WWW.INDUSTRY.NSW.GOV.AU

primefacts

FOR PROFITABLE, ADAPTIVE AND SUSTAINABLE PRIMARY INDUSTRIES

SEPTEMBER 2010 PRIMEFACT 803 SECOND EDITION

Organic vegetable production - soil management and crop establishment

Robyn Neeson

Organic Farming Liaison Officer, Farming Systems Research, Yanco

Soil fertility and crop nutrition

Organic farming starts with the soil. The organic farmer's primary aim should be to provide crop and animal nutrition by implementing practices that nurture the soil, stimulate soil life, and conserve nutrients. This involves developing both long-term and short-term strategies to improve soil health and to supply crop nutrition.

Organic soil conversion phases

Organic conversion is not just about replacing a high–chemical input system with a no-input, or every 'alternative' input, system. The organic soil-building process goes through three critical stages, which can be referred to as the 'adjustment phase', the 'comfort phase' and the 'maintenance phase'.

The adjustment phase

The adjustment phase involves developing a system that reduces the crop's reliance on artificial chemicals. This could be likened to going 'cold turkey' for farming systems that are heavily dependent on chemical inputs. During this phase some farmers have observed that crop yields can decline as the system converts from a chemical to a biological one and is starved of its regular 'fix' of readily available, chemical fertilisers.

The length of this preliminary soil-building process depends largely on the soil's pre-existing condition and fertiliser history. The challenge for organic farmers is to develop and adopt a cost-effective strategy that encourages and builds biological processes in the soil while maintaining optimal plant nutrition. In addition to standard organic practices—such as planting legumes and green manure crops and applying compost and rock dusts—commercial organic fertilisers, seaweed, fish emulsion, sugar solutions and microbial preparations are applied to stimulate soil biological activity and supplement plant health.

The comfort phase

The comfort phase coincides with an increase in biological activity and a corresponding release of previously 'locked-up', or unavailable, nutrients. It is during this phase that optimal crop yields are reached. Organic farmers need to be careful not to over-fertilise during this phase. This is more likely to occur in intensive horticulture systems, where application of compost and green manuring are common practice. Over-fertilisation usually manifests itself through crop physiological problems and an increased incidence of pests and diseases.

Running down of the nutrient reserve can occur if the soil system is not being monitored properly. Soil and plant tissue testing allows nutrient requirements to be tracked, thus avoiding 'overfeeding' or 'underfeeding' the soil system.

The maintenance phase

Research has shown that some organic systems have, over a relatively long period, experienced a decline in soil nutrient reserves (Small et al. 1994; Penfold et al. 1995). This could be attributed to long-term drawing down of nutrients during harvesting of crop or (less so) livestock products and through natural processes such as leaching. In Australia this has been particularly evident in broad-acre cropping and livestock enterprises where a phosphorous deficiency has been found. This has implications for cereal and legume crops: phosphorous deficiency adversely affects a legume's ability to fix atmospheric nitrogen in root nodules; nitrogen fixed by legumes is an essential nutrient for subsequent crops in a cropping rotation.

Preparing a nutrient budget by reconciling inputs and outputs and correlating this with regular soil tests and crop performance can help track the performance of the annual soil nutrient cycle.

Increasing biological activity

Organic conversion begins with a process that encourages increased activity by microbes and arthropods in the soil. The elemental composition, structure and organic matter content of the soil need to be favourable if biological activity is to be increased.

Biological activity in the soil begins with the breakdown of organic matter. During the decomposition process the organic molecules in organic matter are either broken down into simpler organic molecules that require further decomposition or converted into mineralised nutrients. Organic farmers supply organic matter through incorporation of green manure crops and crop refuse and the addition of compost.

The use of bio-indicators is becoming increasingly important as a way of assessing soil health. Commercial laboratories offering services to assess a soils' microbial status are now becoming more common in Australia.

Green manuring

Green manure crops are grown specifically for cultivation back into the soil in order to build up organic matter and nutrients and to stimulate biological activity. The type of green manure crop and the stage at which it is turned in determine the amount of organic matter or nutrients returned to the soil. A lush, actively growing legume sward (of vetch, faba beans or lupins, for example) contains large amounts of nitrogen (50–140 kilograms of nitrogen gain per hectare) that is released to the soil upon cultivation. The same crop, when allowed to mature, contributes more organic matter but less available nitrogen. If a soil is low in organic matter, a green manure crop that increases organic matter (for example, oats) is desirable.

Green manures can also act as 'break crops' to reduce the carryover of pests and diseases in subsequent crops in the rotation. They are an essential component in intensive organic annual cropping rotations.

Some organic farmers apply foliar sprays of sugar, molasses or compost teas to green manure crops prior to turning the crop in. This is thought to provide additional energy for micro-organisms, enabling a more rapid breakdown of green matter prior to planting the next crop.

Under-sowing crops

Under-sowing crops—for example, barley with the grass or clover pasture that will follow in the rotation in the succeeding year or almost any leguminous crop—is central to organic systems. The practice has been shown to have beneficial effects on the diversity and abundance of insect species, a potential for higher protein content in cereals, improved weed suppression and improved pest and disease control.

Permanent swards and pastures

In both livestock and cropping enterprises legume-based pastures provide the system's main nitrogen input and livestock largely recycle other nutrients. The incorporation of a pasture in the rotation can also help to manage weed, pest & disease problems. A mixture of deep-rooted and shallow-rooted species such as chicory, plantain, yarrow and caraway increases the potential for gaining access to soil nutrients.

Compost

Compost is a primary source of nutrients and organic matter in intensive organic farming systems and an invaluable food source for soil micro-organisms. Animal manures and crop refuse are the main ingredients of compost. Organic standards require that imported manure intended for application be composted before use. If a certified source of compost is available locally, this could be a preferred option, provided it is cost effective (include the transport costs).

The primary benefits of compost are that it is a more stable form of organic matter than raw waste and weed seeds and diseases are destroyed during the composting process. When manure is composted, it is easier to spread, and losses to the environment are minimised. Rock dusts and clay added to compost in small quantities can help reduce nitrogen losses from the heap by absorbing ammonia (Lampkin 1990).

Compost is usually applied at a rate of 5 to 20 tonnes a hectare—the higher rate on sandier soils. Some certifiers put limitations on compost rates above 20 tonnes a hectare. Soil analysis and crop requirements will help determine application rates.

Organic farmers should aim to establish on-farm composting and handling facilities, which should be sited well away from watercourses and dams. Efforts should be made to avoid run-off and nutrient loss—for example, by covering the compost windrow. A grassed buffer area downslope of the windrow will help absorb nutrient run-off.

Suitable equipment is needed for handling, turning and spreading the compost. This might include a front-end loader or tractor-mounted bucket for loading and turning and a manure spreader for application.

Rock dusts and re-mineralisation

The re-mineralisation of Australian farming soils is a strategy more recently proposed by some soil health experts. Various techniques for re-mineralisation are gaining an increased following among farmers; they are largely based on balancing soils' cation exchange capacity and achieving a satisfactory calcium–magnesium ratio (Albrecht 1975).

Re-mineralisation involves the addition of various rock-based materials, among them reactive and colloidal rock phosphate, dolomite, limestone and rock dusts (from silicate rocks, including basalt and bentonite), as well as some commercial organic blends.

Rock dusts can be added directly to the soil or to compost heaps. Whatever the method of application, the release of nutrients from the rock dusts is accelerated by moist conditions, high temperatures and high biological activity—for example, during a green manure stage or composting. Finer particle size of the rock dust is preferred as this provides a greater surface area for micro-organisms to act on and hence a more rapid availability of nutrients to plants. Where soils have good biological activity and are subject to irrigation, the effectiveness of the mineral products can be further improved. Rock phosphate becomes available more quickly under acidic soil conditions (a pH less than 5.5) and where rainfall exceeds 600 millimetres.

Because the benefits of rock dusts are not available immediately to a crop, the dusts should be applied a few seasons before cropping. Consistent, small applications throughout the rotation should be considered.

For growers buying mineral rock dusts, it is important to note that unacceptably high levels of heavy metals have been found in some commercial products. Each batch bought should be tested, or a written declaration should be obtained from the manufacturer or supplier, in order to determine whether impurities are present.

Improvements to soil structure

Improvements in the biological activity and cation exchange capacity of soils will generally lead to an improvement in soil structure, but this needs to be supported by suitable cultural practices. Use of suitable machinery at the correct soil moisture, incorporation of soil organic matter, and improvement of soils using differing types of crop root physiology are techniques organic farmers use in order to develop soil structure.

Lampkin (1990) describes cultivation practices as having the greatest impact on the soil of any agricultural activity. He summarises the organic approach to soil cultivation as one that seeks to maintain soil structure and allow the soil to have vegetative cover for as long as possible within the rotation. Shallow cultivations, where only the surface layers of the soil are mixed, are an important element of this approach. Deep cultivation of dry soil is practised to loosen and aerate soil, avoiding inversion of the lower layers. Green manures or cereal crops are sown as soon as practicable following cultivation: their roots help stabilise loosened soil and minimise nitrate leaching.

Correcting deficiencies organically

Unseasonal weather, such as a prolonged dry spell or excessive moisture, or simply a miscalculation of crop nutrient requirements, can result in a nutrient deficiency in the crop. If this happens during a critical crop growth period, plant health can decline, predisposing the crop to pest and disease attack. A permanent yield loss could result, so it is necessary to correct any deficiency quickly. Leaf analysis is the most commonly used method of detecting deficiencies during the crop-growing period.

Organic farmers use foliar sprays (such as fish and seaweed extracts) molasses, compost teas and trace elements to correct temporary deficiencies. Guidelines for foliar feeding of plants can be found on the website of the US National Sustainable Agriculture Information Service <http://www.attra.org/attra-pub/PDF/foliar.pdf>.

The role of livestock on soil nutrition

Livestock play an important part in organic farming. Crop nutrition is improved when a pasture or grazing phase is incorporated in the cropping rotation. This is common practice in broad-acre systems and in some annual vegetable production systems. Among the nutritional benefits offered by a pasture phase are nitrogen fixation through the legume component and the recycling of organic matter and nutrients via livestock manure. The pasture phase can also help to suppress pests, disease and weeds by providing a break in the disease cycle.

If well managed, poultry such as chickens, geese and ducks can provide valuable nutrient inputs as well as contributing to pest, disease and weed control.

Determining crop nutrient requirements

The availability of nutrients in the soil and the growth stage of the crop will determine a crop's nutrient requirements. Augmentation of nutrients in the soil reservoir necessitates a long-term fertility building program. Increasing biological activity and organic matter (and thus humus formation) and balancing other essential elements (for example, the calcium–magnesium balance) should be based on site-specific information collected through regular soil analysis. Soil tests are the first step to planning a soil management program.

Soil tests should be conducted regularly—particularly during the early stages of conversion—to help track the effectiveness of soil improvement and crop nutrition programs. Soil samples should be collected from all representative soils on the farm, with care being taken to map out the location and depth of sampling. A good sampling procedure is described on the Industry and Investment NSW Primary Industries website: www.dpi.nsw.gov.au/aboutus/services/das/soils

Seasonal nutrient requirements

During conversion to organic production and during a crop's growth period additional nutrients might need to be supplied. Nitrogen, phosphorous, potassium and calcium are the elements most often required by crops.

Nitrogen

Nitrogen is required in reasonable quantities by most vegetables. Unlike many elements, it is relatively mobile in the soil nutrient pool.

Although nitrogen mineralisation can be high—up to 900 grams a day—this might be inadequate for a rapidly growing vegetable crop. Short-season crops such as radishes and beets will most probably be able to obtain all their nitrogen requirements from a green manure crop, compost or organic fertiliser that has been applied before planting. Crops with a growing season beyond six to eight weeks will probably require additional nitrogen, applied as a side-dressing or foliar spray or, if used, by means of drip irrigation. Commonly used substances are fish emulsion, worm juice and compost teas (made from stinging nettle, for example).

Phosphorous

Although soil tests might show there is sufficient phosphorus in the soil, the phosphorus might be in a form that is not readily available. Cold, wet soils, which can limit root growth, restrict phosphorus availability. In addition, organic sources of phosphorus are less soluble than conventional forms such as superphosphate, which is treated with sulphuric acid to increase its solubility, so there is a time lag before phosphorus becomes available for the crop. Increasing biological activity improves availability, but additional phosphorus applied in small, regular doses will ensure that a reliable supply is available for crop growth. Rock phosphate, guano, fish meal and bone meal (usually added as an ingredient during composting) all contain moderate levels of phosphorus and are commonly applied in organic systems. Phosphorus should be applied *at least* one year before cropping.

Potassium

The element potassium is needed for flower and fruit development and to improve storage quality; it is particularly important for crops such as tomatoes. Among the organic sources of potassium are compost, seaweed, basic slag, wood ash and sulphate of potash. Some commercial organic fertiliser blends containing potassium are available.

Calcium

Calcium is needed for plant cell strength, pest and disease resistance, and post-harvest quality. The Albrecht theory of plant nutrition holds that calcium and its relationship (ratio) with cations, particularly magnesium, are critical for soil-building processes and crop growth. Like phosphorus, calcium must be applied well before planting, with regular, small doses beneficial to sustain soil levels. Limestone (naturally mined), dolomite and gypsum are sources of calcium. Dolomite is also a source of magnesium, and gypsum also contains sulphur.

Other elements

Other minor elements essential for crop growth might be lacking in the soil. Commercial organic fertilisers, compost and foliar applications of seaweed, worm liquid and compost teas can be used to remedy deficiencies.

Soil preparation and planting

Cultural management of soil in vegetable production systems is a matter of achieving a balance between the primary goal of maintaining or augmenting the level of organic matter and that of achieving an acceptable soil condition through the tillage that is required for crop growth and weed management.

Conventional intensive tillage systems generally have long-term negative effects on organic carbon levels in the soil. Conservation tillage techniques, while minimising soil disturbance and carbon loss, generally leave crop residues on the soil surface. This creates problems for organic producers who rely on tillage to manage weeds, incorporate crop residues, and aerate the soil.

Ground preparation

Following any preliminary soil remediation works, the soil should be cultivated to a depth that will encourage root growth and drainage. On clay soils this might entail deep ripping or deep aeration with an implement such as the Agroplow®. Growing a deep-rooted crop such as sunflower might help break up hard pans and improve drainage. Adding gypsum can also improve drainage in some soils.

Vegetables are generally grown in rows or beds, and ripping should follow this layout. Primary tillage usually involves developing a deep, friable soil, which is then formed into hills; if beds are to be used, a number of hills are combined into a bed.

Green manure should be incorporated well before the crop is planted. Organic matter (in this case, the green manure crop) must first be digested by micro-organisms before any nutritional benefits become available to subsequent crops. Nitrogen is used by micro-organisms as they consume and break down organic matter, and if a vegetable crop is planted when undecomposed organic matter is still present a temporary nitrogen deficiency can occur. Some organic practitioners spray molasses, compost teas, sugar or microbial solutions on the green manure crop before incorporation, to facilitate its breakdown.

Incorporation of the green manure should be shallow, while still burying crop refuse. A bulky green manure might need to be slashed or mulched before incorporation, to facilitate breakdown. A rotary mulcher can be used very effectively to break up large amounts of crop refuse and can be adjusted to operate in the top 5 centimetres of soil.

The timing of incorporating green manures also needs careful consideration. Rapidly growing, immature green manures break down more rapidly than green manures that are allowed to mature. In legumes, once flowering begins, the vegetative growth slows, and nitrogen that has been fixed by the plant begins to be used for seed production. Green manures should never be allowed to go to seed (unless the seed is to be saved for future planting) since this can cause weed problems in subsequent crops. This is lost nitrogen in terms of the vegetable rotation, so incorporation should occur before or during early flowering of the green manure. If a mixture of species is used in the green manure, it might be necessary to forfeit some nitrogen benefit in order to ensure that there is sufficient time for the organic matter to decompose before the vegetable crop is planted. Low soil moisture can also slow the rate of decomposition.

Primary tillage can be very destructive of soil organic matter. The benefits of a green manure crop grown and incorporated before preliminary ground preparation and bed-forming can be quickly lost by excessive cultivation, or by cultivating at inappropriate soil moisture levels. Once the beds are formed, a green manure crop can be grown in situ, then mulched, and shallowly incorporated before the vegetable crop is planted. This cultivation can damage beds, so it is sometimes necessary to reshape the bed following incorporation of the green manure.

Another green manuring technique uses the residues of crops such as vetch grown in the previous season. The vegetable crop is planted into the residual surface mulch of the cover crop. The technique relies on the senescence of growth in the cover crop. The crop is then mulched down to form a surface mulch. The technique relies, however, on the cover crop dying off before the vegetable crop is planted. The growth cycle of the cover crop must be completed in time for that crop to be mowed before the vegetable crop is planted. Provided dry conditions prevail, this can be achieved for a winter-grown cover crop to be followed by late–spring planted vegetables. Late spring rains can, however, cause unacceptable delays to cover crop senescence and crop sowing. In addition, planting into the cover crop residue calls for specialist equipment. Despite these problems, researching suitable cover crops and their management as surface mulches in organic vegetable production systems is worthwhile.

Slowly available and soil-building substances such as compost, rock phosphate and lime are best applied before forming the beds. It is extremely important that the beds or rows be straight and the correct distance apart: otherwise, post-planting cultural operations such as inter-row weeding will be difficult. If well made, beds should last a couple of seasons before needing to be re-formed. If subsurface drip irrigation is to be used, it must be installed after bed-forming and before sowing the crop.

Pre-irrigation

Pre-irrigation or rainfall before planting is advantageous: it helps germinate weed seedlings and provides a moist seedbed into which the crop can be sown. The weeds are usually cultivated out before sowing: in this case, the cultivation should be shallow and should avoid soil inversion since this would promote further germination of weeds. An effective implement is one that ‘slices’ under the soil, lifting and removing young weeds. It is important to avoid cultivating if rain is imminent because the weeds will be transplanted. Flame, steam and brush weeders can also be used to control young weeds. If pre-irrigation is not possible, planting should avoid soil disturbance as much as possible. Some post-planting weed control will nevertheless be required.

Planting

Before planting, soil tests should be done in order to determine whether additional fertiliser is needed, given the crop's known requirements. Organic fertilisers or compost can be surface applied or banded in the crop row. The time of planting should take into account the requirements of the variety to be grown, the market 'window' and if, by delaying planting or planting earlier, potential weed, pest or disease problems might be avoided.

Since 1 January 2004 it has been mandatory to use organically produced planting material. If such material is not available, formal application must be made to the certifier for an exemption.

Germination tests should be carried out before seed is sown. This can be done by placing a few seeds in a pot or between damp (not wet) tissue paper for a few days and recording the germination percentage. The sowing rate can be increased to compensate for reduced germination.

Transplants should be checked for pests and any that are found should be removed before planting. A strong jet of water will physically dislodge some pests. Alternatively, they can be sprayed with an organically acceptable pesticide. The transplants should then be hardened off outdoors for a few days before being planted in the field.

Seeds or transplants?

Vegetables such as carrots do not transplant well, so seeds are the only option for planting. Transplanted (as opposed to direct-seeded) crops have an advantage in that they will be ahead of any weeds that germinate after planting and, if growing vigorously, will quickly shade out the weeds. Direct seeding tends to disturb the soil surface, encouraging weed germination. Irrigation can be crucial, especially for small-seeded species because they are not sown as deeply as large-seeded species. The soil surface must remain moist for longer to ensure good germination. Shallow-planted seeds are also more likely to be eaten by ants and birds.

Another consideration is seedling vigour. Some species—for example, onions—have extremely slow early growth, particularly in cold and wet conditions. Weeds, on the other hand, are better adapted to these conditions and will quickly smother struggling vegetable seedlings.

In general, small-seeded species are best transplanted—unless, like carrots, they do not like root disturbance—while larger seeded species such as pumpkin can be direct seeded.

When seeding or transplanting, it is important that rows are uniform and straight, so that inter-row operations such as weeding can be carried out accurately.

Plant spacing

The sowing rate between and within rows is generally higher in organic systems compared with conventional systems. Higher sowing rates mean that gaps between the crop plants will be quickly filled, which discourages weed competition. Care is needed, however, to avoid compromising crop quality. A higher sowing rate also increases inter-crop competition and can result in a reduced overall yield or smaller sizes for produce; for example, onion bulb size and cauliflower head size decrease with increased sowing density, although this can also be used to advantage if the aim is to produce 'mini-vegetables'.

Post-planting operations

Post-planting cultural operations consist of weed and pest management and, if required, application of organic fertiliser. Accuracy when operating equipment and precision timing of operations are essential. Specially designed inter-row cultivators can remove young weeds from around the crop. One such implement is the WeedFix®, which consists of a series of rotating tines mounted either side of crop guards. The tines 'stir' the soil surface, dislodging weeds, while the guards prevent damage to the crop. The tines can be operated in two directions—either throwing soil towards the crop, thus smothering weeds in close proximity to the crop, or throwing soil away from the crop, removing the weeds.

Other types of equipment are also available for post-planting cultural operations, among them flame or hot-air weeders, brush weeders, rotating cultivators, and various toolbar attachments such as bean knives and Alabama sweeps. Highly recommended reading is Steel in the Field: a farmer's guide to weed management tools (Bowman 1997), which documents farmers' experiences in this regard. See: www.sare.org/publications/steel/steel.pdf

Irrigation

Organic standards require that irrigation monitoring and scheduling techniques be used and that irrigation practices minimise disturbances to the environment and natural ecosystems.

The best possible yields are obtained by maintaining uniform soil moisture in the root zone during the growing season. This requires a thorough knowledge of the crop's water requirements and the soil's water-holding capacity. Applying only the amount of water required by the crop leads to savings on pumping, fertigation (irrigation incorporating nutrients) and water costs and limits run-off problems. Drip irrigation is the most efficient form of irrigation; providing water directly to the plant and nutrients can be supplied by fertigation to the crop during the growing season. Cultural operations can, however, be made more difficult if the drip lines are laid on the bed's surface.

Drip lines can be installed beneath the surface to facilitate cultural operations, although roots can grow into the lines and cause blockages. Most subsurface drip is impregnated with a herbicide to prevent root intrusion, so organic producers need to inform manufacturers that they require herbicide-free drip line.

Irrigation management is also a valuable tool for controlling weeds. Strategic scheduling of irrigation can be used to germinate weeds so that control action can be taken before the main crop is planted.

Information about good irrigation management practice is available on the Industry and Investment NSW Primary Industries website: www.dpi.nsw.govau/agriculture/resources/water/irrigation/crops

Also available are guidelines for irrigation of processing tomatoes, onions and carrots, and melons.

Post-harvest management and marketing

Post-harvest management must ensure that the quality and the organic integrity of the product are retained—from paddock to plate.

Vegetable producers must ensure that harvested product does not become contaminated after it leaves the paddock. Harvest bins and transport—particularly if provided by contractors—need to be thoroughly cleaned to remove potential contaminants. Few chemicals for prolonging post-harvest storage of the product are permitted, so optimum hygiene and storage conditions must be provided. Certifiers will require that freight transporters be inspected & information about post-harvest storage and disinfestation procedures be provided. Storage and packaging facilities will also have to be inspected. Any processing of organic vegetables must be certified. Certification is sometimes a deterrent to processors, particularly if only a small quantity of organic produce is to be processed. Producers could consider forming processing cooperatives.

ISSN 1832-6668

Check for updates of this Primefact at:
www.dpi.nsw.gov.au/primefacts

Job number 10273 PUB10/133