USE OF INDUSTRIAL BY-PRODUCTS AND BIO-EFFECTORS IN CROP PRODUCTION

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Abstract: The utilization of bio-effects (BEs), including various plant growth promoting microorganisms has been addressed to the sustainable agriculture.
In this study, a combination of a bacterial BE (Proradix WG) based on *Pseudomonas* sp (DMSZ 1314) with root growth promoting and pathogen suppressive properties and a *Laminaria* seaweed extract (NEMATEC) were tested to investigate the nutrient acquisition of maize (cv Colisee) from sewage sludge and sewage sludge compost as recycling products from poppy shell-based alkaloid production on a low P organic farming soil (clay loam pH 6.8, 20 mg CAL-P/kg soil). The experiment was conducted in pots (3 kg soil) under controlled growth chamber conditions with phosphate (P) as major limiting nutrient.
All organic fertiliser amendments had a positive effect on plant growth but did not reach the values of a full mineral P fertilisation. In the sewage sludge compost treatment, plant biomass production and particularly root length were increased by inoculation with Proradix while no effects were detectable in the sewage sludge treatment. No further improvements could be observed by additional inoculation with the seaweed extract NEMATEC. The results suggest that a proper selection of organic fertilisers with compatible BEs is a pre-requisite for successful strategies to improve utilisation efficiency of organic recycling fertilisers.

Keywords: bio-effectors, compost, maize, seaweed-extract, sewage sludge

Introduction

Plant growth promoting rhizobacteria (PGPR) have been studied for long time. Many studies examined the effect of bacteria strains on plant growth, yield and different crops to save fertilizers, or to diminish pollution caused by agrochemicals, or, both (Lévai 2005; Kennedy et al., 2004; Tóth et al., 2013). Moreover, commercial bio-preparations (or bio-effectors so called BEs) support the healthy plants and mineral uptake. Given the negative environmental impact of artificial fertilizers and their increasing costs, the use of beneficial soil microorganisms such as PGPR, recycling organic fertilizers, fungi and alga (seaweed) extracts or preparations for sustainable and safe agriculture has increased during the last couple of decades (Tóth et al., 2015).
Phosphorus is one of the major plant nutrients limiting plant growth. Most of the essential plant nutrients, including phosphorus, remain in insoluble form in soil (Malviya et al., 2011). A large portion of inorganic phosphates applied to soil as fertilizer is rapidly immobilized after application and becomes unavailable to plants (Mikanová and Nováková, 2002). Thus, the insoluble and sparingly soluble forms of phosphorus are important aspect of increasing soil phosphorus availability. Seed or soil inoculation with phosphate-solubilizing bacteria is known to improve solubilization of soil phosphorus and applied phosphates resulting in higher crop yields (Nisha et al., 2014).

In our study, a combination of a bacterial BE with seaweed extract were tested to investigate basic plant physiological parameters and nutrient acquisition of maize from sewage sludge and sewage sludge compost as recycling organic fertilizers. Our hypothesis was that the BE and seaweed extract improve the P-uptake from recycling organic fertilizer, so the P-deficiency could be modify.

Materials and methods

The experimental plant was maize (*Zea mays* L. cv. Colisee). The experiment was conducted in pots (3 kg soil) under controlled environmental conditions. The seedlings were grown for 40 days in a growth chamber at 25 °C/18 °C (light/dark, 16:8 h) under a light intensity of 300 μmol $m^{-2}s^{-1}$.
Field soil free of postharvest residues was obtained from the plough depth (top 20 cm) in Kleinhohenheim (research station of Hohenheim University, Stuttgart, Germany) a low P organic farming soil (clay loam pH 6.8, 20 mg CAL-P/kg soil). The soil was moisture until 60 % WHC, water losses was replacement after gravimetric determination (every other day, later on every day).
The following basal fertilization was applied for control (+): 100 mg N kg^{-1} soil, 150 mg K kg^{-1} soil, 50 mg Mg kg^{-1} soil, 100 mg P kg^{-1} soil. No added any additional fertilization to control (-).
The sewage sludge compost and sewage sludge originated from poppy shell-based alkaloid production (ALKALOIDA Chemicals Co. Ltd., Hungary). The sewage sludge was mixed into various kinds of shavings, as bulking agents, and used as a covering material for waste rock piles. The applied amount of compost and sewage sludge was calculated based on their total P content (compost: 10,063 ppm P, sewage sludge: 21,289 ppm P).
Seaweed extract comes from BioAtlantis NEMATEC® (Tralee, Ireland), it contains extract of *Laminaria* species of brown algae. The product is proposed to improve root growth in soils with plant pathogenic nematodes and to increase abundance of beneficial nematodes in the soil. The SWE was used as weekly foliar application (4 ml/plant/week) after germination.
Proradix WG (Sourcon Padena, Tübingen, Germany) contains *Pseudomonas sp.* (DSMZ 13134), which populates the roots after application. The bacterium provides protection and an optimal water and nutrient uptake through various mechanisms of action. The incubation was two weeks, 10^{-9} CFU kg^{-1} soil.

Results and discussion

Root growth and development are critical for early phosphorus uptake by plants since P is relatively unavailable and immobile in many soils (Barber, 1984). Conversely, root growth depends on the P status of the plant. Modelling P uptake by plants therefore requires a good knowledge on how this P plant status affects root growth parameters which are relevant for P uptake.
The total root length (Figure 1.) and fractional (according to diameter) root length were measured at the end of experiment (40 DAS= 40 days after sowing). The total root

length significantly increased at the compost, compost+BE, sewage sludge+BE, sewage sludge+BE+SWE treatments compared to the control (-) P-deficiency treatment.
The same tendency was observed at the fractional root length. Moreover, the root length of >0.8-0.4 mm diameter root fractions are significantly increased at the sewage sludge+BE+SWE treatment compared to the control (+) (results are not shown).
Using a P starvation experiment, Anghinoni and Barber (1980) observed increased root length and dry weight on 12 days old maize when the duration of the P starvation increased between 1 and 6 days. In our experiment, the dry weight of root of maize significantly increased at sewage sludge+BE and sewage sludge+BE+SWE treatments compared to the control (-) and control (+) (Figure 3.).

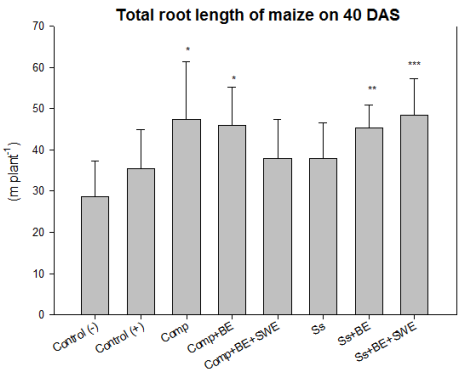

Figure 1. Total root length of maize treated with sewage sludge compost (Comp), sewage sludge (Ss), Proradix (BE) and seaweed extract (SWE). Significant difference compared to the control (-): *p<0.05; **p<0.01; ***p<0.001.

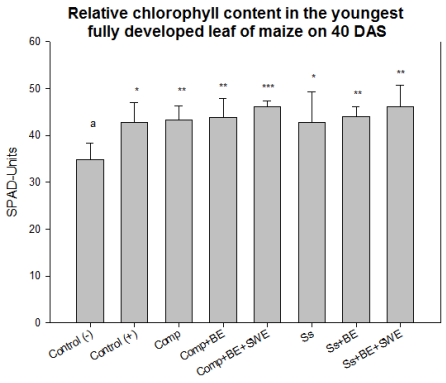

Figure 2. Relative chlorophyll content in the youngest fully developed leaf of maize on 40 DAS Significant difference compared to the control (-): *p<0.05; **p<0.01; ***p<0.001. Significant difference compared to the control (+): [a]p<0.05.

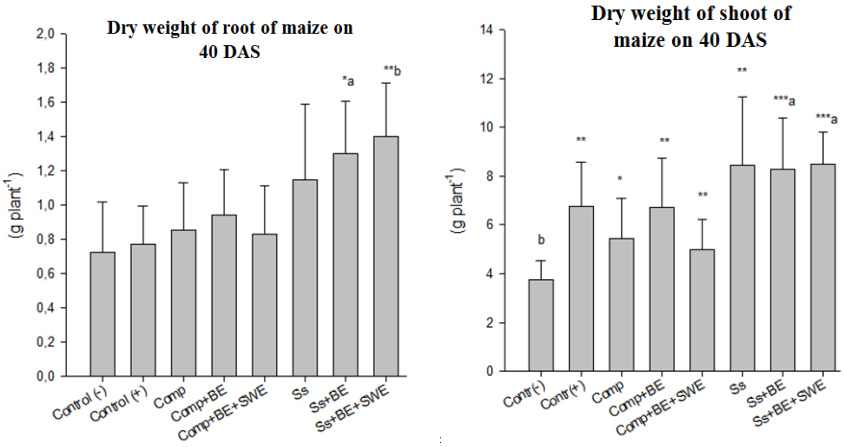

Figure 3-4. Dry weight of root and shoot of maize on 40 DAS.).Significant difference compared to the control (-):*p<0.05; **p<0.01; ***p<0.001. Significant difference compared to the control (+): [a]p<0.05, [b]p<0.01.

The relative chlorophyll content is shown in Figure 2. The relative chlorophyll content significantly increased in all treatments compared to the control (-), and the values are reached the control (+) value.

Conclusions

The examined organic recycling fertilizers had a positive effect on plant growth. In the sewage sludge compost treatment, plant biomass production and particularly root length were increased by inoculation with Proradix, while positive effect of inoculation was observed on dry weight in the compost treatment. No further improvements could be observed by additional inoculation with the seaweed extract NEMATEC in case of compost treatment. The results suggest that a proper selection of organic fertilisers with compatible BEs is a pre-requisite for successful strategies to improve utilisation efficiency of organic recycling fertilisers. Therefore, the results are enhanced fertilizer value of organic recycling fertilizers added to the soil, by combination with BE and SWE application.

Acknowledgements

Supported by: Hungarian Scholarship Board (Hungarian Eötvös Fellowship) and BIOFECTOR (funded by the European Commission within the 7th Framework Programme, Grant Agmt. No. 312117)

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