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Effect of organic fertilizers on apparent nitrogen utilization and yield of sweet pepper (*Capsicum annuum* L.) as influenced by fertilizer timing

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Abstract

A glasshouse experiment was carried out at the University of Natural resources and Life Sciences, Vienna, Austria during the months of April to September in both 2012 and 2013 to investigate the effect of organic fertilizers on apparent nitrogen utilization and yield of sweet pepper as influenced by fertilizer timing. In two subsequent years, sweet peppers were grown in glasshouse and fertilized with 20 g N/m² as Maltaflor®-spezial, coarse meal of fababean and horn at different times within a 30 cm wide fertilizer-band. The experiment was laid out in a Complete Randomized Design (CRD) with four replications. Data was recorded on the various parameters and subjected to statistical analysis. Yields of tomatoes, plant N uptake and apparent N utilization obtained with Maltaflor®-spezial or fababean were comparable to those of horn in both years. The apparent N utilization did not exceed 19-33 % in the first year (2012) due to a high N uptake in the control, but increased in the following year (2013) to 26-57 %, because of the poorer growth in the unfertilized control. There were marked differences in the amount of NO_3^--N remaining in soil during and after cultivation, so that the N supply by Maltaflor®-spezial was higher compared to fababean and horn. Split application of a readily available organic fertilizer could be promising and an additional N mineralization could be expected by a regular hoeing of formerly fertilized plots.

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Introduction

For many years, organic vegetable growers used animal residues like horn-, blood- or meat meal to meet nitrogen (N) demand of the plants, while farmyard manure is seldom used. However, due to the BSE (Bovine Spongiform Encephalopathy) crisis alternative fertilizers are required (Schmitz and Fischer, 2003). Therefore, plant-derived and industrially-processed organic N fertilizers that can be divided into grinded seeds of legumes and processed crop residues from the food and feed industry are becoming more common. Previous studies either determined the N release from plant-based and industry-processed fertilizers (Laber, 2003) or investigated the effect of these fertilizers on the yield of vegetable crops (Koller *et al.,* 2004). The efficiency of the fertilizer on yield depends largely on the synchrony between N release of crop residues and N demand by the growing crop (Båth, 2001). An adaptation of the N release to plant demand will depend on the time of application: incorporation of red clover two weeks after planting resulted in marginally higher N uptake of leek compared to incorporation at planting, but incorporation four weeks after planting caused a significantly reduced N uptake (Båth, 2001). The time course of N uptake markedly differs between vegetable crops (Matsumoto *et al.,* 1999) and for sweet peppers N uptake, measured by the difference of NO_3^- in the soil in the planted vs. unplanted plots, starts 1-3 weeks after planting (Thönnissen *et al.,* 2000b). Yaffa *et al.* (2000) concluded from their application strategy that all fertilizer should be applied within 8 weeks after transplanting to synchronize N availability with early sweet pepper growth. On the other hand, if the whole N amount of fertilizer is applied at planting there will be a high N surplus during the early sweet pepper growth leading to an unbalanced, strong vegetative growth. But, mineral N in soil may be prone to losses by leaching or immobilization (Blankenau and Kuhlmann, 2000). Hence, it might be expected that a split application of plant-based and industry processed organic fertilizers could be favourable for long-growing crops. Two plant-based fertilizers (coarse meal of fababean and Maltaflor®-spezial) were applied to organically grown sweet peppers in glasshouse to investigate (1) their N release in soil, (2) their effect on N uptake and yield of sweet peppers and (3) the role of the timing of fertilizer application.

Materials and methods

Glasshouse experiments

Sweet peppers Tomatoes (*Capsicum annum* L.) were grown in organically managed glasshouses for two years in 2012 and 2013 at the research station of the University of Natural Resources and Life Sciences, Vienna-Austria. The soil was a sandy loam, low in organic matter (OM) (Table 1). Soil texture was analyzed by pipette analysis (Gee and Bauder, 1986), C_{org} and N_t by dry combustion (Hoffmann, 1997), and pH was determined in 0.01 M $CaCl_2$ extract. The experimental soil was well supplied with nutrients as indicated in Table 1. P, K, and Mg were analyzed by ICP (ICP Emission Spectrometer, Liberty 200, VARIAN, Basel, Switzerland) by using Calcium Acetate Lactate (CAL) for P and K, and $CaCl_2$ for Mg as extractants. Previous to the sweet pepper crop, oil radish (*Raphanus sativus* L. var. oleiformis) was used as intercrop in 2012 or winter rye (*Secale cereale* L.) in 2013. Shoots and roots of the intercrop were removed two weeks (2012) or six weeks (2013) before sweet peppers were planted. Soil was tilled to a depth of 20 cm with a rotary hoe. Sweet peppers were

Table 1. Characteristics of the soil (sandy loam (FAO, 1998) in the glasshouses at the research station of the University of Natural Resources and Life Sciences, Vienna.

Clay	***Silt***	***Sand***	***C_{org}***	***N_t***	***C/N***	***pH $CaCl_2$***	***P CAL***	***K CAL***	***Mg $CaCl_2$***
%							(mg / 100 g dry soil)		
9	26	65	1.6	0.13	12.1	7.4	9	9	20

Note: CAL (Calcium Acetate Lactate)

Table 2. N and C content and C/N ratio of the tested organic fertilizers.

Fertilizer	*N content %*		*C content %*		*C/N ratio*	
	2012	2013	2012	2013	2012	2013
Fababean (coarse meal of fababean)	4.2	4.2	40	40	9.4	9.4
Maltaflor (Maltaflor®-spezial)	4.7	3.6	38	39	8.4	10.8
Horn (per 1/3 horn meal, -grit, -chipping)	13.2	14.1	42	45	3.2	3.2

transplanted in spring in the beginning of the month of April in both 2012 and 2013 and in double rows per plot (55 cm plant to plant, 60 cm inter-row distance and 120 cm distance between the double rows, 2 plants/m^2) and crop was terminated at the end of the month of September in both 2012 and 2013. The experimental layout was a Complete Randomized Design (CRD) with four replicates. Plant protection was managed by using beneficial organisms and weeds were regularly removed by hand. Air temperature in the glasshouse ranged between 20°-35°C in 2012 and 20°-30°C in 2013. Drip irrigation (two tubes for each row, 33 cm dripping distance) was regulated by tensiometers, which were monitored four times each day. Irrigation started when the soil matric potential decreased below -80 hPa.

Fertilizer application

Prior to the planting of sweet peppers 10 g K_2O/m^2 was broadcasted as Patentkali® and 20 g N/m^2 was either applied as coarse meal of fababean, Maltaflor®-spezial (Maltaflor), sieved to 2 mm, or horn (Table 2) within a fertilizer-band of 30 cm. These early fertilized treatments were called: Fababean 20/0 g N/m^2, Maltaflor 20/0 g N/m^2, and Horn 20/0 g N/m^2. In both years an unfertilized treatment ("Control") was included to monitor N mineralization from soil.

Sampling and analyses

During the growth period ripe sweet pepper were regularly collected in subplots from twelve plants twice each week and additional samplings which were collected as well included; side shoots collected 1-2 times each week and stripped leaves collected 3 times during the growth period in both 2012 and 2013. The above ground biomass of these twelve plants was harvested at the end of the growth period and divided into remaining ripe and unripe peppers and shoots. For all plant parts fresh biomass weight was determined and sub samples were dried at 105 °C for 24 hours to determine total dry matter yield. Samples of the shoots dried at 105 °C for 24 hours were grinded to pass through a 1.5 mm sieve (shear-mill, BRABENDER, Germany), the ripe and unripe peppers were finely grinded with a coffee mill. N content was analyzed according to the DUMAS method (FP-328 Nitrogen/Protein Determinator, LECO CORPORATION, St. Joseph, Michigan, USA). Composite soil samples for analysis of nitrate-N were taken from 6 cores at each depth (0-15 cm, 15-30 cm, 30-60 cm) within the fertilizer-band before planting of tomatoes and at regular intervals during the growth period. After sampling, soil samples were kept frozen. Gravimetric soil water content was determined and the soil was extracted with 0.01 M $CaCl_2$ (1:2 soil: extractant). After filtration (589/2 ½ SCHLEICHER & SCHÜLL, Dassel, Germany) soil extracts were subsequently frozen. Nitrate was measured photometrically after separation by HPLC (KONTRON INSTRUMENTS, Au i.d. Hallertau, Germany) according to Vilsmeier (1984).

Statistical analysis

SAS Version 8.2 was used for all statistical evaluations. The results of the experiment was subjected to one-way analyses of variance with the significance of the means being tested using LSD, $p \leq 0.05$.

Results

Yield

The yield of sweet peppers included all harvested ripe and unripe fruits at the end of the growth period. Only 1-2 % of all ripe fruits were unmarketable independently of the treatment or year. In both years the yield level of sweet peppers obtained with plant-based and industry-processed organic nitrogen fertilizers was comparable to the horn based fertilizer (Table 3 A). But in 2013 the differences in yield within the fertilized treatments were higher than in 2012.

Table 3 A. Cumulative sweet peppers yield (ripe + unripe) grown in glasshouse (2 plants/m²) fertilized with 20 g N/m² as fababean, Maltaflor (Maltaflor®-spezial) and horn before or six weeks after planting in 2012 and *2013*.

Fertilizer treatment	*Sweet peppers yield (kg/m²)*	
	2012	2013
Control	11.9 a	8.9 b
Fababean 20/0 g N/m²	13.1 a	11.7 a
Maltaflor 20/0 g N/m²	14.1 a	13.9 a
Horn 20/0 g N/m²	14.3 a	12.0 a

Letters indicate significant differences (LSD, p≤0.05) within one year.

Table 3 B. Cumulative Sweet peppers yield (ripe + unripe) grown in glasshouse (2 plants/m²) fertilized with fababean and Maltaflor (Maltaflor®-spezial) at different N rates (10 or 20 g N/m²) and times of application (before or six weeks after planting) in 2012 and 2013.

Fertilizer treatment	*Sweet peppers yield (kg/m²)*	
	2012	2013
Fababean 20/0 g N/m²	13.1 a	-
Fababean 10/10 g N/m²	13.6 a	-
Fababean/Maltaflor 10/10 g N/m²	13.5 a	-
Maltaflor 20/0 g N/m²	-	13.9 a
Maltaflor 0/20 g N/m²	-	11.7 a
Maltaflor 0/10 g N/m²	-	10.9 a

Letters indicate significant differences (LSD, p≤0.05) within one year.

Yield produced in the unfertilized control was high in 2012 and reached 83-91% of the fertilized treatments. In 2013 the differences between the unfertilized and the fertilized plots were higher with 64-76 %, indicating lower soil N supply in 2013 (data not shown). The splitting of the N rate (Fababean 10/10 g N/m², Fababean/ Maltaflor 10/10 g N/m²) did not affect the yield in 2012 (Table 3 B). The sole N application of 20 g N/m² (Maltaflor 0/20 g N/m²) or even 10 g N/m² (Maltaflor 0/10 g N/m²) six weeks after planting in 2013 resulted in a somewhat lower yield compared to the application of 20 g N/m² as Maltaflor®-spezial before planting (Maltaflor 20/0 g N/m²), but the differences were statistically insignificant.

Nitrogen uptake

For the early application of 20 g N/m² the N uptake of plant-based and industry processed organic fertilizers was comparable to horn in both years (Table 4 A). N uptake in the control treatment without fertilizer application that describes the N release from soil was much higher in 2012 than in 2013 (68 as compared to 40 g N uptake / kg soil Nt). Consequently, the N uptake from the unfertilized control reached 76-84 % of the fertilized treatments in 2012 and 53-68 % in 2013. In 2013 also the trend of a lower N uptake from fababean compared to Maltaflor®-spezial was more pronounced than in 2012. The splitting of the N rate into two applications did not affect the N uptake (Table 4 B) in 2012. However, the N application six weeks after planting in 2013 (Maltaflor 0/20 g N/m²) resulted in a significantly lower N uptake compared to the N application before planting (Maltaflor 20/0 g N/m²). This reduction occurred irrespective of whether 20 or 10 g N/m² were applied. The apparent N utilization was generally higher in 2013 (26-57 %) than in 2012 (19-33 %). In both years the apparent N utilization of fababean tended to be lower than that of Maltaflor®-spezial and horn but this was statistically insignificant. Fertilizer splitting in 2012 or late

Table 4 A. Cumulative N uptake of sweet peppers grown in glasshouse (2 plants/m²) and apparent N utilization of sweet peppers fertilized with 20 g N/m² as fababean, Maltaflor (Maltaflor®- spezial) and horn before or six weeks after planting in 2012 and 2013.

Fertilizer treatment	*N uptake (g/m²)*		*Apparent N utilization (%)*	
	2012	2013	2012	2013
Control	20.0 b	12.5 b	-	-
Fababean 20/0 g N/m²	23.7 a	18.5 a	19 a	30 a
Maltaflor 20/0 g N/m²	26.5 a	23.8 a	33 a	57 a
Horn 20/0 g N/m²	26.4 a	20.1 a	32 a	38 a

Letters indicate significant differences (LSD, p≤0.05) within one year.

Table 4 B: Cumulative N uptake of sweet peppers grown in glasshouse (2 plants/m^2) and apparent N utilization of sweet peppers fertilized with fababean and Maltaflor (Maltaflor®-spezial) at different N rates (10 or 20 g N/m^2) and times of application (before or six weeks after planting) in 2012 and 2013.

Fertilizer treatment	***N uptake (g/m²)***		***Apparent N utilization (%)***	
	2012	2013	2012	2013
Fababean 20/0 g N/m²	23.7 a	-	19 a	-
Fababean 10/10 g N/m²	23.7 a	-	19 a	-
Fababean/Maltaflor 10/10 g N/m²	23.7 a	-	19 a	-
Maltaflor 20/0 g N/m²	-	23.8 a	-	57 a
Maltaflor 0/20 g N/m²	-	17.7 b	-	26 a
Maltaflor 0/10 g N/m²	-	15.7 b	-	32 a

Letters indicate significant differences (LSD, $p \leq 0.05$) within one year.

application in 2013 had no effect on the apparent N utilization, despite the somewhat higher apparent N utilization of the early Maltaflor®-spezial application (Maltaflor 20/0 g N/m^2). Table 4 A shows the cumulative N uptake of sweet peppers grown in glasshouse (2 plants/m^2) and apparent N utilization of sweet peppers fertilized with 20 g N/m^2 as fababean, Maltaflor (Maltaflor®- spezial) and horn before or six weeks after planting in 2012 and 2013 while table 4B shows the cumulative N uptake of sweet peppers grown in glasshouse (2 plants/m^2) and apparent N utilization of sweet peppers fertilised with fababean, Maltaflor (Maltaflor®-spezial) and horn at different N rates (10 or 20 g N/m^2) and times of application (before or six weeks after planting) in 2012 and 2013.

Soil nitrate content

In both years fertilizer application markedly affected the nitrate content only in the uppermost layer in 0-15 cm, whereas deeper layers in 15-30 cm and 30-60 cm contained much less nitrate (Fig 1A and 1B). Type of fertilizer, time of application and hand hoeing strongly influenced the nitrate content in the soil. Hand hoeing generally increased the soil nitrate content except in the control. In 2012 the increase in soil nitrate content after the application of Maltaflor®-spezial was higher compared to the other fertilizers. In 2013 the results were somewhat different, the application of horn caused the nitrate content of soil to remain at a quite high level, while "Maltaflor 20/0 g N/m^2" did not increase the nitrate content that much. But, late applications of Maltaflor®-spezial (Maltaflor 0/20 g N/m^2, Maltaflor 0/10 g N/m^2) again strongly increased the soil nitrate content to levels similar to those of 2012. Finally, at the end of the experiments soil nitrate content of all fertilizer treatments was comparable in both years in the uppermost soil layer.

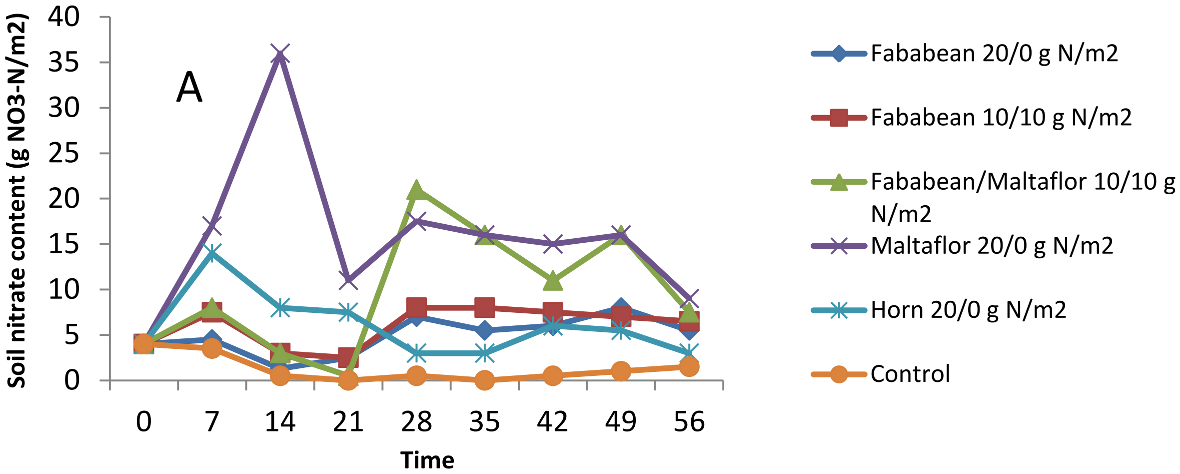
Apparent nitrogen recovery

Apparent N recovery of fertilizers was higher in 2013 than in 2012 (Table 5). Horn released 37-57 %, fababean 34 - 43 % and Maltaflor®-spezial 59 - 68 % of the applied N. Apparent fertilizer N recovery consisted of additional N uptake of sweet peppers (N uptake of fertilizer treatments minus N uptake of control) and additional NO_3^--N in the 0-60 cm soil layer (additional nitrate-N of fertilizer treatments minus nitrate-N of control) compared to the amount of N applied by fertilizers to sweet peppers at the end of the growth period (end of September 2012 and 2013).

Table 5. Apparent fertilizer N recovery of fababean, Maltaflor (Maltaflor®-spezial) and horn applied at different N rates (10 or 20 g N/m^2) and times of application (before or six weeks after planting) in 2012 and 2013.

Fertilizer treatment	*Apparent N recovery %*	
	2012	2013
Fababean 20/0 g N/m²	34 a	37 a
Maltaflor 0/10 g N/m²	-	81 a
Fababean/Maltaflor 10/10 g N/m²	46 a	-
Maltaflor 0/20 g N/m²	-	68 a
Maltaflor 20/0 g N/m²	59 a	68 a
Horn 20/0 g N/m²	37 a	57 a

Letters indicate significant differences between fertilizer treatments (LSD, $p \leq 0.05$) within one year.



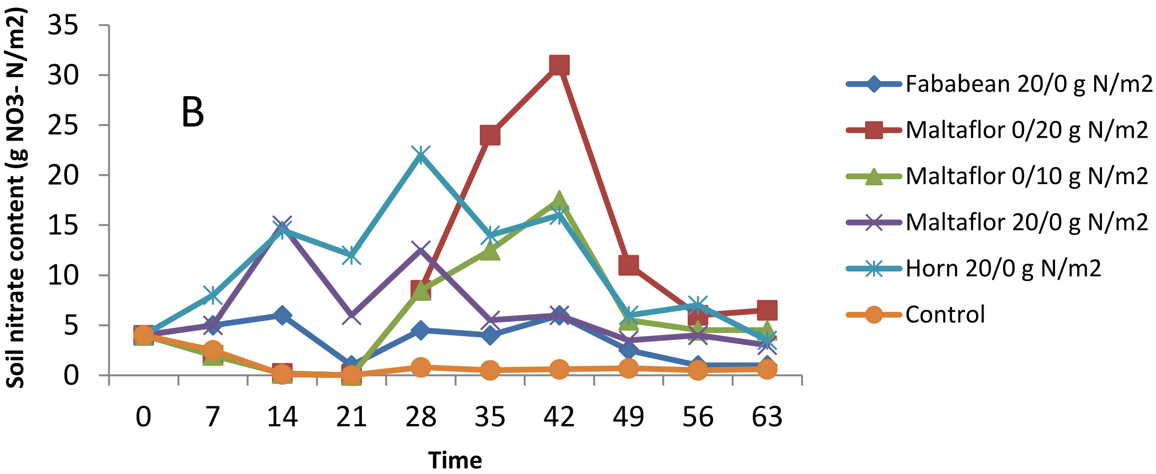


Fig. 1. Nitrate content in soil (0-15 cm) fertilized with fababean, Maltaflor (Maltaflor® spezial) and horn at different N rates (10 or 20 g N/m²) and times of application (before or six weeks after planting) in the glasshouse in 2012 (A) and 2013 (B).

Discussion

Yield and N uptake of sweet peppers fertilized with plant-based and industry-processed organic N fertilizers were similar to those fertilized with horn, indicating that they can substitute for animal residue based organic fertilizers. Comparably, Abdul-Baki (1996) measured higher marketable yield and fruit weight of sweet peppers grown in cover-crop mulches compared to bare plots without mulch. However, Tourte *et al.* (2000) found no significant differences in the yield of marketable sweet peppers between the control and an application of wooly pod vetch, although their N rate (approx. 175 kg N/ha) was similar to ours. These somewhat contrary results may be caused by the often marginal effect of green manure on yield of sweet peppers on fertile soils, but its high effects on poor soils (Thönnissen *et al.*, 2000a). The N supply of the soil may be also the reason for the higher differentiation of sweet peppers yield between fertilized and unfertilized plots in 2013 compared to 2012. This differentiation was more pronounced for the N uptake than for the sweet peppers yield. The very high N uptake of the control in 2012 was partly related to the high nitrate input with the irrigation water (up to 5.3 g N/m²) and partly the result of the high net N mineralization. Therefore, the effect of fertilizer application on yield and N uptake was low, resulting in an apparent N utilization of 19-33 %. In 2013 apparent N utilization of the same treatments was much higher (30-57 %) due to a markedly lower yield of the control. On one hand, any surplus of mineral N in soil may be prone to losses by leaching or immobilization (Blankenau and Kuhlmann, 2000). On the other hand, a minimum content of mineral N in soil is needed to support a proper plant growth (Feller and Fink, 2002). Therefore, a fertilizer application strategy like splitting that reduces intermittently occurring N excess in soil may be favorable. However, in 2012 the splitting of the N rate resulted neither in higher yield nor in higher N uptake or apparent N utilization of sweet peppers. In view of the missing yield differences, the N supply of the sweet peppers in both treatments was obviously not significantly different during crucial stages of development. Therefore, from a split application of a readily available organic fertilizer like Maltaflor®-spezial, a higher N efficiency might be expected. However, particularly if soil N release is low a single late fertilizer application even with a readily available organic fertilizer like Maltaflor®-spezial runs the risk of yield deprivation. Similar results are presented by Båth (2001): a late application of green manure (clover) caused a delay in growth and N uptake of leek and high values of nitrate in soil at harvest. However, further experiments must substantiate the positive yield effect of a split fertilizer application of Maltaflor®-spezial in contrast to those of fababean.

Conclusions

The tested fertilizers Maltaflor®-spezial and fababean will act as rapid N sources, ensuring a sufficient N supply for vegetable crops in organic horticulture comparable to those of established animal-based organic fertilizers like horn. Vegetable crops with a long-lasting growth period should be fertilized before planting. During the vegetation period a regular hoeing of the formerly fertilized plots will generally increase N mineralization and should therefore be part of an optimized fertilizer management strategy. Data suggest that a split application is more promising with a readily available organic fertilizer like Maltaflor®-spezial compared to fababean.

References

Abdul-Baki AA. 1996. Fresh-market pepper production in a low-input alternative system using cover-crop mulch. HortScience **31**, 65-69.

Båth B. 2001. Nitrogen mineralization and uptake in leek after incorporation of red clover strips at different times during the growing period. Biological Agriculture and Horticulture **18**, 243-258.

Blankenau K, Kuhlmann H. 2000. Effect of N supply on apparent recovery of fertiliser N as crop N and Nmin in soil during and after cultivation of winter cereals. Journal of Plant Nutrition and Soil Science **163**, 91-100.

FAO. 1998. World Reference Base for Soil Resources, FAO, Rome.

Feller C, Fink M. 2002. NMIN target values for field vegetables. In: Booij, R., Neeteson, J. (ed.): *Acta Hort*iculturae 571, Proceedings of the ISHS workshop: Towards an ecologically sound fertilisation in field vegetable production, International Society for Horticultural Science, 195-201.

Gee GW, Bauder JW. 1986. Particle-size analysis. In: Klute, A. (ed.): Methods of soil analysis. Part 1. 2nd ed. Agronomy Monograph. 9. ASA and SSSA, Madison, WI., pp. 383-411.

Haworth F. 1961. The effect of organic and inorganic nitrogen fertilizer on the yield of early potatoes, spring cabbage, leeks and summer cabbage. Journal of Horticultural Sciences **36**, 202-215.

Hoffmann G. 1997. Die Untersuchung von Böden. In: VDLUFA-Methodenbuch, Band I, 4th ed., VDLUFA, Darmstadt.

Iritani W M, Arnold C Y. 1960. Nitrogen release of vegetable crop residues during incubation as related to their chemical composition. Soil Science **89**, 74-82.

Koller M, Alföldi T, Siegrist M, Weibel F. 2004. A comparison of plant and animal based fertiliser for the production of organic vegetable transplants. In: Nicola, S., Nowak, J., Vavrina, C.S. (ed.): Acta Horticulturae. **631**, XXVI International Horticultural Congress: Issues and advances in transplant production and stand establishment research, International Society for Horticultural Science, 209-215.

Laber H. 2003. N-Freisetzung aus organischen Handelsdüngern – Übersicht und eigene Versuchsergebnisse im ökologischen Gemüsebau. In: Rahmann, G., Nieberg, H. (ed.): Ressortforschung für den ökologischen Landbau. Landbauforschung Volkenrode, Sonderheft 259, 17-20.

Matsumoto S, Ae N, Yamagata M. 1999. Nitrogen uptake response of vegetable crops to organic materials. Soil Science and Plant Nutrition **45**, 269-278.

Schmitz H.-J, Fischer P. 2003. Vegetabile Dünger in Substraten für den ökologischen Gemüsebau. Gemüse **2**, 18-22.

Thönnissen C, Midmore D J, Ladha JK, Holmer R J, Schmidhalter U. 2000a. Pepper crop response to short-duration legume green manures in tropical vegetable systems. Agronomy Journal **92**, 245-253.

Thönnissen C, Midmore D J, Ladha JK, Olk DC, Schmidhalter U. 2000b. Legume decomposition and nitrogen release when applied as green manures to tropical vegetable production systems. Agronomy Journal **92**, 253-260.

Tourte L, Bugg R, Shennan C. 2000. Foliar-applied seaweed and fish powder do not improve yield and fruit quality of organically grown processing tomatoes. Biological Agriculture and Horticulture **18**, 15-27.

Vilsmeier K. 1984. Kurzmitteilung: Bestimmung von Dicyandiamid, Nitrit und Nitrat in Bodenextrakten mit Hochdruckflüssigkeitschromotographie. Zeitschrift für Pflanzenennahrung und Bodenkunde **14**, 264-268.

Yaffa S, Sainju U M, Singh B P. 2000. Fresh market pepper yield and soil nitrogen as affected by tillage, cover cropping, and nitrogen fertilization. HortScience **35**, 1258-1262.