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Influences of ammonium-nitrate, food waste compost and bacterial fertilizer on soluble soil nitrogen forms and on the growth of carrot (Daucus Carota L.)

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Abstract

This paper reports a greenhouse study to compare the effects of food waste compost, bacterial fertilizer and their combination with the effect of mineral fertilizer on yield of carrot and the available nutrient content of soils. The study was conducted on calcareous chernozem and acidic sandy soils and consisted of 8 treatments in a randomized complete block design with four replications. The NH4NO3 resulted in reduced growing of carrot plant in sandy soil, and the treatment effect of mineral fertilizer was not observed significantly in chernozem soil. Sandy soil showed higher response of growth of carrot to food waste compost fertilization than chernozem soil. Sole application of EM-1 bacterial fertilizer did not have marked effect on yield parameters and sizes of roots. When EM-1 bacterial fertilizer was applied together with ammonium-nitrate or with compost in chernozem soil, the weights of roots and the sizes of roots in some cases became higher compared to the values of appropriate treatments without inoculation. In sandy soil the diameter of roots slightly increased when EM-1 bacterial fertilizer was applied with ammonium-nitrate and with ammonium-nitrate+compost combination compared to appropriate treatment without inoculation. In chernozem soil the maximum weights and sizes of roots were achieved with the combined treatment of ammonium-nitrate+compost+EM-1 bacterial fertilizer and in sandy soil with compost treatment. Our results of soluble nitrogen content of soils are in good agreement with yield parameters of carrot. Results suggest that food waste compost could be a good substitute for mineral fertilizer application in carrot production mainly in sandy soil. EM-1 bacterial fertilizer did not cause marked effect on yield and yield parameters of carrot plant, but its combination with other fertilizers promises a little bit higher yield or plant available nutrient in the soil. These effects do not clear exactly, so further studies are needed.

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Introduction

Organic fertilization is one of the oldest and most valuable methods of soil cultivation. Organic materials increase soil organic matter (Clark et al. 1998), play key roles in terms of maintaining or improving soil fertility and plant nutrition through the direct and indirect effects on microbial activity and nutrient availability.

Different composts or bacterial fertilizers might have been major components of organic farming, which offer an economically and ecologically attractive means of reducing external inputs and improving internal resources (Saxena and Tilak, 1994; Pathak et al., 1997).

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The European Union Landfill Directive (Council of Europian Union, 1999) required the Member States to reduce the amount of biodegradable waste being dumped and improve activities, such as recovery and recycling. Food waste is large component of the waste stream by weight and constitutes in Hungary. Hotels, restaurants, food chains, food factories and schools produce million tons of commercial organic waste that may be composted. If these wastes can be composted, this may represent one of the alternatives for achieving the goal of ensuring integrated and sustainable waste management (Elherradi et al., 2005, Cegarra et al., 2006). Food waste compost is generally higher in nutrient values and lower in other contamination than most types of composts, thus making it more valuable in the market (Roberts et al, 2007; Chang and Hsu, 2008). While programs and facilities to manage any waste are well established, the management of food waste in collecting for treatment in central composting facilities is perhaps only in its infancy (Levis et al. 2010). Food waste compost must be used as a soil conditioner, it not only adds nutrients to the soil, but also improves the soil structure and induces useful microbiological processes.

Use of microbial preparations for enhancement of plant production is becoming a more widely accepted practice in many countries (Rodriguez and Fraga, 1999). Applications of biofertilizers may help to avoid environmental hazards for plants, animals and human beings and may hold a great promise to improve yield trough better nutrient supply (Wu et al, 2005). Biofertilizers are products containing different types of microorganisms, which have an ability to convert nutritionally important elements from unavailable to available form (Hegde et al., 1999; Vance, 1997; Kincses et al, 2008). Bacterial fertilizers may be an alternative for increasing crop production by enhancing soil productivity (Higa and Wididana, 1991). Biofertilizers also may accelerate the decomposition of organic compounds of compost.

Results of different studies with microbial inoculants have been highly variable. According to many researchers microbial inoculants are promising components of integrated nutrient management systems, other investigators have found less expressed effects of applied biofertilizer (Richardson, 2001; Wu et al., 2005; Hegedus et al., 2008; Schenk and Müller, 2009).

The objective of this study was to compare the effects of food waste compost, a commercially available bacterial fertilizer (EM-1), their combined applications and the effect of nitrogen fertilizer on yield of carrot and plant available nitrogen forms of calcareous chernozem and acidic sandy soils.

Material and Methods

The greenhouse pot experiment was performed on carrot (Daucus carota, Katop F1) in the summer season of 2008 in a calcareous chernozem soil and in an acidic sandy soil. The soils are characterized by higher and lower organic matter contents, respectively. Some properties of soils used in trial are included in Table 1.

Table 1. Characteristics of the experimental soils

	Calcareous chernozem soil	Sandy soil
$pH_{(KCl)}$	6.5	4.5
K_A	42	26
Hu %	3.02	0.67
AL-P_2O_5 (mg kg^{-1})	352.4	190.6
AL-K_2O (mg kg^{-1})	1254	217.2

K_A: Plasticity index according to Arany

Ten kg soil was weighed into Mitscherlich type pots. Different fertilization options with similar dosages of total nitrogen (1000mg N 10 kg $soil^{-1}$, the dose of nitrogen was based on the nitrogen requirement of carrot) and bacterial fertilizer EM-1 were compared in a complete randomized design with four replicates and eight treatments: 1) unfertilized control; 2) nitrogen fertilizer (NH_4NO_3); 3) food waste compost at rate of 135 g 10 kg $soil^{-1}$; 4) half dose of food waste compost + half dose of mineral nitrogen. The 1, 2, 3 and 4 treatments were complete with EM-1 bacterial fertilizer as 5, 6, 7 and 8 treatments. For the treatment applied see Table 2.

Table 2. Scheme of treatments applied

Different N Forms	EM-1 bacterial fertilizer	
	no	yes
	treatment code	
Control	1.	5.
NH_4NO_3	2.	6.
Compost	3.	7.
Compost+NH_4NO_3	4.	8.

Compost was obtained from restaurant food residuals. Food residuals are mixed with wood waste and the blended materials are assembled into outdoor windrows and are composted for a total of 90 days. The main characteristics of food waste compost are described in Table 3.

Table 3. Characteristics of the food waste compost applied

Ash, %	19.12
Dry matter, %	97.7
N, %	1.99
C, %	31.5
S, %	0.313
C:N	15.9
pH (1:5)	6.41
Al-P_2O_5 (mg kg^{-1})	2736
Al-K_2O (mg kg^{-1})	673

The applied bacterial fertilizer was a commercially distributed biofertilizer in Hungary, EM-1, which contains different species that belong to for example Azotobacter croococcum, Bacillus megatherium soil bacteria, microelements, heteroauxin, gibberelin, vitamin B. Before application, EM-1 was diluted one-hundredfold and 11 cm^3 10 kg $soil^{-1}$ (means 32 l ha^{-1}) was mixed into appropriate pots. Ion exchanged water was added to all pots to keep the soil at constant moisture (60% of the water-holding capacity) using daily weighing. Six seeds of carrot (Daucus carota) were sown at 11 April and the harvesting process was done at 22 July. Fresh weights and sizes of roots were determined. Soil samples were air dried and sieved (<2mm) for further analysis. Concentration of water soluble nitrogen forms (NO_3-N, NH_4^+-N, organic-N and total-N) were measured in 0.01 M $CaCl_2$ extracts with 1:10 soil:solution ratio (Houba et al., 1991) by autoanalyser (SKALAR Segment Flow Analyser). The soluble organic-N was calculated by the difference of soluble total-N and the sum of NO_3-N and NH_4^+-N. Analysis of variance (two-way ANOVA) was carried out on the data in order to provide a statistical comparison between the treatment means. The least significant difference (LSD) test (P=0.05) was used to detect differences between means.

Results and Discussion

Results of carrot yield

The weights, the length and diameter of carrot roots are presented in Table 4.

Table 4. Effects of treatments on plant biomass and yield parameters (CCS: Calcareous chernozem soil; SS: Sandy soil)

Treatment	weight of roots (g pot^{-1})		length of roots (cm)		diameter of roots (cm)	
	CCS	SS	CCS	SS	CCS	SS
1. control	432a	67.3a	14.0a	9.1a	3.14a	1.67a
2. AN	419a	4.11b	13.6a	3.5b	3.13a	0.62b
3. compost	455a	92.3c	15.3c	9.9a	3.20a	1.88c
4. AN+ compost	470a	52.4d	14.5a	9.2a	3.48b	1.44d
5. EM-1	436a	65.8a	14.3a	9.6a	3.13a	1.62a
6. AN+EM-1	496b	7.4b	13.7a	3.1b	3.48b	0.83e
7. comp.+EM-1	465a	92.9c	15.2c	9.8a	3.34c	1.84c
8.AN+comp.+EM1	523c	52.8d	15.7c	7.8c	3.49b	1.52d
Significance	**	***	***	***	***	***

. *= effect significant at P< 0.01 and P< 0.001, respectively. AN=ammonium-nitrate; EM-1=bacterial fertilizer
Means followed by the same letter are not significantly different (Tukey's studentized range test, p< 0.05).

The yield of carrot grown on two types of soils varied strongly. The plant-growth parameters on calcareous chernozem soil were much higher in all treatments than that of cultivated on acidic sandy soil.

The addition of ammonium-nitrate to chernozem soil did not change the root weights and sizes of roots. Food waste compost in chernozem soil did not alter the weights of roots, but it is worth to mention caused significantly longer roots. Combined treatment of ammonium-nitrate and compost also did not caused changed root weights, but enhanced the diameter of roots. Inoculation of chernozem soil with EM-1 did not resulted in increased yield parameters compared to control. Nevertheless when EM-1 bacterial fertilizer was applied together with ammonium-nitrate or with compost the weights of roots and mainly the sizes of roots became higher compared to the values of appropriate treatments without inoculation. In chernozem soil the maximum weights and sizes of roots were achieved with the combined treatment of ammonium-nitrate+compost+EM-1.

In the case of sandy soil a severe reduction in the weights and sizes of roots appeared when ammonium-nitrate fertilization was applied. On this acidic sandy soil NH_4NO_3 might caused an intensely acidifying effect, caused the reduced increased of plant. A similar negative effect of NH_4-salt mineral fertilizer on biomass production of maize in acidic sandy soil was reported by Kádár and Pusztai (1997). Sánchez et al. (2000) also have experienced that application of high NH_4NO_3 rates in green bean resulted reduced biomass production. As contrasted with the effect of NH_4NO_3, the addition of food waste compost to sandy soil had a beneficial effect on the yield. The compost caused the greatest favourable changes in the plant growth compared to another treatment. The highest root weights were obtained with compost treatment. When half dose of compost was applied with half dose of ammonium-nitrate in sandy soil, the yield parameters were higher as compared to ammonium-nitrate treatment alone, but lower yield appeared compared to compost treatment or control. Biofertilizer, EM-1 did not cause marked effect on the yield and yield parameters of plant on sandy soil also. Although the diameter of roots slightly increased when EM-1 bacterial fertilizer was applied with ammonium-nitrate and with ammonium-nitrate+compost combination compared to appropriate treatment without inoculation.

Results of 0.01 M $CaCl_2$ soluble nitrogen forms in chernozem and sandy soils

Concentrations of 0.01M $CaCl_2$ soluble NO_3-N, NH_4-N, organic N and total N measured in chernozem and sandy soils are presented in Figure 1 and 2.

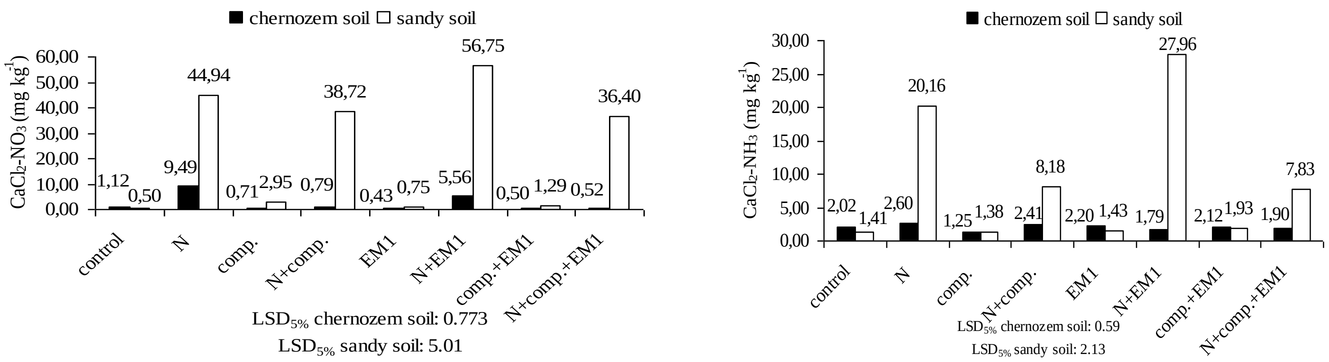


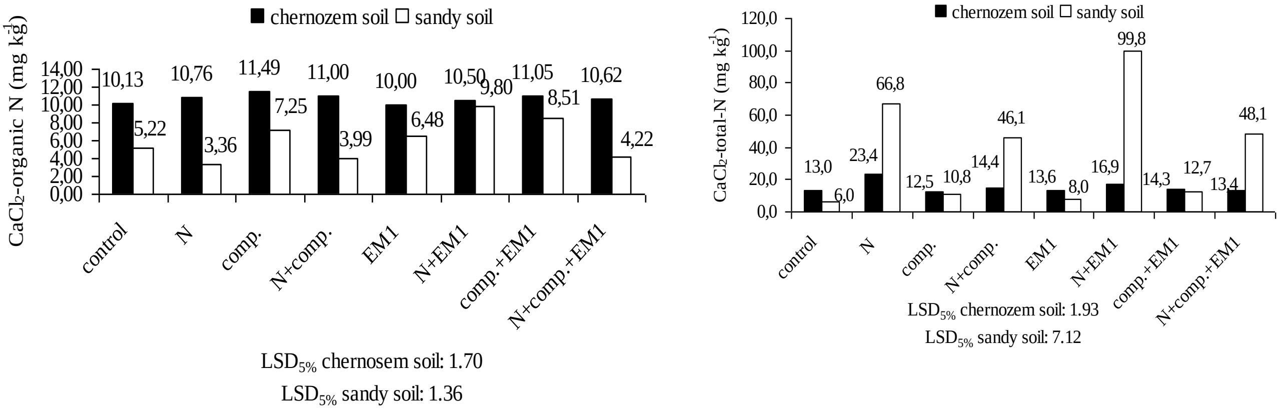
Figure 1. Means of NO_3-N and NH_4-N (mg kg^{-1}) measured in 0.01 M $CaCl_2$ soil extract

Our results of soil parameters are in good agreement with yield parameters of carrot. In sandy soil the concentrations of 0.01M $CaCl_2$-NO_3-N, NH_4-N and total N were the highest in ammonium-nitrate and especially in ammonium-nitrate+EM1 combined treatments, compared to all other treatments. Te reason of this was that mineral fertilizer caused severe reduction in the plant biomass and sizes of roots. As the nitrate and ammonium from ammonium-nitrate fertilizer have not been taken up by plants, by the end of the growing season higher amount of these ions remained in the soil.

In chernozem soil, the increasing effect of ammonium-nitrate on the 0.01 M $CaCl_2$ soluble nitrate and total N also appeared. However these values were much lower than those of sandy soil, because the yield of carrot was higher in chernozem soil.

In compost treatment the quantities of inorganic nitrogen forms did not differed significantly from values of control neither in chernozem nor in sandy soils. Although the quantity of soluble organic-N fractions were balanced in the experiment mainly in chernozem soil, the food waste compost caused significantly enhanced soluble organic N in both types of soils. The increasing effect was higher in sandy soil.

In pots treated with food waste compost an increasing tendency of total N in sandy soil also appeared, but the effect was not significant.



Figures 2. Means of organic N and total N (mg kg^{-1}) measured in 0.01 M $CaCl_2$ soil extract

Sole application of EM-1 bacterial fertilizer did not change the quantity of $CaCl_2$-NO_3-N and NH_4-N neither in chernozem nor in sandy soils. It is worth to mention, that inoculation of sandy soil caused an increased (but not significant) organic-N and total-N measured in 0.01M $CaCl_2$ extract.

When bacterial fertilizer was combined with NH_4NO_3 in sandy soil all 0.01 M $CaCl_2$ soluble N forms increased compared to appropriate treatment being not inoculated. In chernozem soil, there was not any change in these values. Combination of EM-1 with compost resulted in increased values of $CaCl_2$-organic N in sandy soil. This indicates that bacterial fertilizer might help the mineralization of compost.

Conclusion

The yield and yield parameters of carrot grown on calcareous chernozem soil were higher in all treatments than on acidic sandy soil. The same dose of NH_4NO_3 caused different effects on growth of carrot in two different types of soils. In acidic sandy soil, where the buffer systems: soil colloids, humic substances, clay minerals are limited, NH_4NO_3 had an intensely acidifying effect and resulted in reduced increased of carrot plant. In chernozem soil the treatment effect of NH_4NO_3 on the yield of roots were not observed significantly.

Sandy soil showed higher response of yield parameters to food waste compost fertilization than chernozem soil. Labrecque and Teodorescu (2001) also recorded higher response of organic fertilization on growth of two willow species in sandy (poor) soil than in clay (good) soil. Application of combined treatment (compost and NH_4NO_3) in chernozem soil although did not resulted in increased weight of roots compared to other treatments. In sandy soil the combined treatment proved to be less favourable as compost treatment because the weight and size of roots were also unfavourable compared to control. Sole application of bacterial fertilizer did not cause marked effect on yield and yield parameters of carrot plant harvested from two types of soils. The lack of higher effects of different fertilization methods on biomass production of carrot harvested from chernozem soil suggests that this soil type has favourable characteristics and not so limited by nutrient availability. The sandy soil with lower organic compounds generated a better yield increase and a better response to compost compared to chernozem soil.

From the above study, it is clear that nitrogen fertilizer might cause serious decrease in plant production in acidic sandy soil, while effectiveness of food waste compost emerged as a promising management practice on this soil type. Also it would be interesting to assess the nutrient residual effect of compost application on carrot yield. EM-1 bacterial fertilizer did not cause marked effect on yield and yield parameters of carrot plant, but its combination with other fertilizers promises a little bit higher yield or plant available nutrient in the soil. These effects do not clear exactly, so further studies are needed.

References

Jászberényi, I., Loch, J., Sarkadi, J., 1994. Experiences with 0.01 M $CaCl_2$ as an extraction reagent for use as a soil testing procedure in Hungary. *Communications in Soil Science and Plant Analysis* 25: 1771-1777.

Houba, V.J.G., Jászberényi, I., Loch, J., 1991. Application of 0,01 M $CaCl_2$ as a single extraction solution for evalution of the nutritional status of Hungarian soils. Debreceni Agrártudományi Egyetem Tudományos Közleményei. 30. 85-89. p.

Clark, M.S., Horwath, W.R., Shennan, C., Scow, K.M., 1998. Changes in soil chemical properties resulting from organic and low-input farming practices. *Agronomy Journal* 90**:** 662–671.

Saxena, A.K., Tilak, K.V.B.R., 1994. Interaction among beneficial soil microorganisms. Indian J. Microbiol*.,* 34, 91–106.

Council of the European Union, 1999. Directive 1999/31/EC, of 26 April 1999 on the landfill of waste

Pathak, D.V., Khurana, A.L., Singh, S., 1997. Biofertilizers for enhancement of crop productivity – a review. *Agricultural Reviews* 18: 155–166.

Elherradi, E., Soudi, B., Chiang, C., Elkcemi, K., 2005. Evaluation of nitrogen fertilizing value of composted household solid waste under greenhouse conditions. *Agronomy for Sustainable Development* 25 (2): 169-175.

Cegarra, J., Alburquerque, A., Gonzálvez, J., Tortosa, G., Chaw, D., 2006. Effects of the forced ventilation on composting of a solid olive-mill by-product ("alperujo") managed by mechanical turning, *Waste Management* 26: 1377–1383.

Roberts, P., Edwards –Jones, G., Jones, D.L., 2007. In-vessel cocomposting of green waste with biosolids and paper waste. *Compost Science and Utilization* 15: 272–282.

Chang J.I., Tin-En. H.,, 2008. Effects of compositions on food waste composting. *Bioresource Technology* 99(17):256-278.

Levis J.W., Barlaz, M.A., Themelis, N.J., Ulloa, P., 2010. Assessment of the state of food waste treatment in the United States and Canada. *Waste Management* 30(8-9): 1486-1494.

Higa, T., Wididana G.N.. 1991. Changes in the soil micro flora induced by Effective Microorganisms. P.153-162. In J.F. Parr, S.B. Hornick and C.E. Whitman(ed.) Proceedings of the First International Conference on Kyusei nature farming U.S. Department of Agriculture, Washington, D.C., USA.

Richardson, A.E., 2001. Prospects for using soil microorganisms to improve the acquisition of phosphorus by plants. *Australian Journal of Plant Physiology* 28(9): 897 – 906.

Wu, S.C., Cao, Z.H., Li, Z.G., Cheung, K.C., Wong, M.H., 2005. Effects of biofertilizer containing N-fixer, P and K solubilizers and AM fungi on maize growth: a greenhouse trial, *Geoderma* 125**:** 155–166.

Hegedus, S., Kristo, I., Litkei, Cs., Vojnich, V., 2008. Impact of bacterial fertilizer ont he component of industrial poppy varieties. *Cereal Research Communications* 36: 1719-1722.

Schweinsberg-Mickan, M.S., Müller, T., 2009 Impact of effective microorganisms and other biofertilizers on soil microbial characteristics, organic-matter decomposition, and plant growth. *Journal of Plant Nutrition and Soil Science* 172: 704-712.

Kádár, I., Pusztai, A., 1997. N-műtrágyák hatásának vizsgálata tenyészedény-kísérletekben III. Sabvanyú homoktalaj (Nyírlugos) *Agrokémia és Talajtan* 46(1-4): 245-256.

Kincses, S. - Nagy, P. T. - Kremper R. (2008): A mű és baktériumtrágya hatása a növény-talaj rendszer makrotápelem-forgalmára tenyészedénykísérletben. 50. Jubileumi Georgikon Napok Keszthely 09.25-25, 202-206.

Sánchez, E., Soto, J.M., Garcia, P.C., López-Lefebre, L.R., Rivero, R.M., Ruiz, J.M., Romero, L., 2000. Phenolic compounds and oxidative metabolism in green bean plants under nitrogen toxicity. *Australian Journal of Plant Physiology* 27: 272-277.

Hegde, D.M., Dwived, B.S., Sudhakara, S.N., 1999. Biofertilizersfor cereal production in India—a review. *Indian Journal of Agricultural Sciences* 69: 73– 83.

Vance, C.P., 1997. Enhanced agricultural sustainability through biological nitrogen fixation. In: Bio Fix of Nitrogen for Eco and Sustain Agric. Proc. NATO Adv Res. Work, Ponzan, Poland, 10–14 September 1996, Springer-Verlag, Berlin, Germany, pp. 179–185.