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Organic and mineral fertilizer effects on the yield and mineral contents of carrot *(Daucus carota)*

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Summary: A greenhouse pot experiment was conducted to investigate the effects of ammonium-nitrate, food waste compost, bacterial fertilizer (EM-1) and their combinations on production and nutrient contents of carrot. The study was conducted on a calcareous chernozem and acidic sandy soils in a randomized complete block design with 8 treatments and four replications. NH_4NO_3 in chernozem soil increased the weight of carrot leaves only, while in sandy soil resulted in reduced yield and highly increased NO_3-N content of roots. Sandy soil showed higher response of biomass production to food waste compost application than chernozem soil. The highest carotenoid content of roots was measured with compost treatment. Combined application of compost and NH_4NO_3 in chernozem proved to be good combination but in sandy soil have turn out to be less favourable than sole compost treatment. Bacterial fertilizer (EM-1) did not cause marked effect on the yield parameters, but caused increased phosphorus content of plant. In chernozem soil the maximum yield parameters were achieved with the combined treatment of ammonium-nitrate+compost+EM-1. In sandy soil the most favourable treatment proved to be the compost treatment. Results suggest that application of food waste compost as a nutrient source could be a promising agrochemical practice especially in soils having low organic material and low nutrient supply.

Key words: mineral fertilizer, food waste compost, bacterial fertilizer, nutrient, carrot

Introduction

The conventional agriculture uses large quantities of synthetic fertilizers and pesticides to control diseases and to provide nutrients to crops. These practices may have led to a decrease in organic matter content and hence to a decline in soil quality. Organic fertilization is one of the oldest methods of soil cultivation. Every possible type of organic manuring has got vital importance for soil fertility preservation (*Petróczki*, 2004). Organic fertilizers are major components of organic farming, which offer an economically attractive and ecologically sound means of reducing external inputs and improving internal resources. Organic materials play key roles in terms of maintaining or improving soil fertility, soil organic matter and plant nutrition through the direct and indirect effects on microbial activity and nutrient availability (*Clark* et al. 1998).

The European Union Landfill Directive (*Council of European Union*, 1999) required the Member States to reduce the amount of biodegradable waste 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 produce a lot of tons of organic waste that may be composted. If these wastes can be composted to obtain a quality organic soil amendment with humified organic matter and the end product used as soil organic amendment or fertilizer, this may represent one of the alternatives for achieving the goal of ensuring integrated and sustainable waste management (*Chang & Tin-En 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). Use of food waste compost can be a good alternative for increasing crop production by enhancing soil productivity. Food waste compost is generally higher in nutrient value and lower in contamination than most other types of compost, thus making it more valuable in the market (*Roberts* et al, 2007).

Use of microbial preparations for enhancement of plant production is becoming a new practice in many countries (*Rodriguez & Fraga,* 1999; *Higa*, 1994). Bacterial fertilizers may contain different microorganisms, for example nitrogen fixing and phosphates solubilizing microorganisms. They have the ability to fix nitrogen from the air and to solubilize phosphate minerals and so make nitrogen and phosphorus available to plants. Biofertilizers may increase the soil microbial sources, improve crop nutrition conditions, may accelerate the decomposition of organic wastes, increase the availability of mineral nutrients, can dissolve soil phosphorus, potassium, can increase the nitrogen content of soil and may enhance the activities of beneficial micro-organisms.

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 & Müller*, 2009; *Kincses* et al. 2008).

The objective of this study was to compare the effects of food waste compost, a commercially available bacterial fertilizer (EM-1) and their combined applications on biomass production and nutrient content of carrot with the effects of mineral fertilizer (NH_4NO_3) and untreated pots.

Materials and methods

The greenhouse pot experiment was performed on carrot (*Daucus carota*, Katop F1) 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 (mineral and organic fertilization) and bacterial fertilizer were compared in a complete randomized design with four replicates and eight treatments: 1) unfertilized control; 2) nitrogen fertilizer, NH_4NO_3 (1000mg N pot^{-1}, the dose of nitrogen was based on the nitrogen requirement of carrot)); 3) food waste compost at rate of 135g/10kg soil; means 40t/ha; 4) half dose of food waste compost + half dose of mineral nitrogen. The 1, 2, 3, 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	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 to the pots

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-P2O5 (mg kg-1)	2736
AL-K2O (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, micro-elements, heteroauxin, gibberelin, vitamin B. Before application, EM-1 was diluted one-hundredfold and 11 cm^3 10 kg $soil^{-1}$ (means 32 l/ha) 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. Yield, weights of leaves and roots, diameter and length of roots were determined. Total carotenoid content of carrot roots was determined after acetate-hexane extraction by spectrophoto-metrically at 450 nm (MSZ 6830/14-84).

For elemental analysis, plant leaves and roots after drying at 50C^o were digested by H_2SO_4-H_2O_2 method. Total phosphorus content of plant was determined by vanadate-molybdate method given by *Olsen & Sommers* (1982). Potassium content of plant was analysed by atomic emission spectrophotometry. Nitrate was determined by ionchro-matography (*Kovács & Loch,* 2004). The total nitrogen and sulphur analysis was performed by dry combustion method (*Nagy,* 2000).

The experimental design was randomized complete block with four replications. Analysis of variance (one-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

Growth response of carrot to soil-fertility treatments

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

Mineral fertilizer in chernozem soil altered the weights of leaves, the less important parts of the crop without any effect on roots, the more important, edible part of carrot. The leave/root ratio also increased by the addition of NH_4NO_3. Food waste compost in chernozem soil did not

Table 4. Effects of treatments on plant biomass and yield parameters

Treatment	weight of roots (g pot^{-1})		weight of leaves (g pot^{-1})		ratio of weights of leave/root		plant biomass (g pot^{-1})		length of roots (cm)		diameter of roots (cm)	
	chern.	sandy	chern.	sandy	chern.	sandy	chern.	sandy	chern.	sandy	chern.	sandy
1. control	458a	67.3a	84.10a	16.4a	0.184a	0.244a	542a	83.7a	14.0a	9.1a	3.14a	1.67a
2. AN	445a	4.11b	116.2b	3.13b	0.261b	0.762b	562a	7.24b	12.6b	3.5b	3.13a	0.62b
3. compost	482a	92.3c	87.20a	22.1c	0.181a	0.240a	569a	114.4c	15.3c	9.9a	3.20a	1.88c
4. AN+ compost	496a	52.4d	110.9b	16.2a	0.225c	0.309a	607b	68.6d	14.5a	9.2a	3.48b	1.44d
5. EM-1	462a	65.8a	86.40a	16.8a	0.187a	0.255a	549a	82.7a	14.3a	9.6a	3.13a	1.62a
6. AN+EM-1	522b	7.42b	123.0b	2.83b	0.237c	0.378a	645b	10.2b	13.7a	3.1b	3.48b	0.83e
7. comp.+EM-1	491a	92.9c	90.50a	21.3c	0.184a	0.229a	581a	114.2c	15.2c	9.8a	3.34c	1.84c
8.AN+comp.+EM1	549c	52.8d	114.1b	15.8a	0.208a	0.300a	663bc	68.6d	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)

alter the plant biomass, but caused significantly longer roots. With combined treatment of ammonium-nitrate and compost an increasing trend appeared in root weights and the plant biomass and the diameter of roots also were the highest. Inoculation of chernozem soil with EM-1 did not resulted in changed plant biomass or yield parameters compared to control. Nevertheless when EM-1 bacterial fertilizer was applied in combination with ammonium-nitrate the plant biomass and 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, the most favourable leave to root ratio were achieved with the combined treatment of NH_4NO_3+food waste compost+EM-1.

In sandy soil a reduction in the plant biomass and sizes of roots appeared when ammonium-nitrate fertilization was applied. On this acidic sandy soil NH_4NO_3 might have been an intensely acidifying effect, causing 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 & 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 plant biomass. The compost caused the greatest favourable changes in the plant biomass yield compared to other treatments. The highest plant biomass, the highest root and leaf weights, the most favourable leaf to root ratio was obtained with compost treatment. The combined treatment of compost and ammonium-nitrate in sandy soil, resulted in lower yield parameters as compared to sole compost treatment or control, but resulted in higher values compared to sole NH_4NO_3 treatment. Biofertilizer, EM-1 did not cause marked effect on the yield parameters of plant on sandy soil either with sole or combined applications.

Nutrient content of carrot

The total N, NO_3-N, total S, SO_4^{2-}-S, P contents and N/S ratios of plant and total carotenoid content of roots grown on two types of soils are presented in Table 5.

Higher N concentration was found in the leaves and lower in the edible portion of the crop. The NO_3-N content was almost the same in both parts of plant. *Hermann* & *Bernier* (1975) found, that in their experiment the total N concentration in carrot leaves and roots were quite similar, but nitrate concentration differed enormously, being much greater in the leaves.

The sulphur, sulphate and phosphorus mainly accumulated in the leaves than in the roots. *Warman* & *Havard* (1997) reported values for the mineral composition of carrot root and leaves which are similar to the present data, with the exception of phosphorus content which was lower (0.24%, 0.30%, in the roots and leaves, respectively) in their results. The higher phosphorous values (0.319-0.544%, in the roots and leaves) obtained in the present study can probably attributed to the different fertility level of soils and the dissimilar availability of other nutrients.

The total carotenoid content of roots changed between 44.2-73.5 mg kg^{-1}, FW. The same carotenoid content (40-55 mg carotene kg^-1, FW) of carrot root reported *Evers* (1989) and *Hochmuth*, et al., (1999) in their experiments.

Ammonium nitrate in chernozem soil increased the total N and NO_3-N mostly in the leaves than in the roots suggesting the transport of nitrate ions from the root towards the leaves. *Smolen* & *Wlodzimierz* (2009) also reported that in their experment they did not realised statistically significant effect on nitrate concentration in carrot storage roots by nitrogen fertilization. Application of ammonium-nitrate enhanced the total sulphur content of plant, mainly in the leaves. At the same time the SO_4^2-S of leaves and roots decreased compared to control. This means nitrogen had effect on the building of the sulphate into organic

Table 5. Effects of treatments on nutrient and carotenoid contents of carrot

Treatment	N% (DW)				NO_3-N % (DW)				S% (DW)				SO_4^{2-}-S % (DW)			
	roots		leaves		roots		leaves		roots		leaves		roots		leaves	
	chern.	sandy	chern.	sandy	chern.	sandy	chern.	sandy	chern.	sandy	chern.	sandy	chern.	sandy	chern.	sandy
1. control	0.95a	0.800a	1.19a	2.24a	0.180a	0.176a	0.174a	0.163a	0.131a	0.256a	0.273a	0.826a	0.086a	0.056a	0.345a	0.701a
2. AN	1.36b	2.47b	1.95b	3.84b	0.185a	0.332b	0.206b	0.192b	0.140a	0.155b	0.324b	0.477b	0.072b	0.089b	0.097b	0.084b
3. compost	1.00a	0.878a	1.33c	2.21a	0.183a	0.178a	0.184a	0.179a	0.134a	0.182b	0.288a	0.583c	0.074b	0.057a	0.318c	0.478c
4. AN+ compost	1.11c	1.26c	1.61d	2.81c	0.185a	0.210c	0.176a	0.327c	0.142a	0.191b	0.266a	0.353d	0.084a	0.076b	0.157d	0.226d
5. EM-1	0.89a	0.846a	1.20a	2.24a	0.196a	0.181a	0.184a	0.179a	0.141a	0.154b	0.296a	0.802a	0.078a	0.071b	0.471e	0.691a
6. AN+EM-1	1.28b	2.86d	2.04b	4.09b	0.172a	0.310d	0.202b	0.167a	0.130a	0.160b	0.306a	0.468b	0.081a	0.113c	0.156d	0.173e
7. comp.+EM-1	1.17c	0.927a	1.33c	2.22a	0.187a	0.180a	0.187a	0.198b	0.139a	0.164b	0.308a	0.742a	0.081a	0.080b	0.343a	0.677a
8. AN+comp. +EM	1.16c	1.25c	1.58d	3.02c	0.176a	0.217c	0.206b	0.329c	0.130a	0.161b	0.307a	0.490b	0.094a	0.075b	0.172d	0.246d
Significance	***	***	***	***	n.s.	***	**	***	n. s.	*	*	***	***	***	***	***

Treatment	N/S ratio				P% (DW)				total carotenoid content of roots, mg kg-1 (FW)	
	roots		leaves		roots		leaves			
	chern.	sandy	chern.	sandy	chern.	sandy	chern.	sandy	chern.	sandy
1. control	7.27a	3.88a	4.58a	2.72a	0.356a	0.353a	0.426a	0.319a	51.7a	44.7a
2. AN	9.76b	15.9b	6.07b	8.48b	0.544b	0.391b	0.403b	0.361b	64.2a	47.1a
3. compost	7.46a	5.02a	4.63a	3.80a	0.398a	0.398b	0.444a	0.433c	73.2b	60.7b
4. AN+ compost	7.32a	6.71c	6.08b	8.08b	0.382 ac	0.382b	0.401b	0.370b	65.9b	50.8a
5. EM-1	5.91c	5.54a	4.22a	2.79a	0.365a	0.365a	**0.472c**	**0.360b**	49.1a	44.2a
6. AN+EM-1	9.87b	18.1b	7.14c	8.92b	0.466c	**0.466c**	0.375d	**0.411c**	63.1a	47.8a
7. comp.+EM-1	8.38d	5.65a	4.31a	2.99a	0.408a	0.387b	0.443a	0.402 cd	73.5b	61.3b
8.AN+comp.+ EM	8.94b	7.73c	5.15d	6.56b	**0.433c**	**0.441c**	0.391 bd	**0.390 cd**	53.8a	66.8b
Significance	***	***	***	***	***	***	***	***	**	***

+, *, **, ***= effect significant at $P< 0.1$, $P< 0.05$, $P< 0.01$ and $P< 0.001$, respectively, n.s.=not significant, AN=ammonium-nitrate; EM-1=bacterial fertilizer
Means followed by the same letter are not significantly different (Tukey's studentized range test, $p< 0.05$).

compounds. Ammonium-nitrate resulted in increased phosphorus content of roots, while probably due to a dilution effect, decreased P of leaves.

In sandy soil the total N and especially NO_3-N content of carrot roots highly increased (NO_3-N:0.332% (DW) means NO_3^-:2203 mg kg^{-1} (FW) by water content of 75%) due to the application of ammonium-nitrate. Nitrate exceed the limit according to EC Regulation (for carrot: 1500 mg kg^{-1} FW, *Santamaria,* 2006) and was much higher than the maximum permitted level for nitrate in baby foods (200 mg kg^{-1} FW) permitted by the European Commission (*EC,* 2004). In this treatment the sharp fall in root and leaf biomass also appeared. High concentration of nitrate in carrot might have resulted from a worse utilization of nitrogen by plant. *Andreeva* et al. (1998) also found that increased NO_3^- content above the optimum substantially suppressed apparent and potential photosynthesis and reduced plant productivity. In this treatment the total sulphur content of roots and leaves also decreased, that is why the N to S ratios of root highly increased (15.9) compared to control (3.88) and other treatments. The same high change in N/S ratio of carrot (from 23 to 10) with greatly differing rates of N, P, K, Ca and S was reported by *Eppendorfer & Eggum* (2005). Ammonium-nitrate resulted in poorer transport of sulphate and nitrate from the root towards the leaves and minor building up these ions into organic compounds. In mineral fertilizer treatment the phosphorus content of both part of plant were higher compared to control because of lower yield.

Food waste compost in chernozem soil enhanced the nitrogen content of leaves, but did not cause remarkable change in the NO_3-N, P and S contents. In sandy soil compost caused increased P content of roots and leaves. Compost mineralized during the growing season and supply phosphorus to plant. At the same time the total S and SO_4^{2}-S content of plant decreased due to dilution effect (*Jarrell & Beverly*, 1981).

Higher carotenoid content in both soil types were obtained in compost treatment compared to other treatments.

Combined application of half dose of food waste compost and nitrogen fertilizer in chernozem soil caused an increased total N of plant compared to control, but the NO_3-N of carrot did not changed. In this treatment the phosphorus content of leaves decreased.

In sandy soil application of combined treatment of mineral fertilizer+compost resulted in higher total N, NO_3-N and phosphorus content of plant compared to control. The NO_3-N of leaves increased more than roots values. The NO_3-N of roots was not higher than the limits to maximum levels of nitrate of carrot accepted in European countries (*Santamaria*, 2006). In this combined treatment while the N content of plant enhanced, the sulphur content decreased and as a result of this the N/S ratio increased in both parts of the plant.

Sole application of EM-1 bacterial fertilizer enhanced the P content of leaves compared to control. The increasing effect was significant in both soil types. Bacterial fertilizer contains phosphates solubilising bacteria which might solubilise phosphate minerals in soils and make phosphorus more available for carrot. *Vassilev* et al. (2006) have shown in their experiments an increased P uptake by plants through the inoculation of phosphates solubilising microorganisms.

When EM-1 bacterial fertilizer was applied in combination with compost an enhancement of roots nitrogen appeared, compared to values of sole compost treatment. The effect appeared in both soil type but was significant in chernozem soil. EM-1 bacterial fertilizer contains *Azotobacter croococcum* soil bacteria with ability to fix the nitrogen from the air. In order to do that, these bacteria need optimal soil conditions. Food waste compost supplied nutrients for bacteria, created favourable conditions for their multiplication. In this combined treatment the SO_4^{2-}S content of roots and leaves also were higher compared the value of compost treatment.

With combined application of ammonium-nitrate+EM-1 or NH_4NO_3+compost+EM-1 in sandy soil the phosphorus content of plant increased compared to appropriate treatment being not inoculated.

Although the compost treatment increased the carotenoid content of roots, either inoculation of soils or nitrogen fertilizer application did not result any significant change of these values. The same was also observed in the study of *Leclerc* et al., (1991) who found that in paired comparison of conventional and organic method, organic fertilization produced higher carotenoid content in carrots. As opposed to this, in a comparison of mineral fertilizer and compost *Salomon* (1972) found that carrot fertilized with compost or mineral fertilizer did not differ in the levels of carotene. *Gajewski* et al., (2010) also concluded that nitrogen fertilizer did not significantly influence carotenoid content in the roots. Their results showed that carotenoid accumulation in the roots was significantly affected by carrot genotype.

Conclusion

The same dose of NH_4NO_3 caused different effects on biomass production in two different soil types. 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 and highly increased in NO_3-N content of carrot roots. NH_4NO_3 had significant decreasing effect of the total sulphur content of roots and caused highly increased (15.9) N/S ratio of roots compared to control (3.88). In chernozem soil the effect of NH_4NO_3 on the plant biomass and yield of roots were not observed significantly. Nitrogen fertilizer increased the total nitrogen and phosphorus content of roots, the total carotenoid and sulphur content did not change. The N/S ratio slightly increased from 7.27 to 9.76.

Sandy soil showed higher response of biomass production and nutrients change in plant to food waste compost fertilization than chernozem soil. Food waste compost caused the highest total carotenoid content on both soil types. Compost increased the phosphorus of roots in sandy soil. *Labrecque & Teodorescu* (2001) also recorded higher response of organic fertilization on growth of two willow species in sandy (poor) soil than in clay (good) soil.

The combination of half dose of compost and NH_4NO_3 in chernozem soil proved to be advantageous treatment, higher plant biomass, sizes of roots and higher N and S contents of carrot compared to values of control were recorded. In sandy soil the NH_4NO_3+compost combined treatment proved to be less favourable than compost treatment, but was preferable as mineral fertilizer treatment.

Sole application of bacterial fertilizer did not influence the yield of carrot, but enhanced the phosphorus content of carrot leaves. With combined applications of NH_4NO_3+EM-1 or NH_4NO_3+compost+EM-1 the P content of plant also increased compared to appropriate treatment being not inoculated. The effect was significant mainly in sandy soil.

In chernozem soil the maximum yield and yield parameters were achieved with the combined treatment of NH_4NO_3+compost+EM-1 and in sandy soil with compost and compost+EM-1 treatments.

From the above studies, it is clear that effectiveness of food waste compost emerged as a promising management practice especially in soils having low organic material and low nutrient supply. Also it would be interesting to assess the nutrient residual effect of food waste compost application. EM-1 bacterial fertilizer did not cause marked effect on yield and yield parameters of carrot plant so further studies are needed.

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