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Growing Plants on Vermicompost as a Way to Produce High Quality Foods*

by

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Summary. During the period of 1993–1997 experiments were conducted to check features of carrot, cucumber, tomato, leek, celery and potato cultivated on vermicompost and mineral fertilisers.

Key words: carrot, cucumber, tomato, leek, celery, potato, vermicompost, mineral fertiliser, nitrate content, heavy metals, qualitative value.

Fertiliser application plays an important role for quantity of crops. Consideration of soil degradation as an effect of over-fertiliser application is also important. A large concentration of mineral nitrogen and potassium in soil disturbs biological relationships between soil, plants and human health. In many fruits and vegetables the nitrate and heavy metal contents exceed their permissible levels. It is possible to prevent this by replacing mineral fertilisers with vermicompost. There are some evidences that vermicompost can promote the growth of plants [1, 2, 7, 8].

Materials and Methods

During 1993–1997, studies were conducted to check qualitative and quantitative characteristics of carrot, cucumber, tomato, celery and potato cultivated on vermicompost.

Experiments were conducted with the use of vermicompost and mineral fertiliser. Vermicompost had been produced from cattle manure using a very strict technology (a bed with earthworms was watered twice daily and cattle manure was provided as food in small amounts, spread evenly all over the vermiculture surface in ~10 cm layers; the next layer of manure was provided, when the previous layer had been transformed to coprolits by earthworms). Vermicompost produced that way contained

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the following available nutrients: 450–665 mg NO_3, 80 –2230 mg P, 1400–5225 mg K, 1000–1450 mg Ca, 500–1500 mg Mg · kg^{-1} of dry mass. Also, 300 mg Na, 4 mg B, 8 mg Cu, 120 mg Mn, 60 mg Zn, 800 mg Fe were present per dm^3 .

Generally all experiments fitted into the established pattern:

The culture bed was always checked first for the content of nutrients needed by definite species of cultivated plant. Then the fertilisation mode was determined to achieve a balance between nutrients contributed in vermicompost, mineral fertilisers and plants requirements.

Watering and other cultivation and protective measures were conducted at the same time on all parts of the experiment.

Samples of plants from vermicompost and mineral fertilisers were then compared and contents of nitrates and heavy metals (Pb, Cd, Cu and Zn) in them were determined. Nitrate content was analysed using a potentiometric methods, heavy metals content was checked using atomic adsorption. Detailed description of methods employed are presented in, for example, Kostecka *at al.* [4] or Kostecka & Błażej [6]. The results were interpreted statistically ($p = 0.05$).

To compare the relative "tastiness" of vegetables produced by mineral fertilisation or vermicompost addition, blind- testing was undertaken using a group of five people. This group were asked to indicate which of the two vegetable offered (e.g. tomato (either mineral fertilised, or vermicompost treated) was preferred.

Results

Carrots

In the experiment "Trojka", "Nantejska" and "Carera", varieties had been cultivated on an area of 11 ares. Table 1 shows, that the nitrate content in carrot from vermicompost was 50% lower, than that in the same vegetables cultivated on mineral fertiliser. Contents of cadmium and lead in all carrot cultivars were also lower in samples from vermicompost. Contents of nitrogen, phosphorus, potassium, calcium and magnesium were similar in both samples. Only the level of sodium was higher in carrot from vermicompost (Table 2). As a consequence, potassium to sodium ratio was wider.

Crops of carrot from vermicompost and mineral fertilisers were similar (about 470 kg · m^{-2}), but carrot from vermicompost had all roots regularly formed. In carrots from mineral fertiliser, a lot of offshoots in the root system were noticed, which resulted in a lower processing quality.

Cucumbers

Cucumbers were tested in glasshouses. Harvesting was conducted systematically by manual picking as fruit matured. Samples of cucumbers from both fertilisation types, were taken every two weeks. Fourfold analyses showed lower contents of nitrates and heavy metals in cucumber fruits from vermicompost, as compared with crop from mineral fertiliser (30–50%) difference in nitrate content, 15–30% in Pb; 17–46% in Cd; 2–8% in Cu; 10–12% in Zn content). The crop on vermicompost was also considered to be more tasty.

TABLE 1

Influence of fertilisation (F) and variety (V) on nitrates and heavy metals contents in carrot roots

Variety	Nitrates NO_3 (mg ·kg $^{-1}$ fresh mass)			Heavy metals (mg ·kg $^{-1}$ fresh mass) Cd			Pb		
	Ver.	Min. Fert.	Mean	Ver.	Min. Fert.	Mean	Ver.	Min. Fert.	Mean
Trojka	34	99	66.5	0.03	0.05	0.04	0.17	0.26	0.215
Nantejska	35	55	45.0	0.02	0.05	0.035	0.21	0.34	0.275
Carera	26	37	31.5	0.03	0.04	0.035	0.22	0.39	0.305
Mean	**31.7**	**63.6**	**-**	**0.026**	**0.046**	**-**	**0.20**	**0.33**	**-**
LSD 0,05	FxV =15	F = 8	V = 11	FxV = ns	F = ns	V = ns	FxV = ns	F = 0.04	V = 0.06

TABLE 2

Influence of fertilisation (F) and variety (V) on contents of mineral elements in carrot roots

Fertilisation	Variety	Percentage of contents (in the dry mass) N- org	P	K	Ca	Mg	Na	Ion ratio K/Mg+Ca	K/Na	Ca/P
Vermicompost	Trojka	0.91	0.26	2.34	0.28	0.06	0.35	6.9	6.7	1.1
	Nantejska	0.87	0.28	2.70	0.25	0.09	0.31	7.9	8.7	0.9
	Carera	1.05	0.31	3.35	0.29	0.08	0.16	9.0	20.9	0.9
	Mean	**0.94**	**0.28**	**2.80**	**0.27**	**0.08**	**0.27**	**8.0**	**10.4**	**1.0**
Mineral fertiliser	Trojka	1.08	0.23	2.61	0.25	0.07	0.25	8.2	10.9	1.1
	Nantejska	1.12	0.28	2.36	0.23	0.09	0.24	7.4	9.8	0.8
	Carera	1.64	0.31	3.40	0.32	0.09	0.13	8.3	26.1	1.0
	Mean	**1.28**	**0.27**	**2.80**	**0.27**	**0.08**	**0.21**	**8.0**	**15.6**	**0.96**
Mean Regardless fertility	Trojka	0.99	0.25	2.47	0.27	0.06	0.30	7.6	8.8	1,1
	Nantejska	1.0	0.28	2.53	0.24	0.09	0.28	7.7	9.4	0,8
	Carera	1.35	0.31	2.38	0.31	0.08	0.15	8.6	23.5	1,0
LSD 0.05		FxV =0,23 F =0.12 V =0,17	FxV =ns F =ns V =0.03	FxV =ns F =ns V =ns	FxV =ns F =ns V = 0.03	FxV =ns F =ns V =ns	FxV =ns F =0.03 V =0.04	FxV =ns F =ns V =ns	FxV =ns F =1.8 V =2.3	FxV =ns F =ns V =ns

TABLE 3

Results of analyses of cucumber fruit from the glasshouses for level of nitrates and heavy metal content [mg ∙kg $^{-1}$ fresh mass] according to fertilisation (F) and term of cropping (T)

Location	Date	$N\text{-}NO_3$			Pb			Cd			Cu			Zn		
		Ver.	Min. fert.	Mean	Ver.	Min. fert.	Mean	Ver.	Min. fert.	Mean	Ver.	Min fert.	Mean	Ver.	Min. fert.	Mean
Słocina in 1993	28.06.	158	398	278	0.14	0.28	0,21	0.01	0.03	0,02	*	*		*	*	
	15.07.	80	194	137	0.17	0.30	0,23	0.02	0.06	0,04						
	23.07.	114	250	132	0,12	0.20	0,16	0.02	0.04	0,03						
	12.08.	128	144	136	0.19	0.23	0,21	0.01	0.02	0,015						
mean		**120**	**246**	**-**	**0.15**	**0.25**	**-**	**0.01**	**0.04**	**-**						
LSD		*FxT =38*	*F =17*	*T =24*	*FxT =ns*	*F =0,02*	*T =0,03*	*FxT =ns*	*F =0,003 =0,004*	*T*						
Słocina in 1996	11.06.	230	284	257	0.20	0.20	0,20	0.013	0.021	0,017	0.50	0.55	0,52	2.30	2.75	2,53
	25.06.	134	261	198	0.18	0.21	0,20	0.014	0.018	0,016	0.50	0.45	0,47	2.10	2.60	2,35
	16.06.	72	102	87	0.11	0.15	0,13	0.020	0.021	0,020	1.50	1.30	1,40	1.90	2.00	1,95
	1.08.	74	83	79	0.20	0.22	0,21	0.026	0.030	0,028	1.60	1.20	1,40	2.00	2.10	2,05
mean		**128**	**183**	**-**	**0.17**	**0.20**	**-**	**0.018**	**0.023**	**-**	**1.03**	**0.88**		**2.08**	**2.36**	**-**
LSD		*FxT = ns*	*F = 15*	*T = 24*	*FxT = ns*	*F = 0,02*	*T = 0,03*	*FxT = ns*	*F = 0,003*	*T = 0,004*	*FxT = ns*	*F = 0,09*	*T = 0,11*	*FxT = ns*	*F = 0,22*	*T = 0,28*
Ropczyce in 1996	11.07.	57	119	88	0.11	0.15	0,13	0.016	0.033	0,024	1.50	1.60	1,55	1.60	1.70	1,65
	16.07.	79	93	86	0.07	0.15	0,11	0.019	0.030	0,024	1.00	0.90	1,45	1.70	1.90	1,80
	1.08.	64	229	147	0.11	0.15	0,13	0.020	0.035	0,027	1.50	1.40	1,45	1.60	1.90	1,75
	8.08.	41	51	46	0.08	0.07	0,08	0.025	0.051	0,038	0.90	1.10	1,00	2.00	2.20	2,10
mean		**60**	**123**		**0.09**	**0.13**		**0.02**	**0.037**	**-**	**1.23**	**1.25**	**-**	**1.73**	**1.93**	**-**
LSD		*FxT = 21*	*F = 11*	*T = 14*	*FxT = 0,03*	*F = 0,01*	*T = 0,02*	*FxT = 0.005*	*F = 0,002*	*T = 0,003*	*FxT =ns*	*F = ns*	*T = 0,15*	*FxT =ns*	*F = 0,19*	*T 0,24*

* no data available

TABLE 4

Nitrate and heavy metal contents (mg ·kg $^{-1}$ fresh mass) in tomato fruit cultivated in glasshouse according to fertilisation (F) and term of a cropping (T)

Location	Date	$N\text{-}NO_3$			Pb			Cd			Cu			Zn		
		Ver.	Min. fert.	Mean	Ver.	Min. fert.	Mean	Ver.	Min. fert.	Mean	Ver.	Min. fert.	Mean	Ver.	Min. fert.	Mean
Słocina in 1996	16.07	49	131	90	0.15	0.20	0.18	0.027	0.030	0.029	0.90	1.10	1.00	2.00	2.20	2.10
	1.08	20	57	39	0.25	0.27	0.26	0.029	0.032	0.031	0.80	1.00	0.90	2.00	2.10	2.05
	12.08	19	23	21	0.13	0.17	0.15	0.015	0.015	0.015	0.60	0.80	0.70	2.10	2.30	2.20
	29.08	16	19	18	0.13	0.19	0.16	0.023	0.028	0.026	0.80	0.90	0.85	1.90	2.00	1.95
mean		**26**	**57.5**	-	**0.17**	**0.21**	-	**0.024**	**0.026**	-	**0.78**	**0.96**	-	**2.0**	**2.15**	-
LSD $_{0.05}$		*FxT =9.4*	*F =5.0*	*T =6.8*	*FxT =ns*	*F =0.02*	*T =0.03*	*FxT =ns*	*F =ns*	*T =0.003*	*FxT =ns*	*F =0.11*	*T =0.17*	*FxT =ns*	*F =ns*	*T =0.23*

Tomato

The tomato crop, as for cucumber, was harvested by systematic manual picking. Fourfold analyses showed similar tendency: lower content of nitrates and heavy metals in fruits from vermicompost. Compared to the same crop from mineral fertiliser the nitrate content was 40% lower, Pb — 19%, Cd — 8%, Cu — 18%, and Zn — 7%. It was also found that growing tomato on vermicompost was less labour consuming, because tomato plants had a less-developed foliage system and therefore fruit matured faster and were easier to pick. Crop on vermicompost was more tasty. Also, it was observed that tomato plants from mineral fertiliser stopped fruiting two weeks earlier.

Leek and celery

Studies on leek and celery were conducted in a similar experimental arrangement, but with an additional control with no fertilisation. Two cultivars of leek ("Bartek" winter variety an "Arkansas" summer-autum variety) and "Zefir" variety of celery were under observation (Table 5).

The crops from vermicompost and mineral fertiliser were similar („Arkansas" leek variety — 13.4 $t \cdot h^{-1}$, and "Zefir" variety of celery — 11.7 $t \cdot h^{-1}$) but compared to the control with no fertilisation, were significantly ($p < 0.05$) higher (leek in control — 9.3 $t \cdot h^{-1}$, LSD of 0.9 $t \cdot h^{-1}$, celery control crop — 7.0 $t \cdot h^{-1}$, LSD of 0.8 $t \cdot h^{-1)}$. In the case of "Bartek" winter variety of leek, the crop from vermicompost was significantly ($p < 0.05$) higher (vermicompost — 18.4 $t \cdot h^{-1}$, mineral fertiliser — 13.4 $t \cdot h^{-1}$, control — 7.0 t h^{-1}, LSD of 1.0 $t \cdot h^{-1}$.

Analyses of nitrate and heavy metals contents in leek plants generally confirmed the tendency of lower uptake of these substances by plants from vermicompost, previously obtained in carrot, cucumber and tomato. Both nitrate and nitrite contents were lower in leek from vermicompost but higher than those in plants from the control — with no fertilisation.

A clear tendency to lower Pb content in plants from vermicompost can be seen in Table 5, while Cd and Zn contents varied widely.

Potato

Studies on a potato, *Solanum tuberosum*, were conducted on "Atol" variety. They were cultivated on balanced doses of vermicompost and mineral fertiliser. The crop level was differed (ver.: 6.1–7.3 $t \cdot h^{-1}$, min. fert.: 6.6–7.9 $t \cdot h^{-1}$), but its value on the objects with both fertilisation modes was not significantly different. Chemical analysis of the tubers from vermicompost showed lower contents of nitrates (by 46%), cadmium (by 33%) and nickel (by 34%). Alternatively, lead content was similar in tubers from vermicompost and from mineral fertiliser, but there were positive effect on the healthiness of the potato tubers. It reduced the infection of tubers by *Phytophthora infestans, Rhizoctonia solani, Fusarium sp.* and *Streptomyces scabies* (Fig. 1).

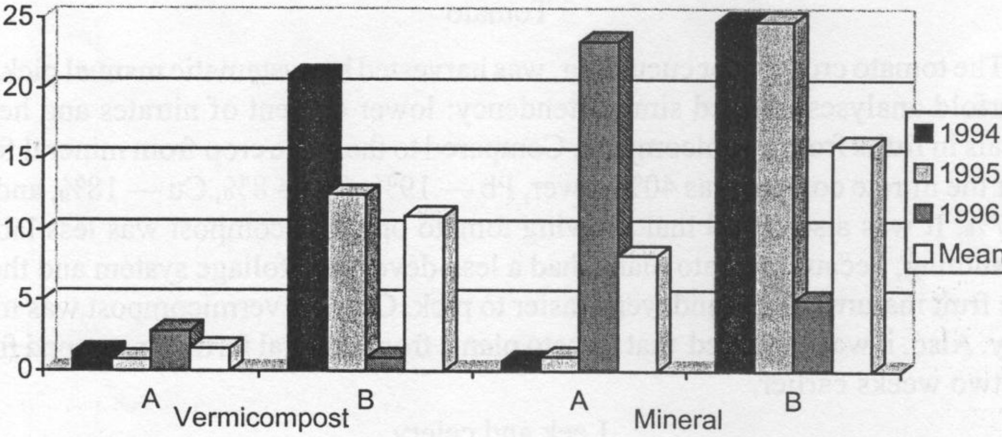

Fig. 1. Share [%] of infected *Solanum tuberosum* tubers in crop: (A) during harvest and (B) after 4 months of storage

TABLE 5

Content of nitrates, nitrites and heavy metals (mg · kg^{-1} fresh mass) in leek and celery cultivated on vermicompost, mineral fertiliser and with no fertilisation according to fertilisation (F)

Plant	Fertilisation	$N\text{-}NO_3$	NO_2	Zn	Pb	Cd
Leek	Vermicompost	30	0.64	13.2	0.73	0.08
„Bartek"	Mineral fertiliser	102	0.70	4.8	0.86	0.13
winter variety	Control	41	0.55	12.7	0.97	0.13
$LSD_{0.05}$		9	0.08	2.1	0.10	0.02
Leek	Vermicompost	35	0.64	11.5	0.75	0.05
"Arkansas"	Mineral fertiliser	97	0.76	6.5	0.84	0.04
summer –autumn variety	Control	30	0.58	9.1	0.95	0.06
$LSD_{0.05}$		15	0.09	1.1	0.08	ns
Celery	Vermicompost	238	1.29	6.0	0.47	0.07
"Zefir"	Mineral fertiliser	336	1.21	5.2	0.52	0.09
variety	Control	309	1.81	4.3	0.49	0.14
$LSD_{0.05}$		26	0.16	0.7	0.04	0.02

Discussion

Production of fruits and vegetables with high qualitative parameters, provides a chance to improve human health, and the environment.

Vermicompost produced from cattle manure is an universal fertiliser and, being characterised by good physical structure as well as rich and diversified composition [3], it is providing plants fully with macro and microelements.

The beneficial characteristics of carrot, cucumber, tomato, leek, celery and potato from vermicompost presented above (i.e. low content of nitrates and harmful heavy metals) are probably the result of the presence of such elements as: boron, copper, zinc, and manganese, molybdenum and sodium in vermicompost.

Microelements present in a horticultural bed, in required amounts, ensure the proper course of physiological and biochemical plant processes. In the process of mineral noutrishment of plants, microelements, among others, are safeguarding the ability of selective uptake of optimum levels of other necessary elements. Due to that, plants absorb (in limited quantities) such harmful elements as cadmium and lead.

Another important aspect is that macronutrients are available in vermicompost, partly in mineral form (i.e. immediately absorbable) and partly in organic form, from which they are gradually set free to the soil solution. It assures that plants are systematically supplied with nutrients, while nutrients are protected against leaching from soil. That is why vermicompost outcompetes highly concentrated mineral fertiliser, which is a source of macronutrients, but does not assure the plants sufficient access to many microelements.

The most probable cause of the fact that the relation between microelements and macroelements in the chemical composition of plants grown on mineral fertilisers shifts in favour macroelements (their ratio becomes wider).

As shown in the research described above, plants growing on vermicompost were characterised by lower contents of nitrates and heavy metals, in comparison with plants cultivated on mineral fertiliser. Differences between nitrate contents in plants grown on vermicompost and those on mineral fertiliser varied within: 50% for carrot, 30–50% for cucumbers, 54% for tomato, 63–70% for leek, 29% for celery and 47% for potato.

Differences between heavy metals levels were (varied) as follows: for carrot: Pb 39%, Cd 40%; for cucumbers: Pb 1–40%, Cd 2–75%, for tomato: Pb 19%, Cd 8%; for leek: Pb 11–15%, Cd 20–38%; for celery: Pb 10%, Cd 22%; and for potato: Pb — no difference, Cd 33%.

Vermicompost also had positive effects on crops by improving their processing properties: for instance better shaped carrot roots, better taste (checked by blind-testing group of people), lower foliage of cultivated tomato, therefore faster ripening of fruits and easier harvesting. Potato cultivated on vermicompost was characterised by profitable crop structure: the fraction of tubers bigger than 4 cm was more numerous [4].

Some authors inform that, vermicompost can also be active in plant disease control [6, 9]. Szczech & Brzeski [9] have shown that the addition of vermicompost to the growth medium suppressed the infection caused by pathogenic fungi. Kostecka & Błażej [6] also found, that vermicompost had a very positive effect on the healthiness of potato tubers, by reducing their infection by *Phytophthora infestans, Rhizoctonia solani, Fusarium sp.* and *Streptomyces scabies*. The symptoms of blight disease were found on plants from vermicompost 7 days later than those on plants cultivated on mineral NPK fertiliser.

This suggests that vermicompost may also be used as a biopesticide. However, preventive properties of vermicompost can be limited by many factors such as thermal sterilisation, the addition of fresh pine sawdust to vermicompost [10] or bad and long-lasting storage of this manure [5]. These factors have negative influences on the population of microorganisms present in vermicompost or contribute to loss of vermicompost nutrients. Comparing yield from crops cultivated on mineral fertiliser and vermicompost proved that crops levels were similar. However, in a three-year experiment with "Atol" potatoes cultivated on vermicompost and mineral fertiliser Kostecka & Błażej [6] showed that it is much more profitable to use vermicompost for fertilisation. After four months of storage, tuber yield reduction due to diseases, was much lower for vermicompost (3.6%). In tubers grown on mineral fertiliser the loss of loss of crop was much higher (30%).

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