were observed in more favorable years – 2001 and 2002, and lower yields recorded in dry and hot year 2003. The features of the varieties and the plant protection had a significant effect on root yield (Table 2) but the increased rate on N fertilization by 90 kg N/ha did not increase the yield significantly. In the investigated years, higher root yields were obtained from variety Cortina and from the plots were fungicides, especially Duett 250 SC, were applied. Leaf yields were similar in both varieties. A significant increase in leaf yield was observed when N fertilization was applied at a rate of 180 kg N/ha, and on the plots with fungal control. Both leaf yield and root yield had an effect on the total sugar beet yield – leaves and roots (Table 2). Considerably higher yields were obtained from Cortina. A positive effect on yield was observed when fungal control and a higher N rate (180 kg N/ha) were applied.

In 2001–2002 the average percentage content of dry matter and sugar in the roots was similar in all the plots, a considerable decrease of sugar content was only observed after changing N fertilizer rate from 90 to 180 kg N/ha. Dry matter and sugar yields were mainly related to root yield. Dry matter and sugar yields were higher from Cortina variety that also gave a higher root yield, and on the plots were fungal control was applied, while N fertilization rate had a significant effect only on dry matter yield (Table 3).

Table 3. Dry matter and sugar content (%) in sugar beet roots and root dry matter yield and sugar biological yield (t/ha) (2001–2003)

Variety	N fertilization (kg/ha)	Plant protection	Dry matter	Sugar	Dry matter yield	Sugar yield
Kassandra	–	–	23.0	17.3	15.3	11.5
Cortina	–	–	23.6	17.6	17.4	13.0
NIR ($\alpha_{0.05}$)			r.n.	r.n.	1.2	0.8
–	90	–	23.1	17.8	15.8	12.2
–	180	–	23.3	17.1	16.8	12.3
NIR ($\alpha_{0.05}$)			r.n.	0.4	0.7	r.n.
–	–	control	23.1	17.5	15.1	11.5
–	–	Alert 375 SC	23.3	17.3	16.8	12.4
–	–	Duett 250 SC	23.3	17.2	17.0	12.6
NIR ($\alpha_{0.05}$)			r.n.	r.n.	1.4	1.0

Table 4. Content of K, Na and N-αNH_2 in sugar beet roots (2001–2003)

Variety	N fertilization (kg/ha)	Plant protection	K	Na	N-αNH_2
			(mval/100 g)		
Kassandra	–	–	3.63	0.50	2.13
Cortina	–	–	3.81	0.52	2.83
NIR ($\alpha_{0.05}$)			0.1	r.n.	0.4
–	90	–	3.60	0.49	2.20
–	180	–	3.84	0.53	2.76
NIR ($\alpha_{0.05}$)			0.1	r.n.	0.2
–	–	control	3.68	0.52	2.48
–	–	Alert 375 SC	3.73	0.51	2.50
–	–	Duett 250 SC	3.75	0.51	2.47
NIR ($\alpha_{0.05}$)			r.n.	r.n.	r.n.

The content of compounds producing treacle (potassium, sodium and N-αNH_2) in the roots of the investigated varieties (mean for the investigated years) was on a medium level. A higher concentration of these substances was recorded in 2003 because sugar beets were harvested earlier this year than in the preceding years (end of September). A significant effect of variety features and N fertilization rate on the content of potassium and N-αNH_2 was observed. Potassium and N-αNH_2 contents were higher in Cortina, and the values for those compounds, were also higher on the plots were a higher rate of N fertilization was applied. Sodium content in the roots was similar in all the investigated plots, and was slightly higher in Cortina and with the fertilization rate of 180 kg N/ha (Table 4).

Taking into consideration the results of the three-year experiment, it is possible to conclude that the weather conditions in the vegetation period had a decisive effect on sugar beet development (Kalinowska-Zdun et al. 1986, Słowiński et al. 1995, Borówczak 2002) and on fungal disease infestation (Praczyk and Miziniak 2002).

The research carried out on the varieties Cortina and Kassandra showed that Cortina was characterized with a considerably higher root mass, root yield and the total yield, and dry matter and sugar yield, as well as a higher content of treacle forming compounds. The increase of N rate in fertilization from 90 to 180 kg N/ha resulted in a significantly higher average root mass, total yield and leaves yield, and dry matter yield, but it also led to a considerable increase of potassium and N-αNH_2 content in the roots, which deteriorated production values of the roots (Podlaska and Podlaski 1994), which was also confirmed in the research done by Grzebisz and Barłóg (2002), Kalinowska-Zdun and Podlaska (1978).

Furthermore, the increased N fertilization caused also a significant decrease in sugar content in the roots, which is also pointed out in the papers of Grzebisz and Barłóg (2002), Nowakowski et al. (1997), Słowiński et al. (1995). It also lowered slightly plant density per ha. In the years 2001 and 2003 which had favorable conditions for fungal disease spreading, the application of fungicides helped to obtain a higher leaf/root ratio and a higher average root mass, as well as a better root, leaf, sugar and dry matter yields. This is in agreement with the results reported by Schäufele and Wevers (1994). The fungicides used in the experiment increased dry matter and sugar yields, but did not affect the content of molasses-forming compounds present in the roots of sugar beet under investigation.

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ABSTRAKT

Vliv hnojení dusíkem a ochrany rostlin proti houbovým chorobám na výnos cukrovky

Polní pokusy proběhly v letech 2001–2003 na pozemcích soukromého zemědělce z obce Biala v opolském kraji. Jejich cílem bylo ověřit vliv různého minerálního hnojení dusíkem v dávkách 90 a 180 kg N/ha a ochrany rostlin proti houbovým chorobám na výnosy a jakost dvou odrůd cukrovky (Cortina a Kasandra). Výsledky tříletého polního pokusu prokázaly, že průběh počasí ve vegetačním období má rozhodující vliv na vývoj rostlin a na houbové nákazy. Odrůda Cortina měla prokazatelně vyšší výnosy a také vyšší obsah sloučenin, které mají vliv na tvorbu melasy. Zvýšení dávky z 90 na 180 kg N/ha způsobilo prokazatelný růst průměrné hmotnosti kořenů, množství listů a suché hmoty a též růst obsahu draslíku a N-αNH_2 v kořenech a pokles obsahu cukru. V letech příznivých pro rozvoj houbových chorob se použití fungicidu projevilo ve vyšších výnosech kořenů a listů a nemělo vliv na obsah sloučenin, které tvoří melasu.

Klíčová slova: cukrovka; hnojení dusíkem; ochrana rostlin; odrůdy

Corresponding author:

Dr. Ing. Pytlarz-Kozicka Maria, Agricultural University, ul. Norwida 25, 50-375 Wrocław, Poland
phone: + 48 71 3205 163, e-mail: kozicka@ekonom.ar.wroc.pl