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A Study on the Effects of Pulp and Paper Industry Sludge on Sweet Corn Crops Grown in Containers

Daniela Krasteva – Malinova*[1], Ventsislava Vancheva[2], Ekaterina Valcheva[3]

1 - University of Plovdiv "Paisii Hilendarski", Faculty of Biology, Department of Ecology and Environmental Conservation, 24 Tsar Assen Str., BG-4000 Plovdiv, BULGARIA
2 – Agricultural University, Faculty of Plant Protection and Agroecology, 12 Mendeleev Blvd., BG-4000 Plovdiv, BULGARIA
3 - Agricultural University, Faculty of Plant Protection and Agroecology, 12 Mendeleev Blvd., BG-4000 Plovdiv, BULGARIA
* Corresponding author: daniela1975@abv.bg

Abstract. Sludge which are produced from waste-water treatment facilities represent a serious environmental problem in terms of their storage. However, they also represent an organic reserve, biomass rich in macro and micronutrients for soils. Thus, sludge could be used to recover the balance of organic matter in soils. We aimed in the present study to determine the influence of sludge produced from a pulp factory on the development of mays (*Zea mays*) in laboratory conditions.

Keywords: sludge, corn, farming, soil

Introduction

Sludge coming from wastewater treatment facilities is an environmental issue in regard with its production, disposal and reuse. On the other hand, it is an organic soil conditioner, containing high concentration of macro- and microelements (ELMEDIA, 2011). Therefore, sludge could successfully be used for obtaining organic balance in soils (EEA, 2011).

The objective of this research is to estimate the effects of the active sludge produced by pulp and paper industry, wastewater plant on the sweet corn farming in containers.

Materials and Methods

To carry out the experiments an activated sludge material taken from a wastewater treatment plant of a pulp and paper mill was provided. It was previously dewatered on the sludge drying bed next to the plant.

Out coming chemical analyses on the results of the samples was carried out according to the requirements of the Bulgarian Regulation for Sludge treatment, management and utilization in farming, approved with Ministerial Order and issued in State Gazette with Regulation number 339/14.12.2004 - Ordinance Sludge treatment, management and utilization in farming (Ministry of Agriculture and Food, 2004).

The experiments were performed with sweet corn (*Zea mais*) var. "Kneja 613". They were executed in four variants, four times each, with different sample soil.

Each container had capacity of 1 kg.

- Variant I – 100% soil /reference/
- Variant II – 75% soil / 25% sludge
- Variant III – 50% soil / 50% sludge
- Variant IV – 25% soil / 75% sludge

The bottoms of the containers covered with a layer of 100 g felt and after that the mixtures were laid over the felt.

Three grains of sweet corn were planted in every container. They were sowed at depth from 4 to 6 cm. To determine sludge permeability and water retention capacity, the containers were kept moist to 50% and measured every 15 minutes after they had been watered. The weigh measurement showed the following results:

- Variant I – 1.5 kg
- Variant II – 1.4 kg
- Variant III – 1.35 kg
- Variant IV – 1.25 kg
- Variant V – 1.15 kg

The corn samples were planted in a greenhouse on 1st May, 2013. They grew under well-controlled environmental conditions: optimal humidity and ambient temperature between 27-28°C. The moisture was kept at a constant level by regular watering up to the original weight.

The following processes were monitored: germination, first and second leaf growth, third and fourth leaf growth and the stage of fifth and sixth leaf growth.

The experimental soil was put to analysis in 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 determination by the method of Turin*
- *K content was determined in salt- 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 method*

Results and Discussion

Parameters of activated sludge are presented in Table 1.

Table 1. Chemical analysis of activated sludge

Parameter	**Value**
pH	8.07
Organic substance	71.69%
Dry solid	42.58%
Escherichia coli	0.1 g
Salmonella spp.	lack
Clostridium perfringens	0.001 g
Cd	0.46 mg kg^{-1} dry solid
Cu	11.6 mg kg^{-1} dry solid
Ni	6.13 mg kg^{-1} dry solid
Pb	6.15 mg kg^{-1} dry solid
Zn	50 mg kg^{-1} dry solid
Hg	<0.05 mg kg^{-1} dry solid
Cr	7.46 mg kg^{-1} dry solid
As	<0.05 mg kg^{-1} dry solid
Nitrogen /total/	11.38 mg kg^{-1} dry solid
Phosphor /P_2O_5/	1341 mg kg^{-1} dry solid
Potassium /total K_2O/	340 mg kg^{-1} dry solid
PAH /polycyclic aromatic hydrocarbon/	<0.01 mg kg^{-1} dry solid
PCB /polybrominated biphenyl/	<0.005 mg kg^{-1} dry solid

During the preparation of the experimental variants, and namely soil, sludge and soil/ sludge ratio, it was observed that the sludge featured bigger volume and took bigger space in the containers. It also had less density and featured better permeability than the soil and better aeration. Although the sludge was more permeable, it retained the moist longer.

Table 2. Physical and chemical properties

Moisture, %	Humus, %	Total Nitrogen, %	$CaCO_3$, %	pH in H_2O
4.48	1.7	0.25	7.48	7.8

Table 3. Agrochemical parameters

Soil Type	Depth, cm	Min. Nitrogen $NH_4 + NO_3$ mg kg^{-1}	P_2O_3 mg per100g	K_2O mg per100g
Alluvial meadow soil	A_I 0 – 10	13.4	12.4	26

According to the World Soil Classification developed by FAO alluvial meadow soils relate to molikovite fluvisoles class.

Alluvial soils are soils deposited by running water. They feature well-formed humus accumulative horizon, which gradually transforms to C – type horizon.

These types of soil are widely spread in Bulgaria. They are located in the central part of river valleys right after the alluvial meadow soils towards the first land off shore terrace. Such soils exist also at the first low off shore terrace. They are divided in two types: calcic and non – calcic ones. Further they are classified according to the depth of soil graying (swallow – 100-150 cm, average deep – 150-200 cm, deep – bellow 200 cm.)

Humus horizon as well as the fixed soil layers is colored in brown with different intensity of the color shades. The humus horizon is about 30-40 cm high.

The examined soils had an average sandy – clay composition. They featured high permeability, average water retaining capacity and relatively good aeration capacity.

Humus content in the upper horizon was 1.7 %. Carbonates have been detected at the surface. Their availability explained the slight alkaline reaction (see Table 1) – pH=7.8.

Regarding the microelements, their content in the examined soil samples was evaluated as poor – regarding the nitrogen, as average – regarding the phosphor, and good – regarding the potassium. (see Table 2)

They are considered being beneficial in regard with their physical and chemical qualities and are the most fertile soils in the municipality land. Being friable and not very flexible or clayey, these soils show slight resistance when processing. They are suitable for farming serials.

The seeds sprouted on the sixth day after their sowing (Table 4)

Table 4. Seed germination

Variant	Number of containers	Number of sprouts	% sprouts
Variant I	4	11	92
Variant II	4	12	100
Variant III	4	8	67
Variant IV	4	3	25
Variant V	4	2	17

The results in the table show that the biggest number of sprouts was observed at Variant II, followed by Variant III. The experimental Variants IV and V obtained little number of sprouts. Therefore, it can be concluded that the increasing the sludge content in soil delays the germination/sprouting.

Next table shows the records made on 9th May, 2013 when the appearance of 1st and 2nd leaves was observed (Table 5).

Table 5. Number of sprouts at the 9th day of the experiment

Variant	Number of containers	Number of sprouts
Variant I	4	12
Variant II	4	12
Variant III	4	12
Variant IV	1 1 2	2 1 0
Variant V	2 1 1	4 1 0

As the table shows, the results in Variant IV remained (See Tables 4 and 5).

Observation on the 3rd and 4th sprout stage was recorded on 26th May, 2013 and the results are shown on Table 6.

The report shows that all the sprouts in the soil, which was used as a reference, were in a stage of the 4th leaf. In Variant II, there were plants in 5th leaf stage. In Variant III we observed massive germination of 5th leaf. There were least number of sprouts in Variant V, however the sixth leaf of the plants was best formed.

Table 6. Number of sprouts at the 25th day of the experiment

Variant	Number of plants	Stage of growth
Variant I	All the plants are in stage of 4th leaf	
Variant II	10 2	4th leaf stage 5th leaf stage
Variant III	All the plants are in stage of 5th leaf	
Variant IV	1 2	4th leaf stage 5th leaf
Variant V	1 1 1	4th leaf stage 5th leaf stage 6th leaf stage

The last record on the growth stages was done on 30th May, 2013. The records showed that most of the plants were in their stage of development 5th-6th leaf. More precisely: Variants I and II had plants in 5th leaf stage; Variants IV and V – plants in 6th leaf stage, respectively.

At true leaf stage we carried out measurements of the plants height, stems length and thickness (Fig. 1).

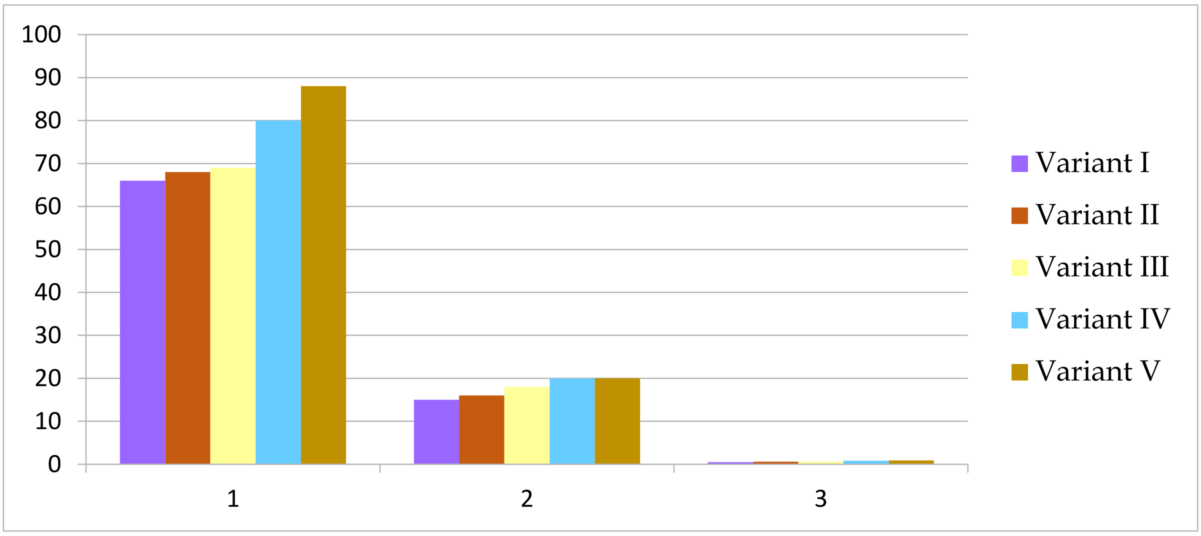

Fig.1. Biometrical data about the plants grown in containers (cm)

The records show that the plants in Variants IV and V obtained the most favorable characteristics. They stood out from the rest of the variants for having the highest plants with the longest and thickest stems.

From the obtained results, it was concluded that the plants, which grew in soils with greater sludge content, grew faster, had greater biomass and much better developed root system. The root system development was proportional to the sludge proportion in the soil.

Conclusions

As a results of the experiment carried out with corn seeds of sort "Kneja 613", grown in a soil and active sludge with content ratio: 3:1; 1:1; 1:3 and 100% sludge, it was concluded that:

1. Plants in Variant II and III grow earlier in comparison with the rest of variants, however Variants IV and V has faster growth.

2. At the time of growth assessment of 3rd – 4th leaf stages, Variant III showed massive appearance of fifth leaf. Variant V showed least number of sprouts; however, the same plants had the best-formed sixth leaf.

3. With best plant development/ growth are Variants IV and IV. They stand out from the rest of the Variants for having the highest plants with the longest and thickest stems.

4. Plants, which grow in soils with greater sludge content, grow faster, have greater biomass and much better developed root system. Root system development is proportional to the sludge proportion in the soil.

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