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A Study on the Influence of Sludge WWTP from the Paper Industry on Growth and Development of Zea mays (Poaceae)

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Abstract. The sludge, which is produced from wastewater treatment facilities features concentration of harmful substances, including heavy metals. Therefore, before being used in agriculture, it is necessary to process the sludge in order to meet the requirements of the regulation concerning sludge utilization. The purpose of this study was to explore the possibility of growing corn using sewage sludge from the paper industry. A two-year experiment was performed with „Kneja 613"variety, which was grown in the field and fertilized by WWTP sludge, two standards - 1000 and 1500 kg/dka. The experiment was displayed on alluvial soil near the town of Stamboliyski (Southern Bulgaria). The following properties were monitored: germination, third and fourth leaves growth phase, phase of fifth and sixth leaves growth, stem thickness, number of the cobs and cob length. The results indicate the dependence of the amount of the deposited precipitate. The growth and development of plants grown at fertilization with 1500 kg/dka sludge showed much higher values of biometric properties than the control.

Key words: sludge, WWTP, wastewater, paper industry, corn.

Introduction

Nowadays sludge treatment in the Republic of Bulgaria is mainly carried out through its regulated or sometimes unregulated disposal. The sludge always brings risks for the environment and human's health when relevant measures for sludge dewatering, stabilizing, storage and/or utilization are not taken (MOEW, 2011). Sewage sludge (biosolids) is a by-product of the treatment of municipal wastewater. As a result of the implementation in 2005 of the Urban Waste Water Treatment Directive 91/271/EEC, the generation of sewage sludge has increased significantly. In Europe, the total amount of sludge generated by urban waste water treatment plants has increased from 5.5 million (1992) to 10 million tons dry matter in 2007 (Carbonell *et al*., 2009).

The sludge itself can be valuable organic supplementary reserve, which can find a wide application in agriculture for improving soil qualities and land reclamation as well. However, the sludge, which is produced from wastewater treatment facilities, features concentration of harmful substances, including heavy metals. Therefore, before being used in agriculture, it is necessary to process the sludge in order to meet the requirements of the regulation concerning sludge utilization.

The objective of this study was to analyze the possibilities for corn farming helped with sludge of the paper industry.

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Material and Methods

A two-year experiment was performed with „Kneja 613“variety, which was grown in the field and fertilized by waste water treatment plant (WWTP) sludge. The used sludge quantities were decided after careful examination of the Bulgarian Regulation for Sludge Treatment and Methods of Utilization in Farming, approved with Ministerial Order 339/12.14.2004 (BAFS, 2004).

The sludge analysis was carried out in the laboratory of the Executive Environment Agency (ExEA) in the city of Plovdiv, Bulgaria. The experiment was executed in two variants, four times each, with a test sample in alluvial soils. Twelve test fields of 50 m^2, with a distance of 50 cm between them were used. Before the corn sowing the soil was prepared. It was ploughed deeply and harrowed.

Variants:

- Variant I - Control (without use of sludge)
- Variant II - 1000 kg/dka sludge
- Variant III - 1500 kg/dka sludge

Second harrowing was carried out after the sludge was implemented in to the soil. The test fields ware arranged in rows with a 75 cm distance between them. Two corn kernels were planted at a depth of 6-8 cm at every 20 cm along the rows. The following properties were monitored: germination, third and fourth leaves growth phase, phase of fifth and sixth leaves growth, stem thickness, number of the cobs and cob length. The plants were earthed up twice and watered seven times during the vegetation period. The experimental soil was put to analysis in the Agricultural Chemistry and Soil Science Department at Agricultural University of Plovdiv. The following analysis methods were applied to it:

- Mechanical composition analysis by means of FRITISH vibratory sieve shaker
- pH in H_2O – potentiometric ph measurement
- Humus content by the method of Turin
- K - determined in salty acid-based extraction of 2n HCL
- Movable phosphates were determined by Egner-Riem method (DL-method)
- Ammonium and nitrate N in an extract of 1% KCL
- Determining carbonate concentration level by Schibler

Results and Discussion

The results on the chemical analysis of the activated WWTP sludge are presented in Table 1.

Table 1. Results on the hemical analysis of the activated WWTP sludge.

Parameter	Value	Permissible values
pH	8.07	>7.4
Organic substance	71.69%	-
Solid substance	42.58%	-
Escherichia coli	0.1 g	> 1 g
Salmonella spp.	not available	not allowed in 20 g
Clostridium perfringens	0.001 g	> 1 g
Cd	0.46 mg/kg solid substance	30.00 mg/kg solid substance
Cu	1.6 mg/kg solid substance	1600.00 mg/kg solid substance
Ni	6.13 mg/kg solid substance	350.00 mg/kg solid substance
Pb	6.15 mg/kg solid substance	800.00 mg/kg solid substance
Zn	50 mg/kg solid substance	3000.00 mg/kg solid substance
Hg	0.05 mg/kg solid substance	16.00 mg/kg solid substance
Cr	7.46 mg/kg solid substance	500.00 mg/kg solid substance
As	< 0.05 mg/kg solid substance	25.00 mg/kg solid substance
Nitrogen /common form/	11.38 mg/kg solid substance	-
P /P_2O_5/	1 mg/kg solid substance	-
K /common form K_2O/	340 mg/kg solid substance	-
polycyclic aromatic hydrocarbons	< 0.01 mg/kg solid substance	6.20 mg/kg solid substance
Polybrominated biphenyls	< 0.005 mg/kg solid substance	1.0 mg/kg solid substance

The analysis prove that the values did not exceed the regulated permissible values; moreover they were far below them. According to LOGAN *et al*. (1997) the high content of organic matter and substantial N and P concentrations suggest that the sludge can be used as a fertilizer in agriculture or as a regenerator for soil. In fact, decomposition of organic manures produces some organic acids such as fulvic, humic and carbonic acid, which lead to solubilize soil nutrients and increase their availability and supply for plant uptake (DAHDOH & EL-HASSANIN, 1993).

Table 2 presents the results on the physical and chemical analysis on the soil for discharge of the first and second year.

During the second year an increase of the macro elements content in the soil was observed. This increase was probably due to the introduced activated sludge. Many studies have demonstrated the positive effect that sewage sludge or sludge compost application has on corn, as well as other forage yields and soils (CATROUX *et al*., 1981; HORNICK *et al*., 1984; DAVIS *et al*., 1985; WARMAN, 1986; TIFFANY *et al*., 2000). During the corn farming the germination was registered on the 5th day after the corn planting.

Table 3 presents the number of the germinated corn kernels for the two years test period. The results in the table show that Variant III had most germinated corn kernels, followed by Variant II. The least number of germinated corn kernels showed the test sample.

The increased number of germinated seeds show the positive effects of the offered sludge amounts. As stated by (HORNICK *et al*., 1984) in their study the higher values in the second year are associated with nutrients accumulation in the soil. In addition, as the sludge tend to absorb more moisture from the soil, the corn kernels, which were planted in the test fields containing more sludge germinated faster.

The 3rd and 4th leaf growth phase results on the 15th day after the kernel planting are presented in Table 4. On the 20th day after the kernel planting an observation on the average growth phase of the plants and their height was carried out (Table 5).

Table 2. Results on the physical and chemical analysis of the soil.

Soil type	Moisture %	Humus %	Nitrogen /common form/ %	$CaCO_3$, %	pH in H_2O	Depth, sm	Nitrogen /mineral form/ $NH_4 + NO_3$ mg/kg	P_2O_3 mg/100g	K_2O mg/100 g
Alluvial meadow soil - 1st year	4.48	1.7	0.25	7.48	7.8	A_I 0 - 10	13.4	12.4	26
Alluvial meadow soil - 2nd year	5.12	1.9	0.30	7.37	7.9	A_I 0 - 10	14.2	12.6	27.1

Table 3. Results on germinated corn kernels.

Variant	% germinated corn kernels		% compared to the test sample	
	1st year	2nd year	1st year	2nd year
Variant I	60	85	100	100
Variant II	80	98	134	112
Variant III	95	100	158	118

The results show that the corn planted in the test sample soil was in the 4th leaf growth phase. During the first year 20% of the corn plants of Variant II were in the 5th leaf growth phase. During the second year of the experiment, the percentage of the corn plants in the 5th leaf growth rose with 10. Variant III had highest percentage of plants in the phase of 5th-6th leaf growth - 55% in the first year and 60% in the second year, respectively. Upon the sludge implementation the plants' growth was faster in both years. In Variant III for both years the emergence of 5th - 6th leaf considerably exceeded the phase of 3rd - 4th leaf. The results for the plant growth observed on the 30th day were relative to the ones for the phase of germination. Illustrative are the results of the second year – the increase in Variant II is with 1.6 cm and in Variant III – with 3.9 cm compared with the control.

After the corn harvests, carried out on 31.08.2013 and on 20.09.2014, the following results were obtained - stem height, stem thickness, cob length, number of cobs. Figure 1 shows that the parameters for plant growth of Variant III are much better than the parameters of the test sample variant.

From the results on the average stem height it is notable that the highest plants were from Variant III. The growth for the first year was with 20 cm more and for the second – with 25 cm, respectively. The results on the stem thickness also show the same trend. Once again the highest values are reported in Variant III during the first and second year. After harvesting the cob growth was determined. Similarly, the registered growth was bigger in Variant III compared with the control – 6 cm for the second year. In terms of the average number of cobs the increase was with 0.5 numbers for Variant II during both years. For Variant II this number increased with 0.5 for the first year and with 1 for the second, respectively. In economic point of view, the number of cobs of a single corn plant is the most important parameter. According to FERNANDEZ-LUQUENO *et al*. (2009) the increasing mass of straw in the second year is comparable to the first year as a result of the already high supply of N; when water supply is adequate, high levels of N can over-stimulate plant growth, and thus biomass accumulation.

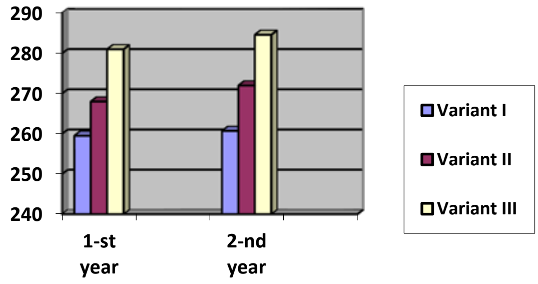
Overall, the present study does not include results on the harvest data. Therefore, further research in this particular area should be carried out in order to get better data on the possibilities to use paper industry sludge in agriculture.

Table 4. Results on the third and fourth leaf growth phase - the 15th day after the kernel planting.

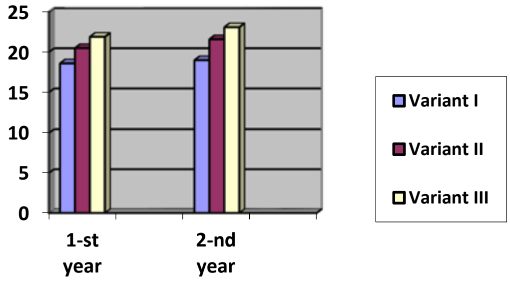
Variant	% plants third and fourth leaf growth phase 1st year	% plants third and fourth leaf growth phase 2nd year
Variant I	90	87
Variant II	95	98
Variant III	100	100

Table 5. Results on the prevailing development phase.

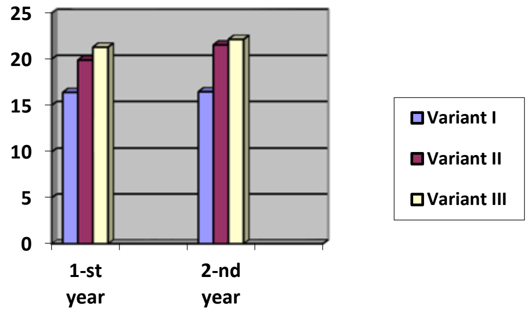
Variant	% prevailing growth phase		Plant height (cm)	
	1st year	2nd year	1st year	2nd year
Variant I	100% - 3rd —4th leaf	100% - 3rd —4th leaf	28.10	28.75
Variant II	80% - 3rd —4th leaf 20% - 5th —6th leaf	70% - 3rd —4th leaf 30% - 5th —6th leaf	29.55	30.35
Variant III	45% - 3rd —4th leaf 55% - 5th —6th leaf	40% - 3rd —4th leaf 60% - 5th —6th leaf	31.65	32.65



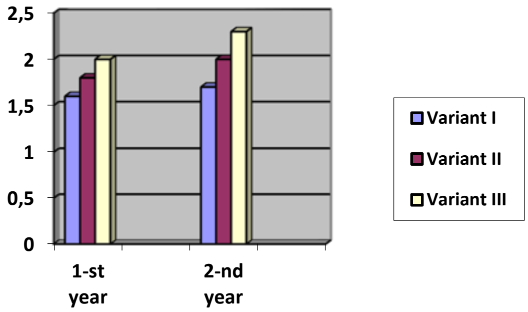
a. Stem height /cm/



b. Stem thickness /mm/



c. Cob length /cm/



d. Number of cobs

Fig. 1 (a, b, c, d). Plant biometrical parameters.

Conclusions

On the ground of the obtained results of the agricultural experiment carried out with „Kneja 613" variety, grown in the field and fertilized by WWTP paper industry sludge, we can conclude:

1. It was confirmed for the first time the opportunity of corn farming in fields fertilized by sludge produced by paper industry wastewater plant.
2. It was found out that the corn fertilized with 1500 kg/dka sludge grew faster.
3. The plants grown in the soil treated with higher sludge content had faster growth and development.
4. Under these conditions the plants were higher with thicker stems, cob length and number.

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