Info Note

Sustainable fertilization of vegetable crops in the highland of Lembang, West Java, Indonesia

Findings from a pilot with vegetable farmers using dairy cattle manure

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Key messages

- Sustainable fertilization can increase income of farmers and reduce environmental pollution.
- Farmers should learn to align fertilizer use with crop requirements and soil fertility.
- Organic manures should be applied first, whereafter chemical nitrogen and potassium fertilizers should be used to complement nutrient requirements.
- Phosphate levels in soils in Lembang are high and limit the use of manure.
- Cow manure is a good source of nutrients and organic matter in vegetable crops and can lower environmental pollution in case of weight-based replacement of chicken manure.

Fertilizers are used in vegetable farming for crop growth and quality and to maintain soil fertility. Organic fertilizers are also appreciated by farmers for their positive effect on soil quality and structure. At the same time, excessive and inappropriate fertilizer use is causing serious environmental problems, including local ecosystem pollution and greenhouse gas emissions causing climate change.

For an environmentally sustainable production of healthy vegetables a responsible use of nutrients is needed. Too low use will result in low yield and poor-quality vegetables. While too much will lead to pollution of the environment and loss of income. Therefore, when using fertilizers farmers should consider the crop need and soil fertility, type of fertilizers used, and how and when to apply fertilizers in relation to soil characteristics.

The aim of this practice brief is to summarize findings of a pilot implemented in 2020 and 2021 in Lembang sub-district in West Java. In this pilot the use of nutrients and crop performance of 6 vegetable farms was tracked for half a year. In addition, soil samples were taken at 31 farms in Lembang to determine the soil fertility status. The pilot focused on the use of cow manure as organic fertilizer because cow manure is currently discharged at large scale in Lembang, causing environmental pollution.

Nutrient requirements of vegetable crops

In Indonesian horticulture, many different types of crops are grown, and it is difficult to get the right information about appropriate fertilizer rates per crop. Currently the Indonesian Vegetable Research Institute is developing recommendations for the most important crops. The appropriate rates depend on the crops, yield and soil fertility.

Each crop has it owns nutrient requirement, in quantity and nutrient ratio (N, P, K). The more yield is expected, the higher the nutrient supply should be. Next to total amounts it is also important to look at the nutrient ratios. Leafy vegetables for instance require relatively high levels of nitrogen (N) and not so much potassium (K) while fruiting crops also require N but relatively high levels of potassium. For all vegetable crops phosphorus (P) requirements are relatively low. Therefore, using only NPK is not recommended, because most NPK fertilizer contains more or less similar percentages for all three nutrients.

Soil fertility also has an impact on recommended rates. Since nutrients can compete with each other, it is important to have optimum levels in the soil. In case of high soil nutrient levels, it is recommended to decrease fertilizer application rates and when soil nutrient levels are too low it is advised is to add more than the crop needs.

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Fertilizer types

Common fertilizer types to apply nutrients to vegetables in Indonesia are:

- Chemical fertilizers like urea, ammonium sulphate, potassium nitrate and many NPK mixes contain, in most cases, only a few nutrients at high concentrations.
- Salts that are mined from the earth, like rock phosphate and magnesium sulfate, contain high concentrations of a few specific nutrients.
- Organic fertilizers like animal manures, which typically contain a wide range of different nutrients, including macro nutrients and trace elements, as well as organic matter.

Animal manures

Besides chemical fertilizer most vegetable farmers in Lembang apply organic fertilizer, such as manure. Using manure has several advantages, since it contains:

- Macro nutrients (N, P, K), which can reduce the need for chemical fertilizer;
- Micro-nutrients, such as Fe, Mn, B, Zn and Cu, which are essential for plant growth and not contained in chemical fertilizers;
- Manure can also improve other soil chemical properties (soil organic matter, CEC, and pH), soil biology (microbial and faunal activity), and soil physical properties (e.g., bulk density, infiltration rate and water-holding capacity).

Disadvantages of manures include the low nutrient density (manure is 'bulky') and variation in nutrient composition. Also, manure can pose risks of contamination to food or feed crops with unwanted biota or abiota, such as parasites, pathogens or heavy metals.

In Lembang horticulture, most farmers use chicken manure as organic fertilizer, whereas fewer use cow, goat, or other manures. Chicken manure has a relatively high dry matter content and is high in N and K content compared to cow manure (see table 1).

Table 1. Average nutrient composition of a few animal manure products used in horticulture in Lembang (% based on wet weight of the manure).

Types	Dry matter %	N total (%)	N-NH3 (%)	P (%)	K (%)
Dairy:					
Heap manure	39	0.7	0.03	0.2	0.3
Compost	42	0.9	0.03	0.3	0.4
Vermi-compost	35	0.8	0.03	0.4	0.4
Broiler chicken manure with rice husks (Postal)	71	2.0	0.20	0.6	1.7

How to use manure in horticulture

Amount

The total required quantity of nutrients from manure needed for a vegetable crop depends on the presence of nutrients in the manure. The manure nutrient content varies depending on the animal type, animal feeding, manure amendments (such as feed leftovers, bedding material or other manures), and methods of storing and processing the manure. For this it is recommended to analyze from time to time the manure that is used. Also using manure from a same source (livestock farm) will reduce the variation.

However, nutrient ratios in manure often do not fullfill crop requirements. Vegetable crops require relatively high nitrogen, wheras manure contains relatively high phosphate compared to the nitrogen content. So when the amount of manure applied based on the nitrogen requirement of plants, this will mean that excess phosphate is applied. Therefore, manure should be applied until the phosphate requirement is met, whereafter additional required nitrogen and potassium are added with chemical fertilizer.

Timing

A vegetable crop requires different levels of nutrients over time. At the start of a crop when the plants are small less is needed while at the stage of fast crop and formation of marketable plant parts higher amounts are needed. This means that nutrients should be available to plants at the right time and the right rates. When using manure, it is even more important since it takes time to convert organic nutrients in the manure into mineral nutrients that plants can utilize, whereas minerals in chemical fertilizers are quickly available to crops. The conversion of organically bound nutrients into mineral nutrients that are available to plants is called 'mineralization'. The mineralization rate of nutrients depends on the soil quality, climatic conditions, and the type of manure used. For example, compost can release nitrogen more slowly than farmyard manure. The nutrients will not be lost but will only become available for the next crop. Therefore, when using manure, one should plan carefully and estimate the availability of nutrients next to the total quantity present in manures.

Avoiding risks of crop burning

For vegetables organic manures should preferably have relatively low ammonium and phosphate contents and a high dry matter content. This is because too high ammonium content can lead to so-called crop burning, and because vegetables require relatively low phosphate. For example, chicken manure is relatively high in ammonium, whereas composted cattle manure shows low ammonium levels and releases nitrogen more gradually.

Handling manure

Most vegetable farmers prefer manures with a high dry matter content (low moisture content) because these are easier to handle, transport and apply to the field than liquid manure products. Moreover, the nutrient content of relatively dry manures is often higher than in liquid manure products.

Taking care of the soil

Besides manure type, soil quality is important for mineralization of nutrients and should be taken care of. Mineralization of nutrients is optimized when soil moisture, temperature, aeration and presence of microorganisms are at a suitable level. Using a lot of pesticides will reduce the number of organisms in the soil resulting in low mineralization.

Compacted soil will also result in less mineralization. Increasing organic matter contents (OM) of soils can also reduce nutrient losses because OM binds the nutrients to some extent. It is important to consider pH level of the soils, which is relatively low (acid) in the Lembang area (Table 2). At low pH levels, the availability of phosphate can be reduced. In this case, the phosphate can react with other nutrients making it no longer available for uptake by plants. This is called P-fixation. Adding lime to the soil will increase pH and improves the uptake of phosphate.

For acidic soils, one should also realize that the use of urea and ammonium fertilizers will make soils even more acidic. With the use of manure as an alternative for nitrogen chemical fertilizers, the impact on soil acidity or pH is less.

Table 2. Nutrient content (lowest, mean and highest value) in soils in Lembang sub-district.

	pH H2O (1:5)	C-Org % (Walkley-Black)	N tot % (Kjeldahl)	P2O5 Bray (ppm)	K2O mg/100g
Min	4.1	1.3	0.13	8.5	21.8
Mean	5.0	4.7	0.44	68.2	104.1
Max	6.1	8.1	0.71	235.7	748.6

Mineral nutrients in the soil are not stable and levels fluctuate depending on soil and climatic conditions. Another major factor is of course the amendment of fertilizers to the soil. Also, the mineralization of organic matter already present in the soil is influenced by soil and climatic conditions, adding mineral nutrients to the soil slower or faster.

Reducing environmental pollution

Applying nutrients at excessive rates is a waste of valuable nutrients and also causes two types of environmental pollution:

- The leaching and run-off of nutrients from the soils causes environmental pollution of local ecosystems (‘eutrophication’);
- During the production and application of fertilizers greenhouse gas (GHG) emissions occur, contributing to climate change.

There are several methods to prevent nutrient loss and environmental pollution during application:

- First, ideally, the exact quantity of nutrients needed by the plant should be applied on a daily basis. Application of fertilizers in split applications is therefore recommended.
- Second, nutrients should be placed as close as possible to the roots to enhance uptake. One should be aware of the risk of overuse, since a high concentration of fertilizers close to the roots can lead to burning of the roots. Placing phosphate in the root proximity also enables plants to take up the phosphate before it can be fixed in the soil.
- Third, it is recommended to incorporate manure, urea and ammonium sulphate into the soil to avoid loss of N to the air by volatilization of ammonia during application.
- Fourth, replacing part of the chemical fertilizer by organic fertilizer reduces GHG emissions. Also, weight-based replacement of chicken manure by cow manure will reduce GHG emissions.

Assuming a nutrient composition of vermi-compost in Table 1, as a rule of a thumb, it is advised to apply vermi-compost at a level of 10 – 15 t/ha for crops in Table 3, with a maximum of two applications per year to cover P demand. Chemical N and K fertilizers should then be applied to complement nutrients from animal manures.

Table 3. Example of fertilizer recommendation for vegetable crops when applying vermi-compost.

	Vermi-compost t/ha	Urea Kg/ha	SP36 Kg/ha	KCl Kg/ha
Hot pepper	10	144	0	92
Shallot	10	195	44	152
Cabbage	10	141	8	27
Potato	15	203	194	141

Conclusions and policy implications

For an environmentally sustainable use of fertilizers horticultural farmers need to be trained about the fertilizer requirements of crops and soil fertility, types of fertilizers, and how and when to apply these fertilizers in relation to soil characteristics. To enhance the use of cow manure in horticulture in Lembang, a reliable manure supply chain should be developed with a constant supply and quality of manure products that are frequently analyzed and easy to handle and transport.

Further reading

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This info note summarizes findings of a project entitled Closing Regional Nutrient Cycles for Low Emission Agriculture in Indonesia (NutReCycle).

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