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„Áburðargjöf í lífrænni ræktun á Íslandi – 2014“

FINAL REPORT

Christina Stadler

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Christina Stadler

Landbúnaðarháskóli Íslands

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Final report of the research project

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Abbreviations

C	carbon
CAL	calcium acetate lactate
C : N	carbon : nitrogen ratio
C_{org}	organic carbon
$CaCl_2$	calcium chloride
DM	dry matter yield
HSD	honestly significant difference
K	potassium
N	nitrogen
N_t	total nitrogen
NO_3^--N	nitrate-nitrogen
OM	organic matter
$p \leq 0,05$	5% probability level
P	phosphor
pH	potential of hydrogen

Other abbreviations are explained in the text.

1 SUMMARY

In the past, organic vegetable crops in Iceland were fertilised mainly with mushroom compost (1,9% N). However, due to the contamination with conventional chicken manure this fertiliser is to be replaced. Thus, substitutes are urgently needed.

Composted cow manure (1,9% N), residues from the fish industry (10,9% N), and commercial organic fertilisers (216 mg N/l) have been tested in a greenhouse experiment with tomatoes (variety 'Dirk'). Plants were grown with a plant distance in the row of 49,25 cm, 2,5 plants/m² and 250 kg N/ha fertiliser was applied in a split application within a fertiliser band of 30 cm during a growth period of seven months. The yield of tomatoes was measured and soil samples regularly taken and analysed for nitrate-N.

Due to the high soil N supply of the soil in the greenhouse did the fertiliser treatments show no significant differences in tomato yield and even not to the unfertilised control. A tendentially higher yield was reached after application of Pioner complete 6-1-3®. In general was the yield level low. The reason for that was a relatively low natural solar irradiation during the whole growth period compared to other years. A fertiliser application markedly affected the nitrate content in the soil. Also, hand hoeing increased the soil nitrate content and should therefore be part of an optimised fertiliser management strategy.

When just observing the price for one kg of N, mushroom compost seems to be a cheap fertiliser. However, when also the N utilisation is considered, both fishmeal and Pioner complete 6-1-3® are even cheaper than mushroom compost. Taking more years into account would probably result in similar values for all fertilisers as mushroom compost is not only mineralising N in the year of application.

The prohibition of mushroom compost should not really effect the organic vegetable growers as there are at least equal (composted animal manures) or even better fertilisers (e.g. fishmeal) with a similar price range on the market.

YFIRLIT

Fram til þessa hafa grænmetisbændur í lífrænni ræktun einkum notað sveppamassa (1,9% N) til áburðargjafar. En nú hefur verið bannað að nota sveppamassa í lífrænni ræktun vegna þess að hann inniheldur hænsnaskít úr hefðbundinni hænsnarækt. Það er því brýn þörf á því að finna aðra áburðargjafa sem uppfylla næringarþörf plantna og má jafnframt nota í lífrænni ræktun.

Moltu úr búfjáráburði (1,9% N), leifum frá fiskiðnaði (fiskimjöl, 10,9% N) og innfluttum verksmiðjuframleiddum áburði (216 mg N/l) var prófað í gróðurhúsatilraun með tómötum (yrki 'Dirk'). Plöntur voru ræktaðar með 49,25 cm bili milli plantna í röðinni og 2,5 plöntur / m^2. Borið var á 30 cm breitt svæði, alls 250 kg N / ha skipt í fimm (5 × 50) yfir vaxtatímabilið, sem var sjö mánuðir. Uppskera af tómötum var mæld og jarðvegssýni tekin reglulega og nítrat-N mælt.

Vegna mikils N framboðs í jarðvegi úr gróðurhúsi var ekki marktækur munur milli áburðarliða í tómatauppskeru og jafnvel ekki í samanburði við liðinn án áburður. Heldur meiri uppskeru fékkst eftir notkun á Pioner complete 6-1-3® en var ekki marktækur munur. Almennt var uppskeran lág. Ástæða þess var líklega mun minni náttúruleg sólarinngeislun á öllu vaxtartímabilinu samanborið við önnur ár. Áburður hafði veruleg áhrif á nítrat í jarðvegi. Það jók nítrat í jarðveginum að hræra í efsta laginu nokkrum sinnum (t.d. við áburðurgjöf) yfir vaxtatímabilið og ætti því að vera hluti af betri áburðurstjórnun.

Þegar einungis er verið að skoða verð fyrir eitt kg af N, virðist sveppamassi vera ódýr áburður. Hins vegar, þegar athuguð er N nýting, eru bæði fiskimjöl og Pioner complete 6-1-3® jafnvel ódýrari en sveppamassi. Að taka fleiri ár í reikninginn myndi líklega leiða í ljós svipað verð fyrir allar áburðartegundirnar, því að sveppamassi gefur ekki aðeins nítrat á áburðargjafarárinu.

Bann við notkun sveppamassa ætti í raun ekki hafa áhrif á lífræna ræktun grænmetis þar sem til staðar er að minnsta kosti jafn góður áburður (molta úr búfjáráburði) eða jafnvel betri áburður (t.d. fiskimjöl) á svipuðu verði á markaði.

2 INTRODUCTION

Vegetable crops, both grown in the greenhouse and outdoor, have a high nitrogen requirement. Therefore, N fertilisers used for organic vegetable production should ensure high N turnover, fast N availability, and continuous N supply. In the past, organic vegetable crops in Iceland were fertilised mainly with mushroom compost. However, due to the organic regulation (Council Regulation (*EC) No 834/2007* of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91) the use of mushroom compost is forbidden due to contamination with conventional chicken manure. Organic chicken husbandry is missing in Iceland and therefore also the possibility for replacement. Thus, substitutes are urgently needed. This study is a response to the imminent need of the Icelandic organic vegetable growers to find a suitable substitute for the mushroom compost they have been using till now.

Potential fertilisers for organic vegetable production are on the one hand animal residues, e.g. horse and sheep manure from organic production or from conventional production after composting and residues from the fish industry (fishmeal). Also, imported industrially processed animal residues e.g. Nugro (liquid fertiliser based on fishmeal) are getting more popular, but are not in line with the general principle of organic horticulture to feed the plants through the soil. On the other hand crop residues, legumes (milled seeds of grain legumes (pea, fababean, lupin), cuttings of e.g. clover mixed into soil or undersowing of clover) and commercial organic fertilisers are popular in other countries. However, traditional compost is mainly used as soil conditioner as its N mineralisation is low and slow.

All these types of fertilisers are implying a different fertiliser composition. In numerous studies, N mineralisation and frequently N content of crop residues (e.g. *Trinsoutrot* et al., 2000) and plant-derived and industrially processed organic N fertilisers (*Stadler* et al., 2006) were strongly correlated. Therefore, possible fertilisers for organic horticulture in Iceland should require a high N content.

So far, studies on organic fertilisers on the yield of vegetable crops are rare in Iceland and mainly based on fertiliser application with mushroom compost (*Gunnlaugsson*, 1995 and 1997) and mushroom compost in comparison to fishmeal (*Gunnlaugsson & Guðfinnsson*, 2004) or a mixture of fishmeal and seaweed was compared to Nugro (*Stadler* et al., 2010). To achieve a synchrony between N release of fertilisers and N demand by the growing crop, time of application is important. Earlier studies have shown that a splitted application of fertiliser amount could be promising to synchronise N availability with growth (*Stadler*, 2006). This was tested in a greenhouse experiment with different organic fertilisers (*Stadler*, 2014) in the year 2013 and it was recommended to use either fishmeal or Pioner complete 6-1-3® to get a high and fast N availability. However, because 2013 was characterized by a low solar irradiation and low harvest, the experiment was repeated in 2014.

The objectives of this study are to test (1) the effect of organic fertilisers on yield of organic vegetable grown indoor and (2) to develop advisory material for organic growers in Iceland.

3 MATERIALS AND METHODS

3.1 Fertilisers

Composted animal residues (manure from cow) from organic production, residues from the fish industry (fishmeal), the imported industrially processed plant residue Pioner complete 6-1-3® (liquid fertiliser based on sugar beets and sugar cane), and mushroom compost as one of the most commonly used fertilisers in organic vegetable production in Iceland were investigated in a greenhouse experiment with tomatoes. Fertilisers that gave in the pot, basil and greenhouse experiments in 2012 and 2013 best results (*Stadler*, 2014) were selected (Tab. 1). The N content was low for mushroom compost and composted cow compost (1,9% N), whereas the N content was much higher for fishmeal (10,9% N). The C content of the investigated organic fertilisers was higher for fishmeal than for mushroom and cow compost. The C : N ratio resulted in much lower values for fishmeal and Pioner complete 6-1-3® than for mushroom and cow compost.

Residues with a small particle size showed a stronger and longer N immobilisation and subsequently lower N mineralisation than did those with a large size (*Jensen*, 1994; *Corbeels* et al., 2003). Therefore, to minimise particle size effects so as to better compare the investigated fertilisers, the composted cow manure was sieved to pass through a 5.0 mm screen.

Table 1: N, C, P and K content and C : N ratio of the tested organic fertilisers.

Fertiliser	N content (%) (mg/l)*	C content (%) (mg/l)*	C : N ratio	P (%) (mg/l)*	K (%) (mg/l)*
Mushroom compost (reference)	1,91	22,2	11,6	0,44	1,04
Cow compost	1,92	21,7	11,3	0,58	0,89
Fishmeal	10,94	42,7	3,9	2,25	1,24
Pioner complete 6-1-3®	216*	609*	2,8	50	150

3.2 Greenhouse experiment

Tomatoes (*Lycopersicum esculentum* MILL. cv. Dirk) were grown in glasshouses at Sólheimar. The soil was high in organic matter (OM) and well supplied with nutrients as indicated in Table 2.

Table 2: Characteristics of the glasshouse soil.

C_{org}	N_t	C : N	pH $CaCl_2$	P CAL	K CAL
(–––––– % ––––––)				(mg / 100 g dry soil)	
21,4	1,5	14,3	6,4	321	33

Previous to the tomato crop green cabbage was grown. Green cabbage received about 82 g N / m^2 (1,5 kg compost per m^2, 0,5 kg fishmeal per m^2, and 0,2 l Bröste 6-1-3 per m^2).

Tomatoes were sown on January 5, 2014 and transplanted in double rows per plot with 49,25 cm plant to plant, 50 cm interrow distance and 75 cm distance between the double rows, 2,5 plants/m^2 on March 19, 2014. Tomatoes were grown until middle of October, 2014. The experimental layout was a randomised block design with three replicates. Plant protection was managed by using beneficial organisms. Bumblebees were used for pollination and hives were most of the time open. Deleafing was done once a week and two leaves in the bottom were taken and one small leaf in the top. Weed was regularly removed by hand. Air temperature in the glasshouse was for tomatoes 21 °C from 09.30-18.00, 15 °C from 18.00-21.00 and 17 °C from 21.00-09.30. Drip irrigation (two tubes for each row, 10 cm dripping distance). Approximately 1,5 l per plant was applied daily (0,75 l at 06.00, 0,50 l at 11.00 and 0,25 l at 15.00) and 1,0 l was added at sunny days.

After planting an amount of 25 g N/m^2 was applied during seven months of growing period in a splitted application of each 5 g N/m^2 in about 40 days intervals as either fishmeal, Pioner complete 6-1-3®, composted cow manure or the reference fertiliser mushroom compost (Tab. 1) within a fertiliser-band of 30 cm. An unfertilised treatment (control) was included to monitor N mineralisation from soil. At each N application all treatments including the control were hand hoed 5-10 cm deep. During the growth period red tomatoes were regularly collected in the subplots from eight plants about twice each week. Total fresh yield, number of fruits, fruit category: A-class (> 55 mm), B-class (45-55 mm) and not marketable fruits (among others too little fruits (< 45 mm)) was determined. During the growth period the interior quality of fruits was determined once. A brix meter (Pocket Refractometer PAL-1, ATAGO, Tokyo, Japan) was used to measure sugar content. From these harvests, the fresh biomass weight was determined and samples were dried at 105 °C for 24 h for DM. Dry samples were milled and N content was analysed according to the DUMAS method (varioMax CN, Macro Elementar Analyser, ELEMENTAR ANALYSENSYSTEME GmbH, Hanau, Germany).

Composite soil samples for analysis of nitrate-N were taken from 6 cores from 0-15 cm depth within the fertiliser-band before planting of tomatoes and at regular intervals during the growth period (at fertiliser application and 10, 20, 40 days after each fertiliser application). 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 (filter paper no. 2, WHATMAN) soil extracts were subsequently frozen. Nitrate was measured by FIAlab 3500b SIA analyser (FIALAB Instruments Inc., 14450 NE 29th Place, Suite 113, Bellevue, WA 98007, USA).

3.3 Statistical analyses

SAS Version 9.4 was used for statistical evaluations. The results were subjected to one-way analyses of variance with the significance of the means tested with a Tukey/Kramer HSD-test at $p \leq 0,05$.

4 RESULTS

4.1 Marketable yield

The yield of tomatoes included all harvested red fruits at the end of the growth period. The fruits were classified in 1. class (> 55 mm), 2. class (45-55 mm) and not marketable fruits (too little fruits (< 45 mm), fruits with blossom end rot, flawed, cracked and not well shaped fruits).

At the beginning of the growth period had all treatments a comparable yield. But, after two months of harvest, it seems that yield differences between treatments did increase. However, at the end of the harvest period was the yield level of marketable fruits low and the yield differences within the fertilised treatments not significant. However, yield of tomatoes that received Pioner complete 6-1-3® was tendentially higher. Yield obtained with the tested organic fertilisers was comparable to mushroom compost (Fig. 1). Even yield in the unfertilised control was high (compared to the fertilised treatments) and with no statistically significances to the fertilised treatments, indicating a high soil N supply.

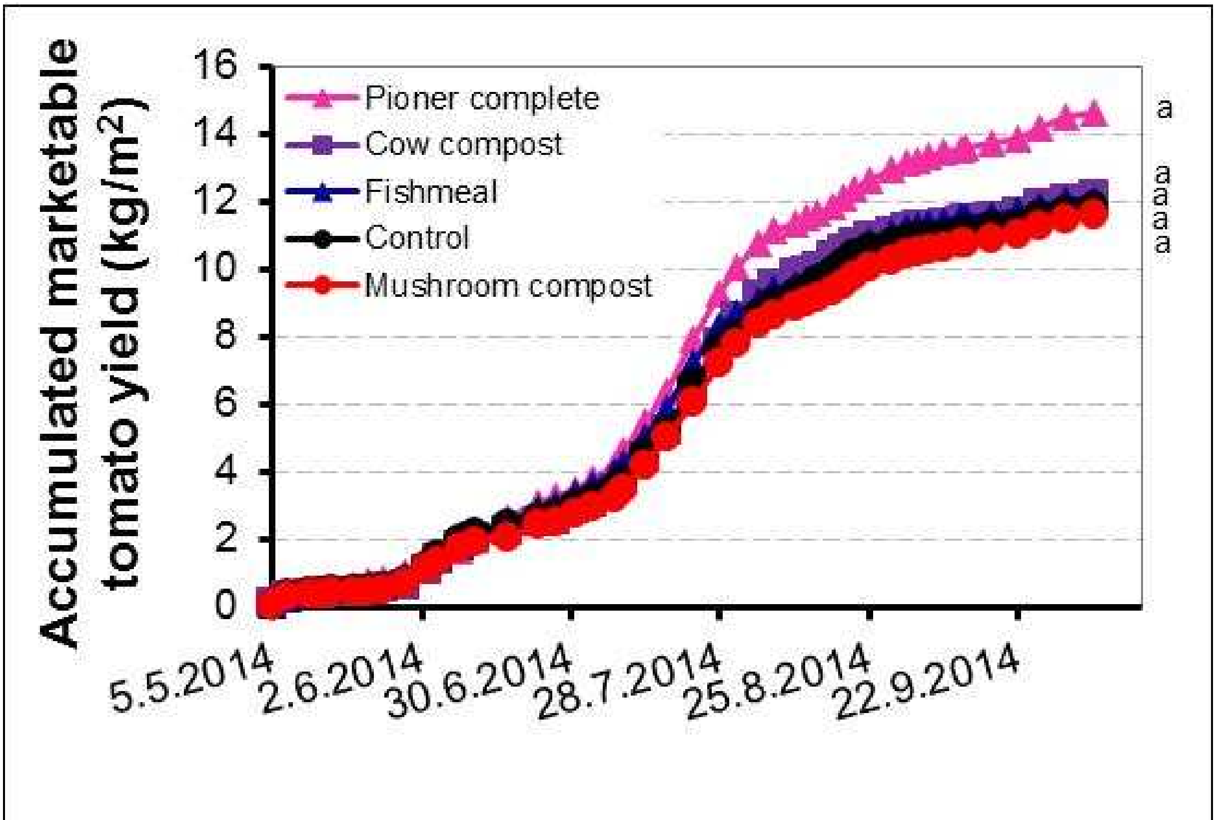

Fig. 1: Time course of accumulated marketable yield of tomatoes (1. and 2. class fruits) during seven months of growth period after application of organic fertilisers.

Letters indicate significant differences at the end of the experiment (LSD, p≤0.05).

Number of marketable fruits was statistically not different between the fertiliser treatments, but a tendentially higher number was reached after application of Pioner complete 6-1-3® (Tab. 3).

Tab. 3: Cumulative total number of marketable tomatoes at different fertiliser treatments.

	Number of marketable fruits	
Treatment	1. class	2. class
Control	81 a	50 a
Mushroom compost	80 a	52 a
Cow manure	83 a	56 a
Fishmeal	85 a	50 a
Pioner complete 6-1-3®	107 a	51 a

Letters indicate significant differences at the end of the harvest period (HSD, p ≤ 0,05).

Average fruit size of first class tomatoes was varying between 80-120 g / fruit (Fig. 2). There seems to be no difference between the fertiliser treatments.

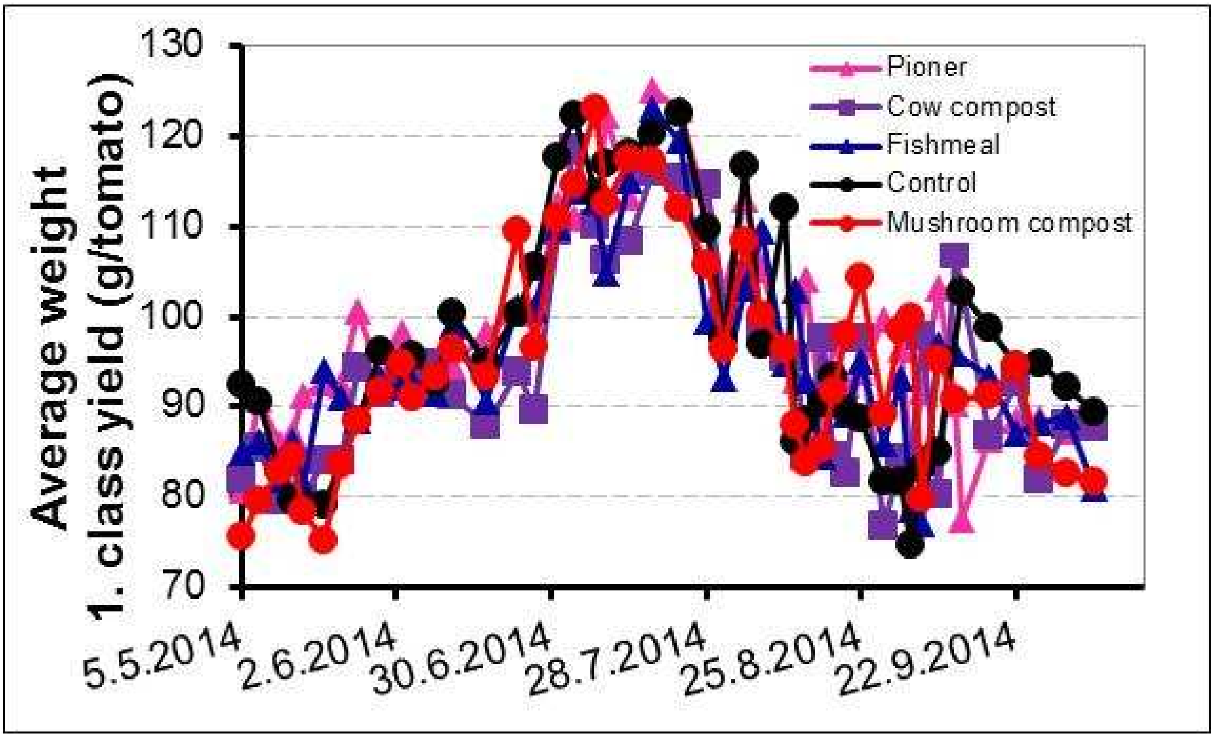

Fig. 2: Average fruit weight of tomatoes at different fertiliser treatments.

4.2. Outer quality of yield

Marketable yield was around 90% (Tab. 4). Unmarketable fruits were mainly because of too small tomato fruits.

Tab. 4: Proportion of marketable and unmarketable tomato yield at different fertiliser treatments.

Treatment	Marketable yield (%)		Unmarketable yield (%)		
	1. class	2. class	too small	flawed	not well shaped
Control	64	25	9	0	1
Mushroom compost	62	26	10	1	1
Cow compost	61	27	11	0	1
Fishmeal	63	25	11	0	1
Pioner complete 6-1-3®	70	21	8	0	1

4.3. Interior quality of yield

4.3.1 Sugar content

Sugar content of tomatoes was measured two times during the harvest period and varied between 3,0 and 4,5 °BRIX (Fig. 3). Sugar co ntent of tomatoes was highest for the unfertilised control.

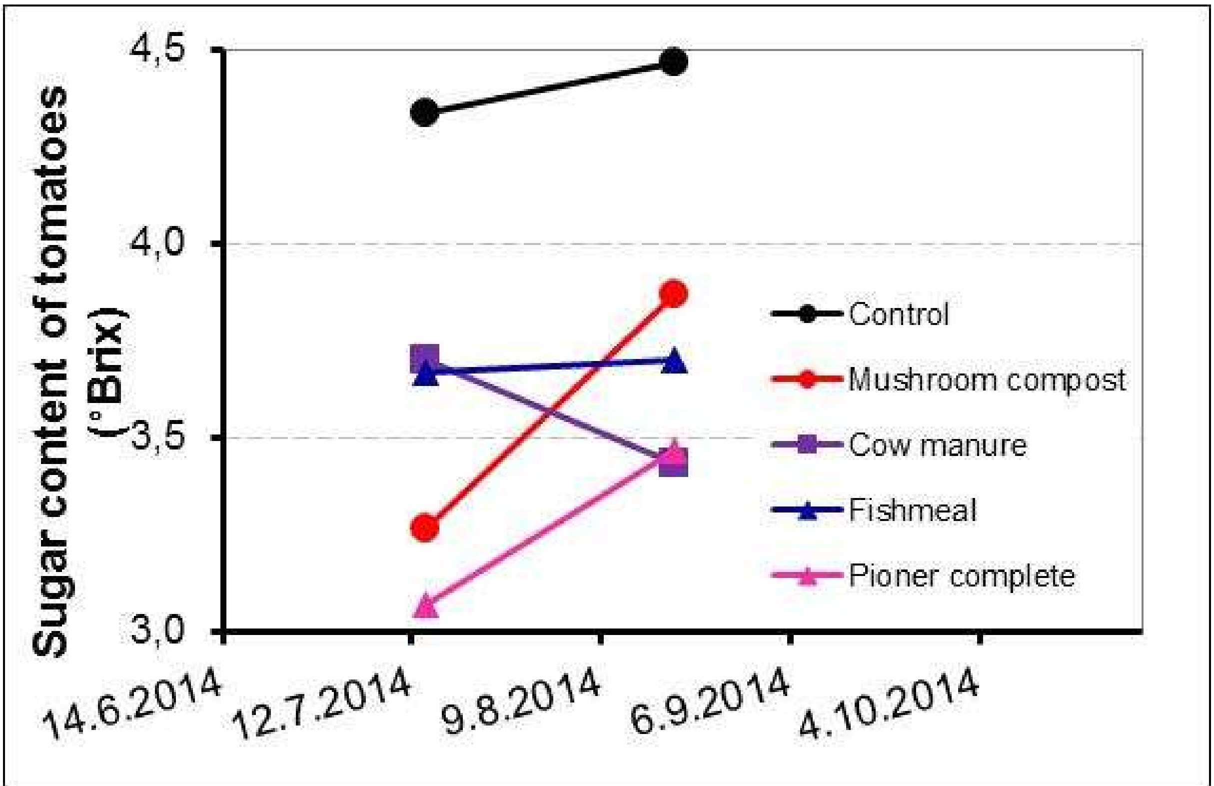

Fig. 3: Sugar content of tomatoes at different fertiliser treatments.

4.3.2 Nitrogen content of fruits

Nitrogen content of tomatoes was measured two times during the harvest period. N content varied between 1,6-2,1% (Fig. 4).

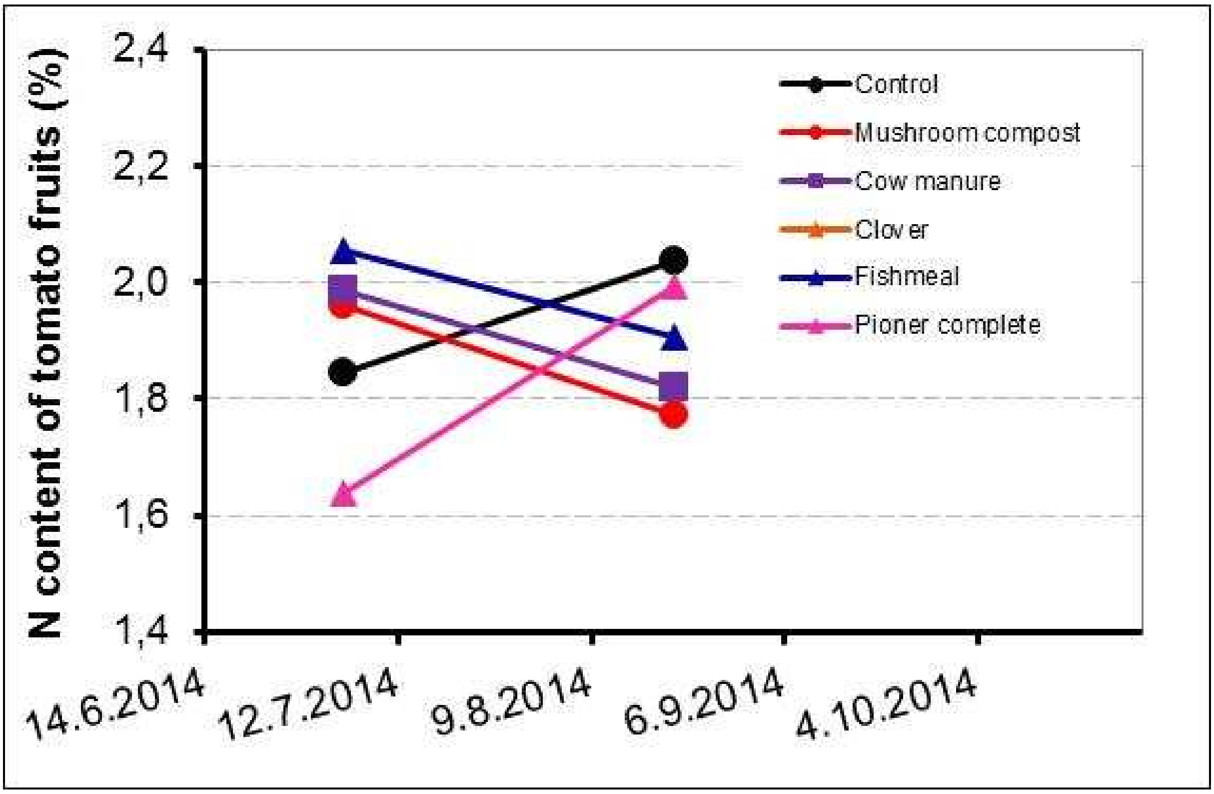

Fig. 4: N content of tomato fruits at different fertiliser treatments.

4.4 Soil nitrate content

Fertiliser application markedly affected the nitrate content in the 0-15 cm layer. In the control treatment, nitrate content was relatively high (compared to the fertiliser treatments). Type of fertiliser strongly influenced the nitrate content in the soil. Hand hoeing increased the soil nitrate content after the second fertiliser application (see unfertilised control).

A fertiliser application increased generally soil nitrate content in soil. The increase in soil nitrate content was highest after the application of fishmeal and Pioner complete 6-1-3®. After each fertiliser application increased soil nitrate content to a higher value compared to the previous fertiliser application and was at the end of the experiment with more than 20 g NO_3^--N / m^2 at a very high value for fishmeal while for Pioner complete 6-1-3® a value of more than 10 g NO_3^--N / m^2 was reached.

Composted cow manure and the reference fertiliser mushroom compost increased the soil nitrate content much less compared to the previous mentioned fertilisers. Values of 2-10 g NO_3^--N / m^2 were reached.

Finally, at the end of the greenhouse experiment soil nitrate content of all treatments was not much different compared to the soil nitrate content measured two months before.

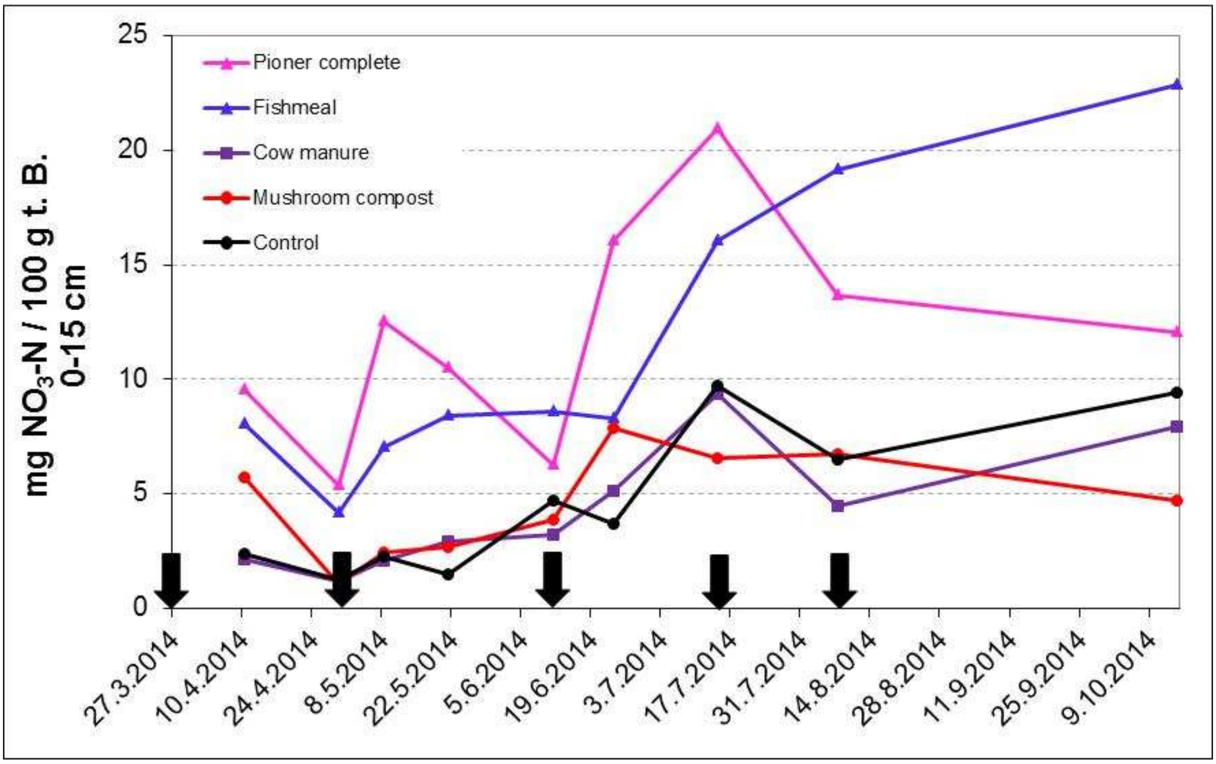

Fig. 5: Soil nitrate content in tomatoes after the split application of different organic fertilisers in the glasshouse. Fertiliser was applied within a 30 cm wide fertiliserband (arrows marking a fertiliser application) and thereafter all treatments were hand hoed 5-10 cm deep.

5 DISCUSSION

5.1 Effect of fertiliser

The tested organic fertilisers differed strongly in soil N mineralisation in the greenhouse experiment with tomatoes. This confirms earlier experiments with organic fertilisers (*Schmitz* and *Fischer*, 2003, *Stadler* et al. 2006). *Gutser* et al., (2005) stated that N availability from organic fertilisers determined as mineral-fertiliser equivalents vary typically between 30-70% in the year of application.

In general, composted animal manure and plant compost are characterised by a low N content and a relatively high C : N ratio, resulting in a low and slow N mineralisation. Therefore, traditional compost is not a real fertiliser, but mainly used as soil conditioner and it will also mineralise nitrogen in low amounts months after application. Furthermore, the weed potential in compost needs to be kept down.

If vegetable requires N very soon, it is recommended to apply either the fast mineralising fishmeal or Pioner complete 6-1-3® even though this fluid fertiliser is not in line with the general principle of organic horticulture to feed the plants through the soil.

The N mineralisation of the fertilisers in the tomato experiment resulted in higher peaks with the fertilisers fishmeal and Pioner complete 6-1-3® compared to the other tested fertilisers. But this was not transferred into yield. The yield level was in general low which was caused by the relatively low natural solar irradiation during the whole growth period compared to other years with normally much higher natural solar irradiation. A low yield level due to low natural solar irradiation was also observed the year before (*Stadler*, 2014).

Yield of tomatoes was comparable between organic fertilisers and the reference fertiliser mushroom compost, pointing out their ability for substitution. Moreover, the application of fertilisers did not significantly increase yield compared to the unfertilised control, indicating a high N supply of the soil. Also, *Tourte* et al. (2000) found no significant differences in the yield of marketable tomatoes between the control and an application of approx. 175 kg N/ha in form of woolypod vetch. This might be explained by the often marginal effect of green manure on yield of tomatoes on fertile soils, but its high effects on poor soils (*Thönnissen* et al., 2000a), which was also observed by *Stadler* (2006).

The lower soil nitrate content of Pioner complete 6-1-3® compared to fishmeal at the end of the growth period is most likely the reason for the tendentially higher yield in the treatment with Pioner complete 6-1-3®. The fertiliser-N was taken up by the tomato plant and transferred into yield.

5.2 Fertiliser application strategies

The data from the pot experiment indicate that N mineralisation of organic fertilisers increased rapidly and was mostly completed after 10-11 weeks after application and declined thereafter (*Stadler*, 2014). Therefore, the time course of the N release of these fertilisers may favourably match the early N demand of fruit vegetables like tomatoes. On the other hand, if the whole N amount of fertiliser is applied at planting there will be a high N surplus during the early tomato growth. But, mineral N in soil may be prone to losses by leaching or immobilisation (*Blankenau* and *Kuhlmann*, 2000). Hence, it might be expected that a split application of organic fertilisers could be favourable for long-growing crops.

The efficiency of the fertiliser on yield depends largely on the synchrony between N release of crop residues and N demand by the growing crop (*Iritani* and *Arnold*, 1960). The time course of N uptake markedly differs between vegetable crops (*Matsumoto* et al., 1999) and for tomatoes 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). According to the pot experiment can from both fishmeal and Pioner complete 6-1-3® a high and rapid N release be expected (*Stadler*, 2014) that may temporarily exceed the N requirement of the tomato plants, which is the reason why a splitted fertiliser strategy was selected to reduce intermittently occurring N excess in soil. However, on the one hand any surplus of mineral N in soil may be prone to losses by leaching or immobilisation (*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). Residual NO_3^--N remained in the soil at the end of the growing period of the tomatoes, showing that there was no limitation of N at the end of the cropping season which was also observed in the greenhouse experiment with tomatoes and sweet pepper the year before (*Stadler*, 2014). However, at the second and third fertiliser application date were nitrate values in the soil quite low and it would have been appropriate to apply fertiliser earlier or give a higher fertiliser amount at the beginning.

In view of the missing yield differences, the N supply of the tomatoes was obviously not significantly different between different treatments during crucial stages of development. Especially after each Pioner complete 6-1-3® application mineral N content was boosted by a high short-term N release. Similar results observed *Båth* (2001), where 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.

Fishmeal and Pioner complete 6-1-3® acted as rapid N sources, ensuring a sufficient N supply for vegetable crops in organic horticulture. The effect of hoeing was not very obvious in this experiment, but from former experiments (*Stadler*, 2014 and 2006) it can be concluded that a regular hoeing of the formerly fertilised plots during the vegetation period will generally increase N mineralisation and should therefore be part of an optimised fertiliser management strategy.

5.3 Economics

Beside the effect of the fertiliser also the economic side is of interest. Table 5 shows the price per kg or l of fertiliser. Mushroom compost is about 6 times cheaper than fishmeal and about 3 times cheaper than Pioner complete 6-1-3®. However, one must keep in mind that a much higher amount of fertiliser in the form of mushroom compost is necessary to get 1 kg N compared to the other fertilisers. Also, the N utilisation was much lower with mushroom compost. Paying attention to the apparent N utilisation that was about 10% for mushroom compost (*Stadler*, 2014) would mean that one kg of mineralised N would nearly cost 3.000 ISK. For fishmeal with 75%

Tab. 5: Costs of organic fertilisers.

Fertiliser	size	ISK / size (without VAT)	N content (%) (mg/l)*	ISK / kg ISK / l*	ISK / kg N ISK / l* N
Mushroom compost	1 m^3	2500	1,91	6 (bulk density: 450 kg/m^3)	291
Fishmeal	1 kg	185	10,94	185	1691
Pioner complete 6-1-3®	20 l	9 336	216*	457	864 (ready mixture)

apparent N utilisation it would be about 2.200 ISK and for Pioner complete 6-1-3® with 85% apparent N utilisation about 2.500 ISK. That means, according to the N utilisation would mushroom compost be the most expensive fertiliser. However, it also needs to taken into account that mushroom compost is releasing N not only in the year of application. Considering also the following years would then probably lead to similar values as for the other fertilisers. Therefore, on the one hand, mushroom compost cannot be classified as cheap fertiliser and on the other hand fishmeal and Pioner complete 6-1-3® cannot be classified as expensive fertilisers.

6 CONCLUSIONS

In the year of application are organic fertilisers mineralising from 10% (compost) up to 80% (fishmeal, Pioner complete 6-1-3®) of the total N applied. Consequently, it can be assumed that the regular application of these fertilisers over several years will tend to increase total soil OM and N that can potentially be mineralised. It should therefore be kept in mind whether long-term application of these fertilisers may require a modified application strategy.

The experiments conducted in both years, 2013 and 2014, have shown, that mushroom compost was one of the fertilisers that reached as good results as most of the other tested fertilisers. Therefore, the prohibition of using mushroom compost should not really effect the organic vegetable growers as there are at least equal (composted animal manures) or even better fertilisers (e.g. fishmeal) that have a similar price on the market.

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