Evaluation of the characteristics of commercial organic fertilizers for use in intensive vegetable organic cropping systems

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Abstract
Vegetable crops are characterized by high nutrient contents and high production levels and consequently require high inputs of nutrients, mainly nitrogen and potassium. Fertilization in organic vegetable production is based on the use of composts or farmyard manures as a base fertilization and commercial organic nitrogen (N) fertilizers as top dressings. There are strong indications in literature that the phosphorus (P) levels in soils intensively used for vegetable production are very high, indicating an imbalance of nutrient supply. An improvement of soil fertility management should include manure treatment methods that avoid gaseous N emissions (e.g. anaerobic digestion instead of composting) and an appropriate combination of base fertilization and commercial organic N fertilizers low in P. The pollutant content of most of the commercial organic fertilizers is low. The results concerning the evaluation of fertilizer heavy metal contents in relation to the nutrient content indicate that there is a need for a re-evaluation of the fertilizers allowed for use in organic farming (OF) systems, as some organic fertilizers currently not allowed in organic farming show better properties as some of the allowed.

Introduction
One of the key issues in organic vegetable production in comparison to conventional production is the approach to soil fertility, as is expressed in the regulations on permitted fertilizers and soil amendments. Vegetable crops are characterized by high nutrient contents and high production levels and consequently require high inputs of nutrients, mainly nitrogen and potassium (K). Furthermore, the cropping period of most crops is rather short in comparison to arable crops. To ensure an appropriate fertilizer level and yields organic vegetable farmers use animal manures and composts as base fertilization and commercial fertilizers high in N like keratins or other wastes from the food industry as top dressings [1]. However, for many of these fertilizers the levels of some of the macro- and most micronutrients have not been systematically compiled. Furthermore, for some of these substances there are no data available. The aim of present work is to compile the available data and to sample the most important sources for production of commercial organic fertilizers to achieve a complete dataset, and to evaluate their suitability for use in OF systems.

Material and Methods
An extensive review of available data in peer-reviewed journals as well as in "grey literature" was carried out to compile available data manure management of organic growers. This includes the nutrient and pollutant contents as well as their manuring effect of commercial fertilizers derived from recycling products of the food industry which are often used by organic growers. In addition, samples of the most important commercial organic fertilizers were collected on farms throughout Germany and in manuring factories with the aim to analyse their nutrient and pollutant content. A total no. of 77 samples belonging to 15 different raw materials were collected and analysed. Analysis included macro- and micronutrients, heavy metals, organic pollutants as well as pharmaceutical substances and pesticides. For evaluation of the suitability of fertilizers the relationship between nutrients and heavy metal contents was calculated according to two index values: the heavy metal-nutrient value (HNV) of Herter & Külling [2] and the provision index (PI) (German: Vorsorgeindex) of the German compost certification association (Bundesgütegemeinschaft Kompost). In both approaches the heavy metal load is evaluated in relation to the benefit obtained by application of the amendments in terms of nutrients (HNV) or in terms of nutrients and soil improvement capability (PI). The higher the value, the higher the heavy metals load in relation to the nutrient contents.

Results and Discussion

The current strategy of most organic vegetable farmers very often leads to high N and P surpluses and strong increase of soil P levels [1, 3]. A strong increase of soil P content especially occurs in soils under organic greenhouse production. The main reasons are the very high fertilizer inputs and the unbalanced nutrient composition of manures and composts used as base fertilization in comparison to vegetable crops. The N:P ratio of vegetables ranges between 5.5 and 6.0 to 1, the N:P ratio of usually used solid farmyard manure and compost base fertilizers ranged between 2.5 and 4.5 (Table 1). Furthermore, the long term N availability from composts ranged between 40 and 60 % of the applied N amounts, while the long term P availability of all amendments is close to 100 %, increasing the unbalance between N and P. Therefore, current management strategies based on the use of composted materials are neither efficient nor sustainable in terms of a balanced nutrient supply of intensive vegetable cropping systems.

Table 1: Nutrient content (% DM), C:N ratio, N:P ratio, heavy metal-nutrient value (HNV) and provision index (PI) of selected base fertilizers

	n	DM	N	P	K	S	OM	C:N	N:P	HNV	PI
Green waste compost[1)]	1061	62.6	1.15	0.22	0.85	-	36.9	19.6	5.2	0.72	8.22
Household compost [1,2)]	978	64.5	1.45	0.31	0.98		39.5	15.5	4.7	0.53	6.34
Household compost [1,3)]	756	64.0	1.53	0.36	1.10	-	39.5	15.9	4.3	0.69	9.74
Champignon substrate	14	36.8	1.30	0.60	2.03	1.04	62.1	34.2	2.3	0.24	4.23
Poultry manure	49	56.5	5.33	1.73	2.31	0.48	78.5	6.0	3.1	0.15	9.50
Poultry litter	77	76.3	4.51	1.90	2.61	0.56	72.1	7.9	2.7	0.66	6.80
Dairy solid farmyard manure	29	24.5	2.04	0.73	2.38	0.20	78.9	15.5	2.8	0.13	2.70
Digestate dedicated energy crops[1,2)]	85	6.77	8.11	1.45	6.45	-	70.3	5.5	5.6	0.14	1.96
Digestate household waste [1,2)]	64	12.0	4.47	0.68	3.24	-	58.1	8.6	6.6	0.19	3.00
Digestate household waste [1,3)]	719	5.2	12.1	1.17	4.31	-	59.5	3.9	7.4	0.12	1.84
Digestate food waste [3)]	97	3.34	16.3	2.21	4.49	0.86	56.5	2.1	7.7	0.06	1.30

[1)] Nutrient and heavy metal data provided by the German certification association for composts and digestates (Bundesgütegemeinschaft Kompost). [2)] With certification for use in OF systems according to EU regulation 889/2008. [3)] Not allowed for use in OF systems according to EU regulation 889/2008. Abbreviations: n – data size; DM – dry matter, N – nitrogen, P – phosphorus, K – potassium, S – sulphur, OM – organic matter, C:N – C:N ratio, N:P – N:P ratio, HNV – heavy metal nutrient value, PI – provision index.

Three approaches are available in OF systems to overcome these shortcomings:

1) Increase of the cropping of legume crops to increase the N-Inputs via biological N_2-fixation.
2) Less use of composted base fertilizers rich in P increasing the use of commercial organic N fertilizers low in P (e.g. keratins), meaning a more targeted combination of base fertilizer and top dressings.
3) Replacement of composting as treatment of manures for base fertilization by anaerobic digestion (AD): AD is carried out in closed systems avoiding unproductive gaseous N losses, leading to a digestate as a manure with a balanced N:P ratio (Table 1). Furthermore, the long term N availability of digestates ranged between 70 and 80 %, leading to a decrease of the demand for N supplements via commercial organic N fertilizers to achieve adequate yields.

The combination of a higher N:P ratio and a higher N-efficiency with digestate application should lead to a more balanced nutrient supply via base fertilizers in terms of a balanced crop N:P supply in comparison to composts.

Nitrogen is one of the most difficult nutrients to manage in organic vegetable production systems. In OF approx. 50 different organic materials are used as N sources for fertilization to meet the high crop N-demand. The main challenges are to predict the N release from fertilizers to synchronize crop N demand and soil N supply and to select commercial N fertilizers which complements the nutrient composition of the base fertilizers, also in relation to the nutrient status and fertility level of the soil. The prediction of the N release of organic N fertilizers is very challenging, as N mineralization is influenced by many factors, including the composition of the manure itself, environmental and soil conditions. In farm manures assessment of the N release is usually carried out based on the ammonium content of the manure. However, many commercial organic N fertilizers are characterised by a high N release in spite of the fact of absence or low ammonium contents. Independently of the ammonium content of manures, the C/N ratio of fertilizers is usually related to the amounts of N released in the year of fertilizer application [4], as also shown in Figure 1. The data show a strong dependence of net N-release in the year of fertilizer application and the C/N ratio of the applied amendment. A deeper insight into the data shows that in field experiments the relative N fertilization effect is approx. 15 - 30 % higher than in incubation experiments (not shown). According to the results in Figure 1 appropriate N release are obtained only with N fertilizers with a C/N ratio < 9 - 10.

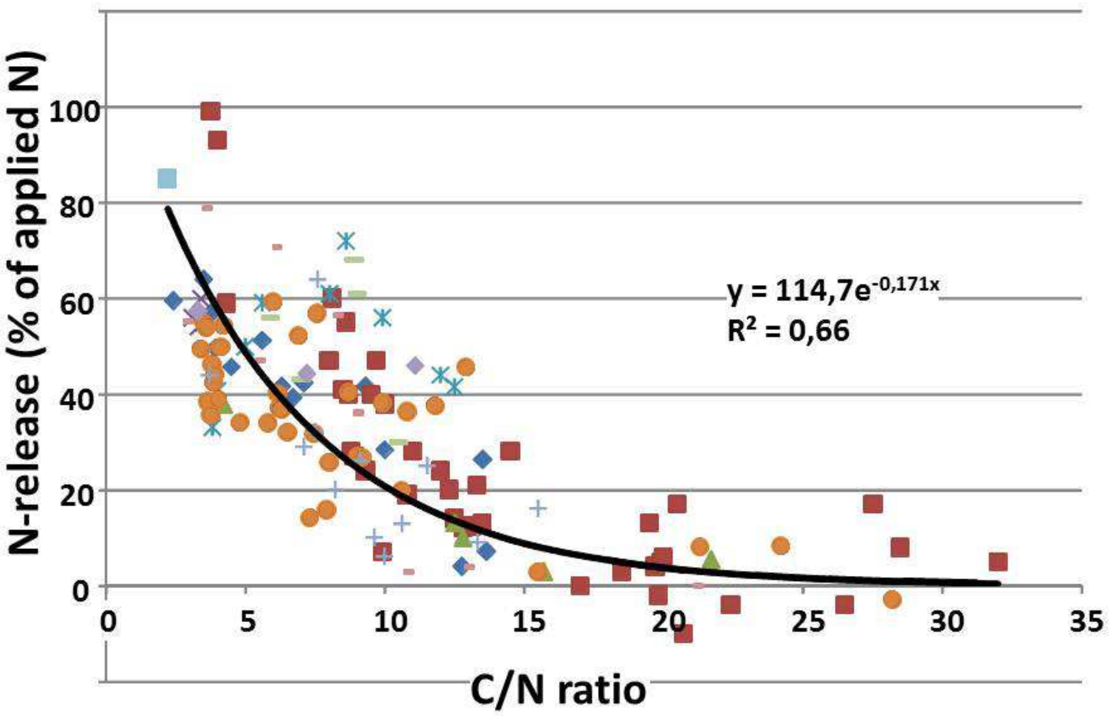

Figure 1: Relationship between C/N ratio and net N release (% of total applied N) in pot and incubation experiments (data compiled from many different experiments)

Another important characteristic of commercial organic fertilizers as a supplement of P rich composts is the ratio of the main nutrients N and P. With increasing N:P ratio rises the suitability as a supplement for P rich base fertilizers. Examples for organic fertilizers low in P are keratins, blood meal, etc. Not suited for use in organic vegetable farming are fertilizers high in P like meat and bone meal. Even fertilizers with a balanced N/P ratio (legume grains, alfalfa meal, and potato protein liquor) are not suited for use as a complement for P-rich composts (Table 2). The composition of the most common organic N fertilizers used in Germany is presented in Table 2.

Table 2: Nutrient content (% DM), C/N ratio, N/P ratio, heavy metal-nutrient value (HNV) and provision index (PI) of selected commercial organic N fertilizers

	n	DM	N	P	K	S	OM	C:N	N:P	HNV	PI
Blood meal	14	94.2	14.2	0.42	0.50	1.00	97.6	3.47	74	0.02	0.98
Feather meal	7	93.9	14.1	0.30	0.28	2.24	94.8	3.6	57	0.06	0.53
Hair meal pellets	12	94.2	14.1	0.39	0.20	1.73	96.1	3.7	37	0.06	1.12
Horn and hooves	14	89.6	14.9	0.31	0.24	2.36	95.7	3.3	77	0.07	1.20
Meat and bone meal	39	95.5	8.44	4.94	0.57	0.62	69.5	4.1	1.8	0.04	1.29
Alfalfa meal	12	92.3	2.74	0.61	3.13	0.33	84.3	17.1	6.3	0.08	2.24
Faba bean meal	4	87.1	4.54	0.65	1.39	0.20	95.9	9.9	7.5	0.08	2.02
Potato protein liquor	13	49.9	4.85	0.99	13.8	1.27	65.8	7.2	5.2	0.04	1.59
Vinasse (sugar beets)	21	65.1	5.23	0.21	7.30	1.80	68.1	7.0	43	0.07	1.19
Biosol	4	94.6	7.33	0.52	0.68	2.00	93.9	6.5	14	0.04	1.03

1) Data: own analyses and compilation from literature references (references not cited).

Another topic of concern is the heavy metal flows related to the use of organic fertilizers. Current legislation and practice in OF only considered the heavy metal contents in the dry matter, without any consideration of the nutrient amounts in the particular manure. This means that the same permissible values are defined for fertilizers with a nutrient load of less than 2 % in the DM and for those with more than 15 to 20 % of nutrients in the DM. The evaluation of the heavy metal loads in relationship show a clear differentiation: most of the commercial N fertilizers are characterized by very low heavy metal loads in relationship to the nutrient contents. Furthermore, the pollutant content of most of the commercial organic fertilizers is very low (data not presented). The heavy metal load of fertilizers used as base fertilizers (Table 1) is much higher than in the commercial N fertilizers. Furthermore, some of the banned fertilizers for use in OF show a more appropriate heavy metal to nutrient relationship than allowed fertilizers. For example, the indexes indicating the heavy metal load for eco-certified digestates indicate a much higher load than digestates containing high amounts of food wastes, currently banned for use in OF. Simultaneously, composition of green waste composts allowed for use in OF is less suited for use than compost of household wastes often banned by farmers organisations.

Conclusions and Perspectives

Vegetable crop growers can overcome the shortcomings in fertilization either by expanding cropping of legume crops, or by reduction of base application of animal manures or composts simultaneously expanding the use of top dressings high in N and very low in P (e.g. keratins, vinasse), or by replacement of a base fertilization based on composted manures by approaches that keep N in the system (e.g. anaerobic digestion of N-rich feedstocks instead of composting). The pollutant content of most of the commercial organic fertilizers is low, however there are large differences in the pollutant content in relation to the macronutrient content. The results concerning the evaluation of fertilizer heavy metal contents in relation to the nutrient content indicate that there is a need for a re-evaluation of the fertilizers allowed for use in OF systems.

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