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ORIGINAL PAPER

# IMPACT OF THE APPLICATION OF NORWAY SPRUCE SAWDUST (*PICEA ABIES*) ON SUGAR BEET GROWTH AND YIELD AND ON SELECTED SOIL PARAMETERS

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Abstract

The decrease in application of organic fertilizers into arable soils in Slovakia observed for the past twenty-five years has caused degradation of their physical, chemical and biological parameters. In order to solve this problem, Slovak farmers often add to soil such carbon-rich substances which either pose a risk of increasing the heavy metal content of soil, or whose purchase and use are economically demanding. Meanwhile, sawdust is a cheap and available carbon-rich material. Therefore, the objective of a two-year pot experiment was to determine the impact of sawdust used alone or with added inorganic nitrogen on the parameters of sugar beet yield as well as on some soil parameters. The results proved that the separate application of sawdust in autumn in doses of 3.4 t $ha^{-1}$ and 6.8 t $ha^{-1}$ caused the retardation of the growth of sugar beet and the decrease of the total chlorophyll content in leaves during the first 80 days of plant growth and development. This application did not have the significant impact on the root yield, but it increased the sugar content of sugar beet roots. The roots contained less $\alpha$-amino nitrogen and more potassium. The number of nitrogen-fixing bacteria of genus *Azotobacter chroococcum* (*AzCh*) and the quantity of organic carbon in soil increased. The addition of mineral nitrogen fertilizer in a dose of 60 kg $ha^{-1}$ into sawdust before sugar beet sowing in spring lowered or even eliminated the negative impact of sawdust itself on the beet growth and the content of total chlorophyll. It also increased the root yield. This addition had positive impact on the number of bacteria of the genus *AzCh* and the quantity of organic carbon in soil.

**Keywords:** retardation of plant growth, lignocellulosic substances, organic matter, assimilative pigments.

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# INTRODUCTION

In Slovakia, the number of livestock such as cattle, sheep and pigs has declined in the last twenty-five years. Consequently, the production of manure has fallen by 55-60% and the production of composts decreased by 80-85% during the given period. As a result, a decrease of the soil organic substance content has emerged. This is due to both the decreased production and use of organic fertilizers, and to the increased transport of carbon through the by-products. The primary source of organic substance in soils in Slovakia has become the crop residues. Nowadays, depending on the crop rotation cycle and harvest technology, they often compensate the requirement of organic substances by just 10%, which is insufficient. The low quantity of organic substances in soil along with the subsequently deteriorated physical, chemical, biological and sanitary and toxicological parameters mean that many agricultural farms have begun to experience stagnation or even a decrease of yields despite maintaining the optimal mineral nutrition of plants (Kováčik et al. 2010). Farmers try to stabilize or increase the yields of crops by counteracting the deficit of organic substances in soil, and have therefore started to apply the different carbonaceous materials into soil (Fecenko et al. 1995, Valšíková, Viteková 2006, Šimanský et al. 2019). Hence, lignite or lignite dust (sources of carbon harder to dissolve) are applied into Slovakian soils in higher quantities. Biochar as a carbon source is used in smaller amounts. Consequently, both yield increases and decreases of cultivated crops are recorded following the application of lignite or biochar, depending largely on the quality of these substances, their doses and dates of application, soil parameters, course of the weather and type of cultivated crop (Kováčik et al. 2016). However, farmers seem unaware that the cheapest sources of carbon, excellent in terms of the impact on soil and crops, are straw and fermented sawdusts (Nolan et al. 2011, Troy et al. 2012).

Special attention needs to be drawn to the quantity and quality of organic substances in soil, which is confirmed by data indicating a positive relationship between the quantity of organic carbon (organic substances) in soil and the soil's fertility (Šimanský, Tobiášová 2012, Kong et al. 2014, Dudek et al. 2020). Zhao et al. (2015*a*,*b*) claim that after straw application an increase in yield was recorded in 92% cases, while a yield decrease appeared in 8% of the cultivated crops. On the contrary, Overholser (1955) and Kováčik (2014) state that a yield decrease can be expected after the application of significant quantities of lignocellulose material (straw, sawdust, shavings).

One of the many reasons why results of studies into the impact of sawdust or straw application on the yield of cultivated crops are divergent is their inaccurate interpretation. The inaccuracy arises from the fact that while the research methods clearly show testing the interactive effect of carbon and fertilizers, the achieved effect is sometimes credited to the applied carbonic materials. Positive results of the interactive impact of straw and industrial fertilizers have been detected by Zhang et al. (2016), Zhao et al. (2016) and Zuo et al. (2017).

Taking into consideration the above considerations, the objective of our experiments was to determine the effect of using sawdust alone and the shared effect of sawdust and mineral nitrogen added by fertilizer on the yield and quality of sugar beet and selected soil parameters.

## MATERIALS AND METHODS

### Experimental design and field management

A pot experiment was carried out for two years (2010-2011) in an outdoor cage for growing plants, located on the premises of the SUA (Slovak University of Agriculture) in Nitra (48°18′N, 18°06′E – Slovakia). The dimensions of the cage were 20 m x 20 m x 5 m. The walls and roof were made of metal mesh, with the mesh size 15 mm x 15 mm, to protect the experiment against birds. The floor was made of interlocking grey pavement slabs. 23.5 kg of Haplic Luvisol (WRB 2006) soil taken from the topmost 0.0-0.3 m soil horizon was put into the pots, having a cylindrical shape, with the height of 35 cm with diameter of 35 cm. While weighing soil batches, the soil was mixed with Norway spruce sawdust (*Picea abies*) (treatments 2, 3, 4, 5), thus sawdust was distributed evenly within the whole pot. 79.62% of sawdust was composed of the size fraction 0.25-3.0 mm, 12.36% represented fraction 3.0-10.0 mm, 1.59% comprised particles larger than 10.0 mm and 6.43% of sawdust consisted of particles smaller than 0.25 mm. The pots with soil and sawdust were placed on saucers able to keep to keep 1000 ml of the flowing soil solution in the period of rainfall. The flowing solution was returned to the pots. The agrochemical parameters of the used soil and sawdust are indicated in Table 1.

The experiment was established according to the method of the random design with four replications and 5 treatments (Table 2). The sawdust doses were selected so that the basic sawdust dose (3.4 t $ha^{-1}$) contained the same quantity of organic substance as 4 t $ha^{-1}$ of straw, which is the quantity recommended to incorporate into soils in Slovakia every year. The dose of 6.8 t $ha^{-1}$ of sawdust (tr. 4) was by 100% higher than the basic dose of sawdust (treatment 2). Sawdust was applied in autumn, when the experiment was set up. It was in October in the first year and in November in the second year. In spring, about 7 days before the sowing of beet, nitrogen was applied in the same dose of 60 kg $ha^{-1}$ to treatments with both sawdust doses. Nitrogen was added as mineral fertilizer, i.e. ammonium nitrate with limestone (27% N), in a dose of 1.67 g of pure nitrogen per pot. The N dose was calculated based on the weight of the soil in the pots. The selected dose complied with the legislation of the Slovak Republic, according to which

Table 1

Chemical parameters of soil and sawdust used in experiment

| Parameters | Unit | Soil | Sawdust |
|---|---|---|---|
| $N_{inorg.}$ | (mg kg$^{-1}$ DM) | 14.3 | 187.5 |
| $N\text{-}NH_4^+$ | | 4.1 | 152.2 |
| $N\text{-}NO_3^-$ | | 10.2 | 35.3 |
| P | | 65.6 | 9.7 |
| K | | 437.5 | 435.8 |
| Ca | | 1053 | 871.5 |
| Mg | | 353.0 | 171.0 |
| $N_{tot.}$ | | 1369 | 806.9 |
| $C_{ox}$ | (g kg$^{-1}$ DM) | 13.4 | 502.3 |
| OM | | 24.2 | 934.3 |
| C:N | – | 9.8:1 | 622.5:1 |
| $pH_{KCl}$ | | 5.98 | 4.35 |
| $pH_{H2O}$ | | 6.27 | 4.75 |

OM – organic mater

the maximum single dose of mineral N fertilizers is 60 kg ha$^{-1}$ N in the soils where the nitrate content in groundwater is higher than 50 mg dm$^{-1}$. The doses of sawdust and nitrogenous fertilizer were calculated in accordance with the hectare application doses per pots. In comparison with manure pot experiments, these doses were fivefold higher (Table 2).

The sowing of sugar beet cultivar Antek seeds took place in the fisrt ten days of April in both years of the experiment. After sowing 10 seeds, the soil surface was covered up evenly with 0.5 kg of siliceous sand. After germination of the first seeds of sugar beet plants, mechanical weeding was carried out. In June, 80 days after sowing, the plants per pot were thinned unified

Table 2

Treatments of the experiment

| Treatments | | | Doses | | Application period |
|---|---|---|---|---|---|
| | | | sawdusts | N | |
| No. | labelling | description | (t ha$^{-1}$) | (kg ha$^{-1}$) | |
| 1 | 0 | control | - | - | - |
| 2 | $Saw_1$ | sawdust | 3.4 | - | autumm |
| 3 | $Saw_1$+N | sawdust+$N_{min}$ | 3.4 | 60 | autumm and spring |
| 4 | $Saw_2$ | sawdust | 6.8 | - | autumm |
| 5 | $Saw_2$+N | sawdust+$N_{min}$ | 6.8 | 60 | autumm and spring |

to three, which continued to grow until the end of the growing season. The experiment was completed in the second ten days of October.

**Analysis of soil and sawdust**

The agrochemical analyses of soil and sawdust before the experiments were made as follows: $NH_4^+$-N by the Nessler's colorimetric method; $NO_3^-$-N by the colorimetric method with phenol - 2,4 disulphonic acid, $N_{inorg.}$ was calculated as the sum of $NH_4^+$-N + $NO_3^-$-N; the content of available P, K, Ca, Mg was determined by Mehlich III extraction procedure (Mehlich 1984). The content of P was determined by the colorimetric method, K and Ca by flame photometry, Mg by atomic absorption spectrophotometry, $pH_{KCl}$ (in solution of 1.0 mol KCl $dm^{-3}$) potentiometrically. The total N content ($N_t$) was determined according to the Kjeldahl method (Bremner 1960), organic carbon content ($C_{ox}$) oxidometrically after oxidation by the Tyurin method (Orlov, Grišina 1985). The content of organic matter (OM) was determined gravimetrically at temperature 550-600°C (Kováčik 1997). For the analysis of bulk density, undisturbed soil cores (100 $cm^3$) were taken from each pot.

**Measurements and analysis during the plant growing season, at the end of the experiment**

Thirty days after sowing, and subsequently 45 days, 80 days and 190 days after sowing, the plant height was measured (length of leaves). The first measurements were done by measuring of the perpendicular distance between the soil surface and the end of the highest leaf. The following two measurements required pulling plants out. On the $80^{th}$ day, 5-7 plants were pulled out from the pot (depending on the number of germinated plants). On the $190^{th}$ day after sowing, 3 plants were pulled out of the pot (the end of experiment). The plants were placed on a pad and the length of the longest leaf of each plant was recorded.

The content of assimilation pigments (chlorophyll *a,* chlorophyll *b*) was also determined on the $80^{th}$ day after sowing (the last ten days of June). The third longest leaf was taken from each removed plant. The pigments were determined in acetonic extract by the spectrophotometric method, using the equations of Lichtenthaler (1987).

In mid-September, a soil sample was taken and the number of nitrogen--fixing bacteria *Azotobacter chroococcum* (*AzChr*) were determined by the plate-dilusion method on Ashby agar (Subba Rao 2005).

On the day of the termination of the experiment, before pulling the plants out of the pots, soil samples were taken, in which the bulk density (Bd), the content of organic carbon ($C_{ox}$) and soil reaction ($pH_{KCl}$) were specified by the methods described above. The root yield of sugar beet was determined by weighing. The following parameters were determined in roots: sugar content (polarimetrically), K content, Na and α-amino N in mmol $kg^{-1}$ of beet pulp (spectrophotometrically), with the help of an automatic line VENEMA (made in Slovakia, by Selekt Bučany, Plc.).

**Statistical analysis**

The results were processed by mathematical and statistical methods, applying the multifactorial analysis of variance (ANOVA). The differences between the treatments were evaluated subsequently by the LSD test at a significance level $\alpha = 0.05$ and in Stathgraphic, version 5.

# RESULTS AND DISCUSSION

A large C and N ratio as well as a significant content of phenols in lignocellulose substances put into soil shortly before planting or sowing crops can cause unequal germination or retardation of plant growth (Kováčik 2014). Our experiment indicates that the application of sawdust caused the retardation of plant growth seven months afterwards. The strongest negative impact of sawdust on the plant growth was evident in the early growth stages of sugar beet (Table 3). On the 30$^{th}$ day after sowing, the plant height

Table 3

Impact of sawdust on height of sugar beet plants

| Treatments | | Sampling / number of days after sowing | | | |
|---|---|---|---|---|---|
| | | I. / 30 | II. / 45 | III. / 80 | IV. / 190 |
| No. | labelling | (cm) | | | |
| 1 | 0 | 3.33*d* | 6.82*e* | 15.92*c* | 18.19*ab* |
| 2 | $Saw_1$ | 1.50*b* | 3.04*b* | 15.47*b* | 18.85*c* |
| 3 | $Saw_1$+N | 2.25*c* | 5.28*d* | 17.74*d* | 18.93*c* |
| 4 | $Saw_2$ | 0.50*a* | 0.70*a* | 10.31*a* | 17.89*a* |
| 5 | $Saw_2$+N | 1.15*b* | 4.90*c* | 15.45*b* | 18.50*bc* |
| $LSD_{0.05}$ | | 0.360 | 0.307 | 0.408 | 0.527 |

$LSD_{0.05}$ – limit of significant differences at the level $\alpha = 0.05$ (LSD test), different letter after a numerical value indicate a statistically significant difference at the level 95.0%.

in treatment 2 (basic sawdust dose) achieved only 45% of the height of the control plants, and on the 45$^{th}$ day – it corresponded to just 44.6% of the control. With the double sawdust dose (treatment 4), the plant height achieved 15% of the height of the control treatment on the 30$^{th}$ day after sowing, and 10.3% on the 45$^{th}$ day after sowing. On the 80$^{th}$ day after sowing, the beet plants in treatments 2 and 4 were still significantly lower in comparison with the plants from the control treatment, although, the differences were proportionally smaller. At the end of the experiment, only the plants from treatment 4 were lower (insignificantly) than the plants from treatment 1. In treatment 4, the double dose of sawdust was used. The plants from treatment 2 were considerably higher than the ones from treatment 1. It is evident that the negative impact of sawdust on the plant hight was only temporary and dependent on the applied dose of sawdust. The higher sawdust dose caused stronger and longer lasting growth retardation.

The data from Table 3 indicate that the spring application of nitrogen into soil containing sawdust before sowing (treatments 3 and 5) had a significant positive impact on the sugar beet growth. On the 30th day after sowing, the beet plants in the treatment 3 were taller by 50% and on the 45th day they were taller by 73.7% than in treatment 2. Similarly, on the 30th day after sowing, the beet plants in treatment 5 were taller by 130% than the plants from treatment 4 and on the 45thday the difference was up to 600%. The statistically significant positive impact of the applied nitrogen on the plant height was recorded almost until the half of the beet growth season (80 days after sowing). At the end of the experiment, the difference between treatments 2 and 3 was insignificant. The difference between treatments 4 and 5 was significant as the negative effect of the double sawdust dose on the plant growth had finished.

Nitrogen applied in the dose of 60 kg $ha^{-1}$ was unable to eliminate the negative impact of both sawdust doses on the beet growth during the first 45 days. Therefore, the height of beet plants in treatments 3 and 5 was lower in comparison with the control treatment. At the end of the experiment, the plants in treatments 3 and 5 were equally tall or taller than in the control treatment. This fact proves the temporary negative impact of sawdust on the plant growth, which we had recorded earlier, and the duration of this effect can be shortened via the application of inorganic nitrogen.

The above findings agree with the observations by other researchers (Pinipaitoon 2011, Bharali et al. 2017), which indicate that simultaneous application of lignocellulose substances and nitrogen has a positive impact on the phytomass formation by crops.

The highest content of total chlorophylls determined in beef leaves on the 80th day after sowing was recorded in the control treatment (Table 4).

Table 4

Impact of sawdust on chlorophyll content in sugar beet leaves on 80th day after sowing

| Treatments | | Chlorophyll | | | |
|---|---|---|---|---|---|
| | | *a* | *b* | *a* + *b* | *a*/*b* |
| No. | labelling | (mg $m^{-2}$) | | | |
| 1 | 0 | 160.98*c* | 72.86*c* | 233.84*c* | 2.21 |
| 2 | $Saw_1$ | 136.11*b* | 60.92*b* | 197.03*b* | 2.23 |
| 3 | $Saw_1$+N | 140.46*b* | 62.04*b* | 202.50*b* | 2.26 |
| 4 | $Saw_2$ | 115.65*a* | 53.14*a* | 168.79*a* | 2.18 |
| 5 | $Saw_2$+N | 118.79*a* | 51.91*a* | 170.70*a* | 2.29 |
| $LSD_{0.05}$ | | 4.905 | 5.376 | 7.960 | |

$LSD_{0.05}$ – limit of significant differences at the level $\alpha$=0.05 (LSD test), different letter after a numerical value indicate a statistically significant difference at the level 95.0%.

The lowest content of total chlorophyll was detected in those treatments where the double sawdust dose was applied (treatments 4 and 5). As there are dependences between the quantity of available nitrogen as well as magnesium, sulphur, phosphorus and other elements in soil versus their content in a plant and the quantity of chlorophyll (Rey-Carames et al. 2016, Wasaya et al. 2017), it is highly possible that the lower content of total chlorophyll detected in treatments 2 and 5 compared with treatment 1 are caused by the biological sorption of these nutrients, resulting in reduced quantities of the available forms of N, P and S in soil.

The content of total chlorophyll we determined is comparable with the one reported by Rochalska (2005). The proportions between chlorophyll *a* and *b* affirm the data of Wang et al. (2009), who claimed that the content of chlorophyll *a* in leaves is higher than chlorophyll *b*. The proportion between chlorophyll *a* and *b* in the treatments was 2.23:1, which is a narrower ratio than detected by Kováčik et al. (2014) in leaves of winter wheat (2.73:1) and winter oilseed rape (2.45:1).

In the early period, the recorded growth retardation and lower content of chlorophylls in leaves of beets growin on soil where sawdust was applied (treatments 2-5, Tables 3 and 4), was manifested slightly in the yield of sugar beet roots (Table 5). Significant differences in yields were caused by the spring application of nitrogen into soils treated with sawdusts (Table 5).

Table 5

Impact of sawdust on parameters of sugar beet yield

| Treatments | | Yield | Sugar content | $\alpha$-amino N | K | Na |
|---|---|---|---|---|---|---|
| No. | labelling | (g pot$^{-1}$) | (g kg$^{-1}$) | (mmol kg$^{-1}$) | | |
| 1 | 0 | 220.73*a* | 172.8*a* | 40.10*b* | 34.80*a* | 1.93*a* |
| 2 | $Saw_1$ | 228.39*a* | 194.9*b* | 36.50*a* | 39.60*b* | 2.07*ab* |
| 3 | $Saw_1$+N | 455.71*c* | 172.3*a* | 35.80*a* | 38.60*b* | 2.09*ab* |
| 4 | $Saw_2$ | 171.95*a* | 195.0*b* | 37.20*a* | 39.70*b* | 2.15*b* |
| 5 | $Saw_2$+N | 348.10*b* | 178.5*a* | 37.00*a* | 38.90*b* | 2.17*b* |
| $LSD_{0.05}$ | | 64.811 | 9.58 | 2.24 | 2.93 | 0.17 |

$LSD_{0.05}$ – limit of significant differences at the level $\alpha$ = 0.05 (LSD test), different letter after a numerical value indicate a statistically significant difference at the level 95.0%.

The differences between treatments 3 and 5 were not considerable, although they suggest that the dose of nitrogen should be increased as a dose of sawdust is higher. The lowest beet root yield was achieved in the treatment where sawdust was applied in the highest dose (tr. 4). These findings confirm the data obtained by Kováčik (2014), where high doses of lignocellulose substances led to yield decreases. Similarly, the information presented in this paper is confirmed by Xie et al. (2017), who materials with the high C:N sorportion should be added to soil in combination with nitrogen.

The application of sawdust (treatments 2 and 4) increased significantly the sugar content of sugar beet roots, and the double dose had an impact on the sugar content similar to the one produced by the basic dose of sawdust (Table 5). The addition of inorganic nitrogen to sawdust (treatments 3 and 5), in comparison with sawdust application alone (treatments 2 and 4) decreased considerably the sugar content of sugar beet roots. This was expected because it agrees with the knowledge about the impact of N fertilizing on the sugar content in sugar beet roots (Halvorson et al. 1978, Tsialtas, Maslaris 2005).

When comparing the sugar content recorded in the control treatment (treatment 1) with the one obtained in treatments 3 and 5, it is apparent that when sawdust is applied together with inorganic N there is no decrease in the sugar content of sugar beet roots in comparison with beetroots from untreated soil. This emphasizes that the application of sawdust in doses 3.4 and 6.8 t $ha^{-1}$ and the following application of inorganic N in the dose 60 kg $ha^{-1}$ are a measure that inceases significantly the yield of sugar beet roots while maintaining the sugar content.

The application sawdust alone (treatments 2 and 4), but also with inorganic nitrogen (treatments 3 and 5), decreased considerably the content of $\alpha$-amino N in beet roots, which is a positive outcome. The addition of nitrogen to sawdust (treatments 3 and 5) did not result in any change of the content of α-amino N, which - along with the highest values of the sugar content in treatments 3 and 5 – is the evidence that the selected dose of N was suitable and could even be higher. The lack of any increase in the $\alpha$-amino N content after the application of nitrogen is not a common finding. On the contrary Hoffmann (2005) claims that after the application of inorganic N, a rise in α-amino N values was recorded. The content of $\alpha$-amino N varied from 35.80 to 40.10 mmol $kg^{-1}$.

The results of our determinations show that the application of sawdust can improve the quality of sugar beet roots by increasing the sugar content and decreasing the content of α-amino N. However, the application of sawdust can increase the content of potassium and sodium, which is an undesirable effect (Table 5). The increase of potassium achieved the level of 10.9-14.1% and that of sodium 7.3-12.4%. The increase of K and Na in beet roots is the consequence of the increase of available nutrients in soil, which begins four months after the application of sawdust to soil. During the first four months after the application of sawdust particles, the decrease in available nutrients in soil was detected as a result of their immobilization, i.e. biological sorption (Kováčik, 2013)

The application of sawdust, bark or any other organic substance has a significant impact on the frequency and composition of the soil microflora (Overholser 1955). Adding sawdust to soil in the quantities of 3.4 and 6.8 t $ha^{-1}$ increased considerably the number of the nitrogen-fixing bacterium *Azotobacter chroococcum* (Table 6). The differences in the frequency of bacte-

Table 6

Impact of experimental treatments on the number of nitrogen-fixing bacteria (*Azotobacter chroococcum*) and selected soil parameters

| Treatments | | *Azotobacter chroococcum* | Bulk density | $C_{ox}$ | $pH_{KCl}$ |
|---|---|---|---|---|---|
| No. | labelling | (CFU x $10^3$ $g^{-1}$ dry soil) | (g $cm^{-3}$) | (g $kg^{-1}$) | |
| 1 | 0 | 433.25*a* | 1.39*c* | 1.29*a* | 6.01*c* |
| 2 | $Saw_1$ | 549.85*b* | 1.27*a* | 1.33*b* | 5.96*c* |
| 3 | $Saw_1$+N | 586.25*b* | 1.36*b* | 1.41*c* | 5.78*b* |
| 4 | $Saw_2$ | 561.90*b* | 1.25*a* | 1.40*c* | 5.81*b* |
| 5 | $Saw_2$+N | 620.80*b* | 1.34*b* | 1.46*d* | 5.64*a* |
| $LSD_{0.05}$ | | 76.945 | 0.028 | 0.034 | 0.129 |

CFU – colony forming unit, $LSD_{0.05}$ – limit of significant differences at the level $\alpha$=0.05 (LSD test), different letter after a numerical value indicate a statistically significant difference at the level 95.0%.

ria between the treatments of with the lower and higher sawdust doses were insignificant. The recorded positive impact of sawdust on the count of nitrogen-fixing bacterium *Azotobacter chroococcum* agrees with the current knowledge on this issue, for example Mockeridge (1915) and Kováčik (2014) claim that one of the essential prerequisites for bacteria *Azotobacter chroococcum* to live is the sufficient amount of easily mineralized organic matter in soil. Similarly, the addition of nitrogen to sawdust (treatments 3 and 5) did not have any considerable impact on the frequency of the bacteria *AzChr*. We can state that the application of the higher dose of sawdust and the application of inorganic nitrogen tended to increase the number of bacteria *AzChr*. Similarly, Abdel-Aziez et al. (2014) claim that the occurrence of the nitrogen-fixing bacterium *Azotobacter chroococcum* in the world soils is determined by the application dose of inorganic N and the season of the year, and that the response of particular phyla of bacteria to the environmental conditions is different.

The finding that there was a significant increase in the number of nitrogen-fixing bacterium *AzChr* in soil after the application of sawdust is important in terms of the possibility of increasing the soil content of N as well as for the health of plants. This bacterium can fix atmopheric nitrogen and has the inhibitory, antagonistic impact on the agents of the genera *Fusarium, Alternaria and Penicillium,* which cause serious mycoid plant diseases (Lakshminarayana 1993, Kováčik 2014). Therefore, rather than trying to remove crop residues (lignocellulise substance) from fields, farmers should try to create the best conditions for the development of this bacterium, for example by ploughing in sawdust.

The content of organic carbon at the end of the experiment was, as expected, the lowest in the control treatment, where sawdust was not used (Table 6). The application of the higher dose of sawdust resulted in a higher content of $C_{ox}$ than after soil was treated with the lower dose of sawdust (treatments 2 and 4). The addition of nitrogen to sawdust (treatments 3 and 5) significantly increased the content $C_{ox}$. This is probably related to the formation of a more massive root system in treatments 3 and 5 than in treatments 2 and 4. The highest content of organic carbon was detected in treatment 5, which emphasizes the rationality of the widespreadue of sawdust and inorganic nitrogen.

When we compare the pH soil values determined at the end of the experiment, it becomes evident that only the higher dose of sawdust (treatment 4) was able to have a significant impact on the soil reaction. Sawdust had an acidifying effect. The addition of commercial nitrogen to sawdust (treatment 3 versus 2 and treatment 5 versus tr. 4) decreased considerably the soil reaction. The lowest pH value was detected in the treatment where the highest dose of sawdust was applied along with inorganic nitrogen (treatment 5). Sarkar et al. (2010), Liu et al. (2010), Głąb and Gondek (2014) arrived at similar conclusions, claiming the decrease of the soil pH value after the application of mineral N fertilizer alone or in combination with manure and straw.

## CONCLUSIONS

1. The initial retardation in sugar beet growth caused by the autumn application of sawdust in the doses of 3.4 t $ha^{-1}$ and 6.8 t $ha^{-1}$ did not result in a significant decrease of sugar beet yield.

2. The use of sawdust significantly reduced the *α*-amino nitrogen content in sugar beet roots and improved some soil parameters. The number of bacteria of the genus *Azotobacter chroococcum* and the amount of organic carbon increased. The bulk density decreased.

3. The addition of nitrogen in the dose of 60 kg $ha^{-1}$ to sawdust before beet sowing:

- lowered or even eliminated the negative impact of sawdust applied alone on the beet growth and the content of total chlorophyll,
- increased more significantly the number of bacteria of the genus *Azotobacter chroococcum* and the quantity of organic carbon in soil than the application of sawdust alone.

4. The autumn application of sawdust in the tested doses together with the spring application of inorganic N in the dose 60 kg $ha^{-1}$, in comparison with the untreated soil, increased significantly the sugar beet root yield, preserved its sugar content, decreased the content of α-amino N and has a positive impact on the content of organic carbon in soil, on the number of bacteria of the genus *Azotobacter chroococcum* and on the bulk density of soil, which decreased.

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