

Nutrient Management in Organic Greenhouse Production: Navigation between Constraints

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Abstract

Organic greenhouse production within the European context is limited both by its own principles, among them restrictions concerning soil and fertilizers, and by legislative restrictions on manure, compost and fertilizer applications. Results of a monitoring project on organic greenhouses were evaluated concerning the various legal constraints. Important bottle necks are related to the limitations in the N and P input, the unbalanced input of nutrients and the restrictions on irrigation with consequently increased salinity problems. The development of an organic fertilizer database and a decision support model for fertilizer and organic matter application is evaluated. Balanced mineral supply is possible within the prevailing legal mineral targets, but risk of salinity is a concrete concern. Challenges in the very near future will be the upcoming targets on N and P emission and new regulations on organic manure.

INTRODUCTION

Organic vegetable production as expressed by the IFOAM Basic Standards (IFOAM, 2007) discerns itself in many aspects from conventional production. One of the key issues is the approach to soil and soil fertility, as is manifest in the regulations on permitted fertilizers and soil amendments in the EU regulation for organic food production (Anonymous, 2002). This entails restrictions for crop production, for the goal in organic production is equilibrium between the production capacity of the soil and other production factors, rather than maximizing yields. Organic greenhouse production operates under the same principles; however, greenhouse crops are characterized by high production levels and consequently require high inputs of nutrients. High yields are considered necessary to recoup investment costs. This aspect, however, conflicts with basic organic principles and guidelines.

In addition to the guidelines and standards of the organic label itself, European and national regulations on fertilizer inputs, as derived from the Nitrate Directive (ND) (Anonymous, 1991) or the WaterFramework Directive (WFD) (Anonymous, 2007), will restrict organic greenhouse production even more. This may sound strange, since organic production is often thought to be synonymous with sustainability and an environmentally friendly way of agricultural production. However, the generic way the regulations are described, by which there is no differentiation between greenhouse and field crops, and the strong dependence on organic fertilizers and composts, makes fertilization in organic greenhouse production quite complicated. In this paper, it will be discussed how greenhouse growers have to deal with the various constraints for fertilization management and which constraints have to be faced in the near future. The focus will be within the Dutch context.

FERTILIZATION PRACTICE

The current fertilization strategy in practice is characterized by a base dressing of compost, and in many cases also animal manure, before planting, partly to amend the soil

micro-organisms and maintain soil structure and partly for nutrient supply. Top dressings are applied throughout the growing season, using a variety of additional fertilizers like dried dairy and chicken manure, dried slaughterhouse waste (bloodmeal, feathermeal) or dried fertilizers derived from plant sources (e.g., remains from malt, sugar beet, ricinus industry). Occasionally, fertigation with liquid organic fertilizer which is dissolved in water with epsom salt or potassium sulphate is used to establish a certain electrical conductivity level (EC) to allow dosage rates to be automatically controlled. The rates applied are mainly based on soil analysis and the grower's own experience (Janmaat and Cuijpers, 2005).

From 2002 on, the fertilizer application and soil management was monitored at 8–10 organic greenhouse companies. In some years, the total net crop nutrient removal was determined by fresh and dry weight of crop plants and plant tissue analysis aimed at estimating the mineral balance. The total available N was estimated using the mineralization model established by Janssen (1984). The greenhouse companies observed had intensive fruit vegetable crop rotations, consisting of tomato, cucumber and sweet pepper and a limited number of smaller crops like lettuce, cauliflower, beans and egg plant. Parts of these results have been described earlier (Cuijpers et al., 2008). The average total supplied N was much higher than the removal by the crop. At the same time, the N supplied was in the same order of magnitude as the estimated total available N, showing that the unavailable fraction of organic N in the yearly applied soil amendments was compensated by the decomposition of the soil organic matter versus the historic soil amendments (Fig. 1). The average application was about double the crop demand. Part of this excess will be lost by denitrification, the other part by leaching and a small fraction will be fixated in the stable organic matter pool. de Visser et al. (2006) showed that denitrification losses could be considerable; it was found to be responsible for as much as 25% of the total N balance output. For P, the results were also troubling; the total supply was almost three times the estimated crop removal, resulting in a significant P excess. Since leaching of P is not to be expected, the majority of P will have accumulated in the soil. The excessive P accumulation in organic greenhouse horticulture was observed previously (Voogt, 1999). Next to the N and P surpluses, it was established that the mutual ratio between N, P and K in the total organic fertilizer supply was not balanced with the ratio in the crop demand (Fig. 2). This was caused mainly by the relatively lower levels of K in compost and manure (45 and 50%, respectively), compared with the crop uptake (57%). Moreover, the portion of P in compost and manure (11%) is relatively much higher than the crop demand (6%). In addition, growers added more specific N fertilizers like blood and feathermeal to compensate for N losses not due to crop uptake but other processes in the N cycle, like denitrification (Cuijpers et al., 2005).

REGULATIONS

Dutch organic greenhouse production has to meet the following standards and regulations:

- A. The principal aims of organic production and processing, as formulated under IFOAM basic standards, are of course leading for organic greenhouse production. Within EU, the EU regulation for Organic Food (837/2007) is leading. This does not need further specification within this context; the fertilizers allowed are certified by SKAL, the Dutch certification body (Anonymous, 2002).
- B. Manure: resulting from the European Nitrate Directive, applicable since 1998. The application of manure is limited to the equivalent of $170 \text{ kg N ha}^{-1} \text{ yr}^{-1}$. This also holds for any additional (dried) fertilizer derived from animal manure, even for the manure component in composts amended with manure like mushroom compost (Anonymous, 1986; Anonymous, 1997; Anonymous, 2010).
- C. Compost: Since 2008, the application of compost is regulated under the new fertilization law. Compost should contain at least 10% organic matter (dry matter) and must comply with the EU standards for heavy metals. There are no more limits in the applied quantity but these are restricted by the application standards for nutrients (D)

(Anonymous, 2010).

- D. Nutrient Application Standards: In order to reduce the nutrient excess in greenhouse crops, the Dutch Government, together with the growers' organization, reached an agreement in 1998. It entails a limitation on the total input for N and P. Tomatoes, for example, are allowed 2200 and 450 kg ha⁻¹ of N and P, respectively. Recently, both parties concluded that the measures are ineffective to reach the goals for both the Nitrate Directive and the Waterframework Directive, so it was decided to change the agreement and to formulate other regulations. Rather than limiting the input, the output will be restricted in the near future, which will result in emission norms for each crop. Unlike soilless culture, the regulation for soil grown crops is not yet (2010) defined, so application standards are still active (AgentschapNL, 2010)
- E. Standards for manure: Recently, standards have been created for the use of manure and additional fertilizers. At least 50% of the input should be from (A) fertilizers. The list of (A) fertilizers consists of organic manure and organic compost from certified organic farming. So far, green compost is also part of the (A) list, but is in discussion. The other 50% should be derived from the (B) list, which are other organically certified additional fertilizers (Skal, 2010).

Comparison of the fertilization strategies that were monitored (Fig. 1) with the legal standards shows that the application of manure is, on an average, 200 kg N ha⁻¹, somewhat higher than the limitation mentioned under (B). Top dressings with additional fertilizers derived from animal manure account for another 160 kg, giving a total of 385 kg N ha⁻¹, much higher than the allowed 170 kg ha⁻¹. In some cases, growers own unfertilized pasture or other land, which may be added to the total area, so the quantity of N per ha becomes lower. The majority of the N is supplied by top dressings, which mainly consist of blood meal, brewery waste and feather meal (Table 1).

Compost provides almost one third of the average N input, and contributes significantly to the total available N, which is remarkable for an input which is commonly used as a source of organic matter rather than for mineral nutrition (Fig. 1). However, the amount of N supplied is within the legal quantities (C), since the maximum crop-specific application standards for N and P are derived from the requirements for conventional (usually substrate-grown) crops, and these standard measurements are much higher than the quantities applied in organic crops, the supply of N and P does not exceed those amounts (D). Since emission standards are not applicable so far, a comparison with those standards cannot yet be made.

The total P application is nearly twice the allowable limit, as seen in section (B). The P application is also far beyond the allowable level if it is based on the regular fertilization recommendation system for conventional greenhouse crops. According to that method, the recommended P supply is based on the soil P buffer calculated from soil analysis; above certain levels, the required P application will be zero. In many organic greenhouses, the consecutive years of P excess has resulted in P accumulation in the soils and consequently the recommended P supply is zero.

Compared with the new regulation on organic manure and compost, the use of (A) fertilizers seems to be underrepresented. However, no discrimination has been made on the origin of the manure or compost at this time, so a good comparison is not possible.

IMPROVEMENTS

A calculation program was developed to support growers to improve their nutrient management in order to comply with the legal standards while meeting the requirements of the crop. Basically, the program aims at tuning supply and demand reckoning with specific data provided by the user. The program simulates the available quantities in the soil during the growing season, based on data of soil analysis, fertilization history, and the grower's choice of manure and compost type and quantity. The N availability by mineralization of the chosen fertilizers, soil organic matter (SOM) and fertilization history is calculated according to Janssen (1984). The expected yield is used to estimate the total crop requirement for N, P and K, using the linear method (Sonneveld and Voogt,

2009). The legal standards for N and P and fertilizers are used to benchmark the outcome of the calculation. By iteration the user has to fine tune the type and quantities of the fertilizers to optimize the result. The applicability of the calculation program was tested by growers, and the recommended fertilization schedule was tested in commercial greenhouses over two years (Cuijpers et al., 2008). The application resulted in a sharp decline in the total N and P supply at the greenhouses (Fig. 3). However, some improvements should be made. In the first place, the ratio of N, P and K is still of concern. This is mainly due to the constraint that the mainstays of organic inputs are compost and manure, with a more or less fixed ratio between N and P. Moreover, there is a lack of choice in single N, P or K fertilizers that are organically acceptable. Although blood- and feathermeal are not restricted, the use will be discouraged as these fertilizers do not contribute positively to the development of soil microorganisms. In addition, there is the problem of salinity build up. Some fertilizers contain residual salts, like Na, Cl and SO₄ in higher quantities than the uptake capacity of the crop. Leaching the soil by over-irrigation will cause N leaching and environmental pollution. Therefore, the input of residual salt should be limited as much as possible. A more sustainable approach in the composition of fertilization schedules is therefore needed. Elaborating on the first version and experiences with the calculation program, some alternatives were implemented. The latest version of this MS Excel-based program is available online (Voogt, 2010)

NEW CHALLENGES

With respect to the standards for organic production and the legal N and P standards, greenhouse vegetable production is difficult, yet not impossible. However, the additional regulation aiming at emission targets will complicate the situation. In addition to fertilization, irrigation should also be adjusted for the crop demand, i.e., the evapotranspiration, as nutrient emission will only come about if leaching occurs. The advantage of greenhouse-growing is that natural precipitation is excluded, so leaching is controlled by the growers. However, fine-tuning irrigation based on evapotranspiration is quite complicated, or even impossible, regarding the heterogeneity of plants and the irrigation system in use. For organic production, this is even more problematic than for conventional growing, due to a less efficient control of diseases and pests, and therefore, more heterogeneity in evapotranspiration. The threat of salinity as a result of unavoidable input of residual salts will increase the need for leaching the soil occasionally. Preliminary results of monitoring show that the emissions of organic greenhouses seem to be rather low, but that Na and SO₄ build up is quite serious sometimes (Voogt, unpublished data).

Matching the newly developed standards as they are formulated now to organic manure for greenhouse vegetable production will be very complicated and restricting. This will be particularly true if green compost is not included on the (A) list, as is in discussion currently. Because the legal maximum manure input is restricted to the equivalent of 170 kg N ha⁻¹ yr⁻¹, the maximum N input is consequently limited to 340 kg N ha⁻¹. As shown in Figure 1, the average crop demand is already 600 kg N ha⁻¹, let alone that for intensive crop rotations where 900–1000 kg ha⁻¹ yr⁻¹ is required.

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Table 1. Fertilizers and soil amendments applied as base or top dressings, as monitored at eight organic greenhouses from 2002–2009. Data of the average quantity (fresh weight) applied yearly per greenhouse holding.

Base dressings (% of the total supply)	N (kg ha ⁻¹ yr ⁻¹)	Top dressings (% of the total supply)	N (kg ha ⁻¹ yr ⁻¹)
Compost	56	Mixed fertilizer	13
Manure	34	Bloodmeal	6
Dried manure	2	Feather meal	6
Brewery waste	1	Brewery waste	12
Mixed fertilizer	1	Vinasse	28
Feather meal	1	Castor oil waste	10
Bone meal	1	Dried chicken manure	6
Bloodmeal	1	Hydrolyzed plant material	4
Seaweed	<1	Tobacco waste	2
Castor oil waste	<1	Bone meal	2
Tobacco waste	<1		
Hydrolyzed plant material	<1		
Rock	<1	Potassium sulphate	5
Magnesium sulphate	<1	Magnesium sulphate	7
Limestone	<1		
Potassium sulphate	<1		
Total	776		685

Mineral fertilizers inputs

Figures

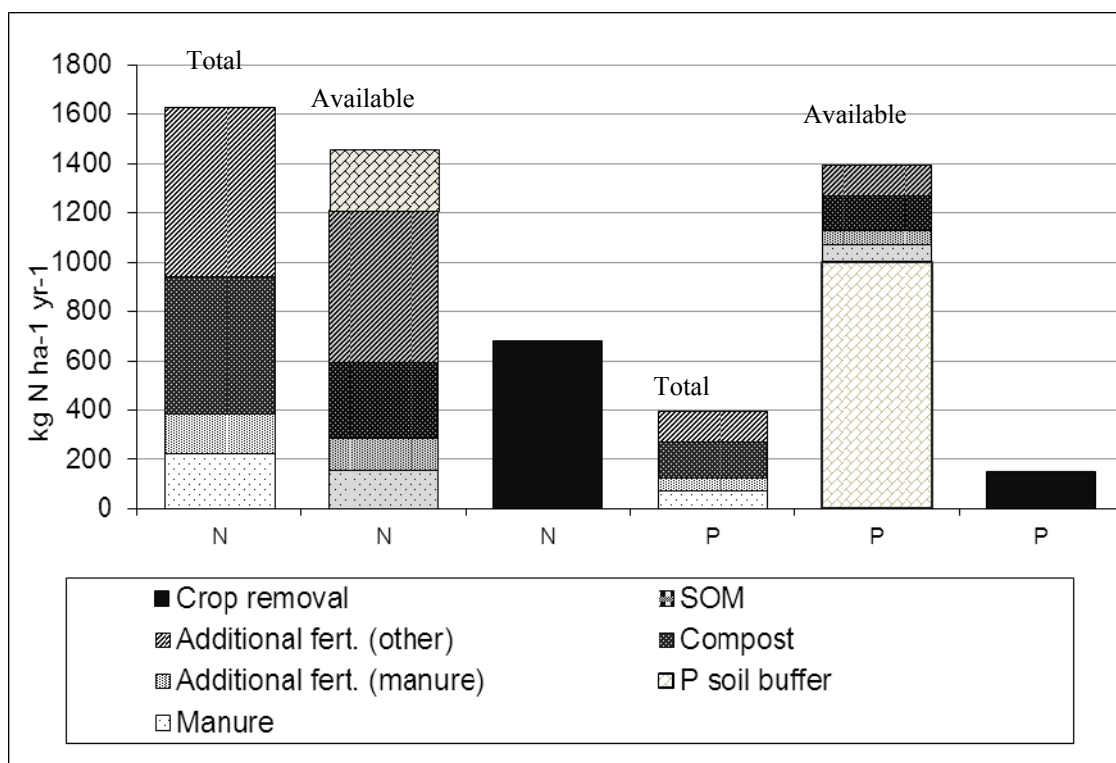


Fig. 1. Average yearly N and P inputs and uptake, in eight organic greenhouse vegetable nurseries, monitored during 2002–2009. Inputs are divided over total manure, compost and additional fertilizers, compared with the estimated available N and P from fertilizer mineralization and soil organic matter (SOM) and from the soil buffer. The uptake is the result of the monitored crop N and P removal.

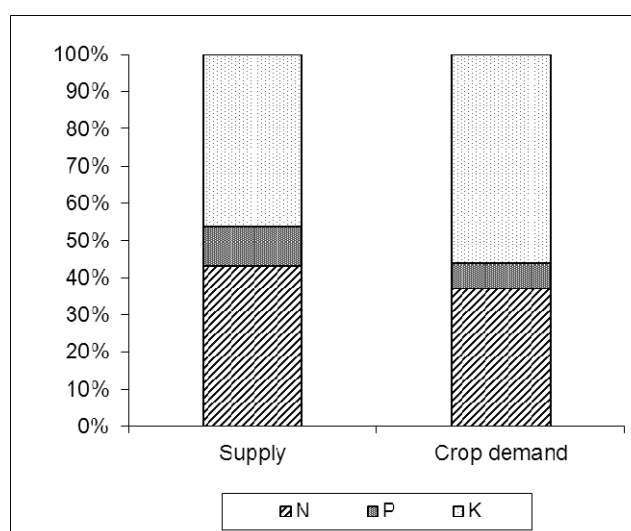


Fig. 2. Mutual ratios of the N, P and K supplied in total by fertilizers and soil amendments and of the crop demand, based on the crop removal, at the eight monitored greenhouses.

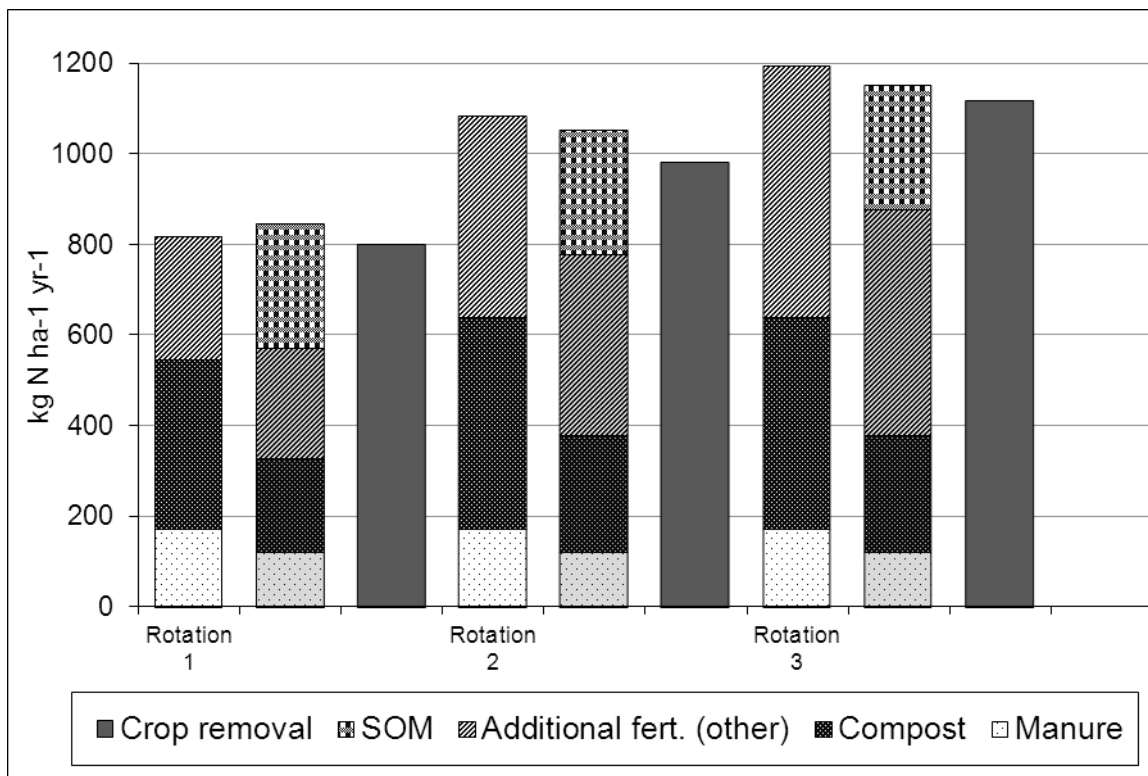


Fig. 3. Recommended fertilization application for 3 different crop rotations (1: sweet pepper yield 15 kg m^{-2} ; 2: cucumber three plantings yield 60 kg m^{-2} ; 3: tomato yield 50 kg m^{-2}), complying with the legal fertilizer inputs and optimizing total supply and ratios towards crop demands.