BALANCING FERTILIZATION STRATEGY WITH CROP REQUIREMENTS IN ORGANIC GREENHOUSE CULTIVATION OF SWEET PEPPER

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Abstract

An on-farm field trial was set up in an organic greenhouse in order to balance the N-uptake by a sweet pepper crop and the mineralization of the organic fertilizers was applied. The effects of six fertilizer treatments were compared regarding yield, nutrient availability and mineral balance. Application of high levels of compost turned out to be favourable in order to reduce surplusses of available-N on the short term. On the long term, such high levels of compost are unfavourable as a high pool of mineralizable-N in the soil organic matter restricts the possiblities for precise fertilization adapted to plant uptake. Application of lower levels of farm yard manure in combination with additional fertilization with feathermeal turned out to be a good fertilization strategy both on the short and the long term unless there is a need for minimizing salt levels in the applied fertilizers.

Introduction

The production of typical glasshouse crops like sweet pepper, tomato and cucumber demands very high levels of nutrient supply to cover the high nutrient uptake. Unlike conventional glasshouse crops grown in substrates and applying a (partially) closed system, organic farming is restricted to cultivation of soil and may be prone to environmental losses when such high nutrient levels are involved. Supply and demand of nitrogen should be balanced in order to prevent leaching and denitrification. The BIOKAS project is a participatory research project, involving 11 organic growers in on-farm monitoring and research. One of the aims is to develop fertilization strategies that support both soil quality and plant production, with a minimum of nutrient emission to the environment. In the experiment, 6 fertilization strategies were tested and analysed regarding plant production, nutrient availability, and mineral balances.

Methodology

An on-farm field trial was carried out in an organic greenhouse with a hot-airheating system during one growing season of sweet pepper. The greenhouse is located in the southwestern part of the Netherlands on young sea clay at Sint Annaland, Tholen. The soil is a light, calcium rich loamy soil with at shallow depth (49 cm) a sandy subsoil, classified as a Poldervaaggrond. The soil organic matter contents is 3.4 percent. N, P and K requirements of the crop were estimated based on a yield expectation of 14.5 kg/m2 sweet pepper. Two types of commercially produced Yard Waste Compost (YWC1 and YWC2) based on pruning and trimming materials and Farm Yard Manure (FYM) of composted, straw-rich cattle manure were used as providers of organic material in the soil. In order to obtain a fast-available source of nitrogen, two treatments were chosen: either feathermeal (FEM) or a mix of two soluble fertilizers (SOL): Aminosol^{TM} (a rest product of gelatin production) and Fontana Potash^{TM} (a rest product of sugarbeet-processing). Sulphate of Potash (SOP) was used as an additional source of potassium. Nutrient contents and C-turnover rates of organic amendments were determined in laboratory analysis. From the C-turnover rate, the initial-age (I-age) of the organic fertilizers was calculated according to Janssen (1986), as input data for the NDICEA model. Before the start of the experiment, estimations of the nitrogen supply by the soil organic matter, previous fertilizations and crop residues were made using NDICEA, as well as estimations of nitrogen supply by the applied organic fertilizers, using default values for the initial age as set in the NDICEA programme (Koopmans and Bokhorst, 2002). Yields of 12 plots were measured weakly. Pruning material was collected during the season from 6 plots as a poolsample in open woven bags to become air-dry. Poolsamples were further dried and analysed for nutrient contents. At the end of the growing seasons, plants of all plots were collected, weighed, dried and analysed. On 4-week intervals, soil samples were taken from 12 plots at 0-25 cm depth. Plant and soil samples were analysed for nutrients and trace elements. The following 6 treatments were compared (Table 1): (1) YWC1-HS; high supply of compost (type I) as base dressing (224 tonnes/ha); (2) YWC1-HB; high supply of compost type I (100 tonnes/ha as base dressing and 124 tonnes/ha in 5 batches as top dressing); (3) YWC1-LS; low supply of compost (type I) as base dressing (100 tonnes/ha), supplemented with FEM and SOP as top dressing; (4) YWC1-SOL; low supply of YWC (type I) as base dressing (100 tonnes/ha) supplemented with a combination of commercial soluble fertilizers (SOL) as top dressing. (5) FYM; cattle manure (30 tonnes/ha) as base dressing supplemented with FEM and SOP as top dressing; (6) YWC2-FT; low supply of compost (type II) as base dressing (Farmer Treatment) (100 tonnes/ha) supplemented with FEM and SOP as top dressing.

Table 1. Overview of fertilizer treatments. The field trial includes two plots per treatment, each plot measuring 32 m2. Supply fertilization was carried out in week 14. Application of additional fertilizers in solid form (FEM and SOP) is done in batches in 4-week intervals at weeks 14, 19, 23, 27 and 31. Application of the additional soluble fertilizers (SOL) Aminosol ™ and Fontana Potash ™ is done in two-week intervals. [1] Composted material type 1; [2] Composted material type 2.

Code	Organic fertilizers	Amount (tonnes/ha)	Timing	Additional fertilizers	Amount (kg/ha)	Timing
FYM	Farm Yard Manure	30	Supply, before start season	Feathermeal Sulphate of Potash	5 x 531 kg/ha 5 x 500 kg/ha	5 batches
YWC1-HB	Yard Waste Compost [1]	224	100 tonnes at start season, 4 batches of 31 tonnes at 4-week intervals	Feathermeal	5 x 313 kg/ha	5 batches
YWC1-SOL	Yard Waste Compost [1]	100	Supply, before start season	Fontana ™ Aminosol ™	10,450 kg/ha 688 kg/ha	10 batches
YWC2-FT	Yard Waste Compost [2]	100	Supply, before start season	Feathermeal Sulphate of Potash	5 x 500 kg/ha 5 x 500 kg/ha	5 batches
YWC1-HS	Yard Waste Compost [1]	224	Supply, before start season	Feathermeal	5 x 313 kg/ha	5 batches
YWC1-LS	Yard Waste Compost [1]	100	Supply, before start season	Feathermeal Sulphate of Potash	5 x 500 kg/ha 5 x 375 kg/ha	5 batches

Results and brief discussion

The N, P and K uptake of sweet pepper were estimated to be 552, 63 and 735 kg/ha respectively, based on a yield expectation of 14.5 kg/m2. The mean yield that was actually obtained in the six treatments was 13.7 kg/m2 and varied between 13.4 and 14.0 kg/m2. Mean values of measured nutrient uptake from peppers, crop residues and plants were 455 kg N/ha, 58 kg P/ha and 655 kg K/ha respectively. N-mineralized was estimated using NDICEA modelling and initial age as determined in lab experiments. Mineral balances of N-mineralized, total-N, P and K varied considerably between the different strategies (see figure 1). The N becoming available during the growing season (26 weeks) through mineralization of soil and fertilizers was in all cases lower than the total plant uptake. This resulted in a decrease of the stock of readily available N-mineral in the soil. The most favourable strategy regarding N-mineralized was the application of 224 tonnes/ha of yard waste compost applied in batches (YMC1-HB), with very little additional fertilizers (FEM). The amount of N becoming available through mineralization of soil and fertilizers in 26 weeks was 217 kg N/ha less than the total plant uptake. The strategy using 100 tonnes of type II compost (farmer treatment) and additional fertilizers (YMC2-FT) was least favourable (55 kg N/ha less mineralized than total plant uptake). The commercial compost type II turned out to have much higher turnover rates in the lab experiments, as well as higher nutrient contents.When analysing the results regarding total N supply of the fertilization strategies, results differ. In the case of total N supply, the treatments using high amounts of compost turned out the most unfavourable, with N-surplusses of 874 kg N/ha (YWC1-HB) and 811 kg N/ha (YWC1-HS) respectively. Calculations are based on total N-contents of harvested peppers, plants and pruning material. The application of farm yard manure (FYM) was most favourable, providing a surplus of only 45 kg total-N/ha. Mineral balances of K where not fine-tuned as the application of SOP was not deminished after having obtained the results of the nutrient analysis of the organic fertilizers. P-balances are highly unfavourable in case of YWC1-HS, YWC1-HB (where 224 tonnes/ha was applied) and YWC2-FT, as the compost type II contained much higher P levels than the commercial compost type I.

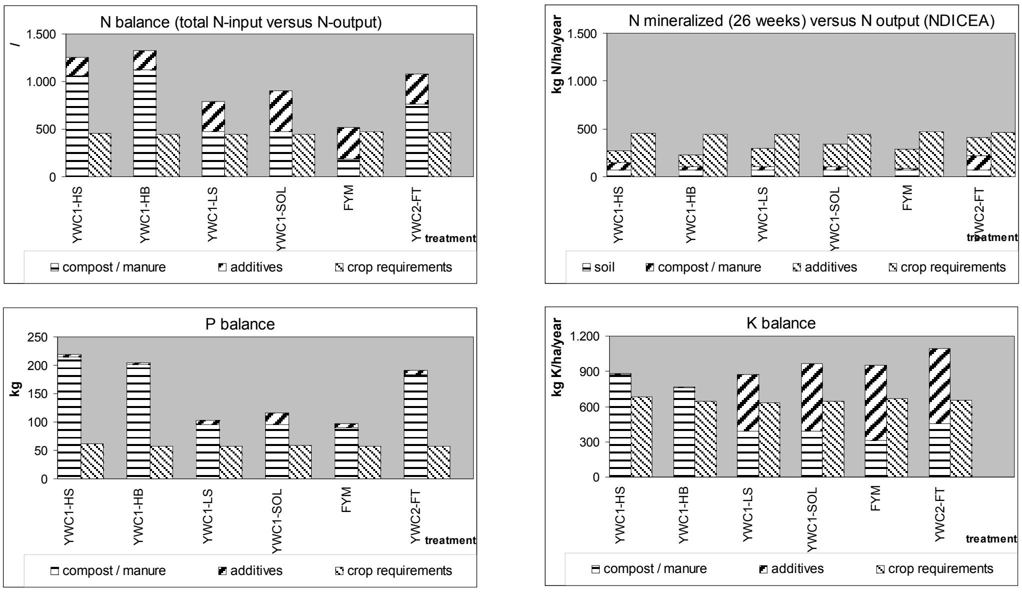

Figure 1. Mineral balances of total-N, N-mineralized, P and K for the different treatments during the growing season (26 weeks). Left columns indicate supply of fertilizers, right columns indicate total plant uptake (peppers, pruning residues and plant contents at the end of the season). N-mineralized was calculated by NDICEA.

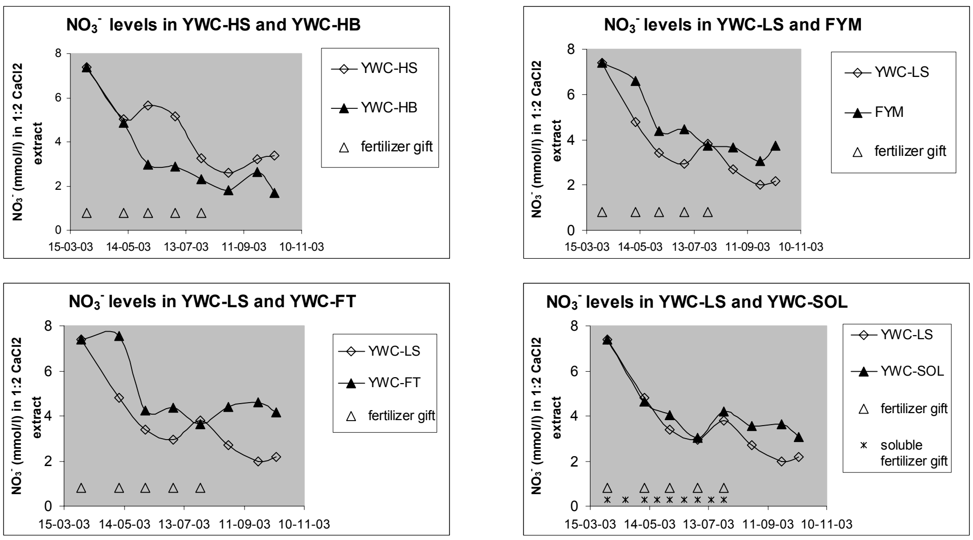

Figure 2. Monitoring of nitrate in 1:2 volume $CaCl_2$ extract during the growing season of sweet pepper. Each graph shows a comparison of two treatments.

Monitoring of nutrient levels (see figure 2 for NO_3^-) showed that both nitrate and potassium levels were lowest in the strategy were compost was applied at a high level, but in batches during the season (YWC1-HB). Also salt levels (sulphate) were lowest using this strategy.

When compost is applied as top dressing without tillage during the growing season (YWC1-HB), decomposition is likely to be restricted. On the short-term, this strategy prevents high nutrient levels and reduces losses to the environment. However, the compost will be mixed into the soil at the end of the growing season and will as yet contribute to the available N-pool. The highest levels of nitrate (average level of 4.7 mmol l^{-1}) were found in the strategy were type-II compost (YWC2-FT) was applied. The highest potassium and sulphate levels (average levels of 4.2 and 10.2 mmol l^{-1}) occurred in the FYM treatment. High levels of potassium and salts will contribute to a higher EC level in the soil, but may also hold the risk of salination. High amounts of compost contribute to a large pool of quickly decomposing organic matter in the soil. This pool is a continuous source of N-supply, also in those periods of the growing season where crop demands are low; for example at the very start and end of the growing season. From the BIOKAS project followed that high peaks of N-mineral occur often at the start of the growing season. (Cuijpers *et. al.*, 2005) From the environmental point of view, it is preferable to reduce compost gifts to the minimum amount necessary to maintain soil organic matter levels at an adequate level. Preference should be given to compost types with slow C-turnover rates, low N-contents or a high C/N ratio. In all strategies the total quantity of available N was higher than the crop requirements. This was due to lower yields than calculated, and lower N contents in plant tissue on the one hand, and higher N availability from the composts on the other. Denitrification in this investigation was estimated using the NDICEA model. From research closely connected to this experiment followed that denitrification losses in organic greenhouses can be substantial, although precise measurements are difficult due to high variability in soil water contents caused by the applied irrigation systems (de Visser *et.al.*, 2004). Hence for practical application, fertilization strategies aiming at a certain surplus are unavoidable. In greenhouse production, with high cost levels, it is unacceptable for growers to take the risk of yield reduction caused by N-shortage. For further improvement of sustainable organic farming, it is necessary to further develop adequate models for prediction of the N-cycle in greenhouse soils. Next to the problem of finetuning the N-availability with crop requirements in total and during the growing period, there is the problem of P accumulation. In all strategies under investigation, the P supply was much higher than the demand. Improving the P-balance in organic farming must be the next step to be taken.

Conclusions

Application of high levels of compost turned out to be favourable in order to reduce surplusses of available-N on the short term. On the long term, such high levels of compost are unfavourable as a high pool of mineralizable-N in the soil organic matter restricts the possiblities for precise fertilization adapted to plant uptake. Application of lower levels of farm yard manure in combination with additional fertilization with feathermeal turned out to be a good fertilization strategy both on the short and the long term unless there is a need of minimizing salt levels in the applied fertilizers.

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