Notes based on the presentation by
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Crop nutrition and composting: notes for the *Market Gardening Group-Agroecology: Enabling the transition* visit to Tomnah'a Market Garden

October 2022

1. SOILS

Soil fertility is the ability of soils to sustain healthy plant growth and productivity by providing essential plant nutrients & favorable chemical, physical and biological characteristics.

Soil fertility and nutrient availability are affected by:

- Soil structure and texture;
- the mix of minerals in the weathered rock material the soil derives from; & the elemental composition of the minerals;
- what you have done to the soil in terms of management, applied lime & fertilisers, cultivations, drainage, irrigation, crops grown/animals produced.

Therefore, and to ensure good soil physical conditions:

- Make sure your soils have good structure;
- make regular additions of organic matter;
- ensure good drainage and sufficient water.

Soil structure

Some key aspects to consider:

1.1 Soil texture - the proportion of sand, silt and clay. Affects soil properties markedly →*can't be changed*

Soil texture can be influenced by:

- drainage
- cultivation ease
- compaction risk
- crop choice
- available water holding
- ***nutrient retention***
- ***nutrient content***
- liming

1.2 Soil structure - the way in which sand, silt, clay and humus particles combine to form aggregates (thus creating pores/channels for water, air and roots to move through)

Good soil structure is vital for healthy soils and crops. The extent to which plant roots can access the nutrients they need depends on how good soil structure is. A good-structure soil **has** lots of vertical channels and pores to let water, air and roots move; and **does not have** compaction, poor drainage or a weak structure.

GOOD STRUCTURE	POOR STRUCTURE
• Has crumbs and small (fine) blocky aggregates • Roots in it are dense and deep • This soil has a rough surface • This soil is easy to dig • It shows no sign of waterlogging • Structure forming a natural process influenced by management	• Large peds with few cracks and pores • Coarse blocky or prismatic structure • Massive or platy structure • Soil is hard to dig • Roots are shallow, few and grow side-ways • Soil has a smooth, crusted surface - capping • Soil is waterlogged
	

2. pH

This is a measure of acidity and alkalinity, and it affects plant growth by influencing nutrient availability for plants; and whether there are toxic ions. pH is measured on a logarithmic scale that ranges from 0 to 14; therefore a soil of pH 5 is ten times more acid than a soil of pH 6.

The key is having a balanced soil pH: each crop has its own optimal pH, but a good average to aim for with fruit and veg is ~ 6.5.

Soils that are too acid or too alkaline can result in a series of problems:

Too acid	Too alkaline
• Aluminium + manganese too well dissolved → taken up at toxic levels (poss also some essential trace elements) • Phosphate not well enough dissolved → deficiency • Soil organisms don't mineralise enough nitrogen → deficiency • Some diseases likely to be worse (e.g. clubroot) • Earthworms fail to thrive	• Phosphate not well enough dissolved → deficiency • Trace elements not well enough dissolved → deficiency (e.g. manganese, boron deficiency) • Some diseases likely to be worse (e.g. potato scab)

Scottish soils tend to be slightly acidic (check them in this link), but there are things that you can do to modify your soil pH. The starting point, however, is to **MEASURE YOUR pH, DO NOT GUESS! (see Annex 1 on measuring)**

Once you know your soil's pH, consider liming to reduce acidity **only if required** (remember, 6.5 is a good average) by liming.

Some aspects that should be considered when doing it:

- Determine lime requirements: the correct amount is important, so measure, don't guess!
- Consider which liming materials available and their strength: the strength (*neutralising value)* of the liming material varies, and the size of particles is also important.
- Lime takes time to react – plan ahead! Lime is normally best applied in autumn.
- Do not apply before susceptible crops.
- Never apply along with phosphate fertiliser!
- Overliming can be a problem: is the phosphate or trace elements are not well dissolved, you might face nutrient deficiencies (e.g. manganese deficiency, boron deficiency, etc)
- Lime before brassicas and not before potatoes.

3. Nutrients

Crops need a variety of nutrients; all crops need N, P & K, and in most cases Ca and Mg (which are usually applied in lime); S is also needed in some cases (definitely for brassicas) and boron for root crops. Trace elements are rarely needed except in high pH soils.

To maintain the fertility and supply of nutrients to crops, natural processes are not enough; in addition to natural weathering and release of elements, here are some ways nutrients make it to your soils:

- Natural nutrient deposition (N and S)
- Nutrients being returned in crop residues.
- Bagged and bulky organic fertilisers (composts, dungs etc.)
- Availability of the nutrients to plants.

The nutrients required by crops and available on soils can come from different sources:

- N – from natural N fixation, from N deposition, from mineralisation of SOM, from bulky and liquid organic fertilisers (e.g. composts, animal manures, comfrey liquid/nettle tea) or from manufactured bagged/liquid inorganic fertilisers (e.g. Tomorite).
- P - from bulky organic fertilisers (as above) and from rock phosphate and from manufactured fertilisers)
- K - from bulky organic fertilisers (as above) and from manufactured fertilisers)
- Ca and Mg, mainly in liming materials, but also from bulky organic fertilisers.
- S - mainly from bulky organic and manufactured fertilisers)
- Trace elements – other than boron for root crops in light soils, sufficient will be added when using well-made compost regularly.

How, when and what to apply

Nutrients might be needed, but before applying make sure you consider/know the following:

- Know what the soil can provide and determine your soil nutrient status;
- find out how much and which nutrients the crop needs (esp. N); look up tables based on crop and the soil status;
- make the best use of nutrient sources available;
- consider making your own compost and using locally available manures but remember to test them to understand what you are applying;
- make sure you don't apply too much!

a) First step, ***measure!***

Although applying nutrients is usually needed, as with pH **MEASURE THE NUTRIENTS IN YOUR SOILS BEFORE APPLYING, DO NOT GUESS!** Guessing how many fertilisers and bulky organic materials should be added can lead to applications *grossly in excess of crop needs,* resulting in problems like:

- Nutrient imbalances in the soil and plant, and increased susceptibility to pests and diseases;
- increased weed problems;
- nutrient leaching and pollution;
- waste of money and resources.

If you are growing high value crops as part of an income, do assess nutrient status annually in polytunnels if possible; or at least every 2 years.

b) Second step: apply the correct products and amounts

Before you start applying nutrients, here are some relevant aspects to consider:

- Maintain soil P and K status at high;
- maintain soil Mg status at moderate;
- apply adequate but never too much nutrient!
- Ensuring crops get enough N without over-applying P and K can be difficult, especially after 5 – 10 years of heavy compost application.

Applying nutrients:

- Determine crop N requirement for this year, based on previous crop and information on soil type and rainfall (SAC TN 734 and TN 740)
- Check soil analysis results before applying P, K and Mg; or, work out crop P and K requirements. Will there be enough P and K in the soil? If not, add more via bagged or bulky fertilisers (SAC TN 699, 734, 736 and 740)
    - ***If using bulky fertilisers***, calculate how much N, P and K will be released in the year of application (TN 736) and determine application rate. Likely to need to extra N from elsewhere in order not to over-apply P and K… (not necessarily at first). How much bulky fertiliser you will need depends on:
        - soil type and soil nutrient status
        - following crop(s) and crop rotation
        - its nutrient content (and the availability of nutrients)
        - its availability (and cost of purchase/transport/spreading)

      Usually apply from 10 t/ha (only 1 kg/m^2!) to about 50 t/ha (5 kg/m^2)

    - ***If using bagged fertilisers***, choose correct product to match ratio of nutrients required and determine rate to supply N (& P, K, Mg if needed)

The simpler version!

1. Once soils are at target status for P and K, only apply ~ 20 - 30 t/ha (2-3 kg/m2) annually in a four-course rotation, omitting a single year in four (e.g. before carrots and/or crops to be eaten raw if manures are to be used).

Must check soil pH and soil nutrient status at least every 2 years to check that soil P and K status are maintained at "high" on SAC scale and Mg at "moderate". (May need to increase application rates if soil nutrient levels start to decline)

2. Extra N will almost certainly be needed (on top of that applied in bulky fertilisers) in order to get good yields of quality crops (esp. in N-hungry crops). Take care not to add too much. Different crops differ! (see SAC Technical notes)

3. And finally…
   Use best practice in soil management to ensure you make the most of the nutrients you apply.

- Regular organic matter returns (feed the soil, which then feeds your crops [use mainly composts and manures])
- Minimise use of synthetic/liquid fertilisers and pesticides
- Minimise cultivations
- Don't work soils, sow or harvest when soils are wet
- Return (non-diseased) crop residues and weeds without seeds/propagules to the soil surface.
- Use cover crops and green manures where possible
- Try never to leave the soil bare, particularly in winter
- Integrate ruminant livestock into longer rotations if possible

4. Composting

Composting is one of nature's miracles, but it is a process which requires attention!

Given their benefits and potential, it is definitely worth learning how composting works, so that you can optimize your process; and you should make sure you **understand your own composts** and the best ways in which to use them.

Composting is the "controlled, aerobic (with oxygen) biological decomposition of biodegradable materials such as garden and food waste". It is achieved through mixing, aeration and self-generated heating, in either open windrows, semi-enclosed or enclosed systems.

This process results in "**true compost**" which is a stable, sanitised organic material made from organic wastes. It is rich in a wide range of beneficial microorganisms, and is suitable for use as a fertiliser, soil conditioner, top dressing for turf (or only the very best ones can be used as constituents of growing media). Its benefits in agriculture and field horticulture are extensive, well-documented and well known.

Pay attention: there is usually confusion about what compost really is, especially as the media uses the concept of compost to refer to a "(usually bagged) substrate used to sow seeds, strike cuttings, pot on young plants or grow fruit, vegetables and salads in". "**True compost" and "growing media" are completely different and are not interchangeable.**

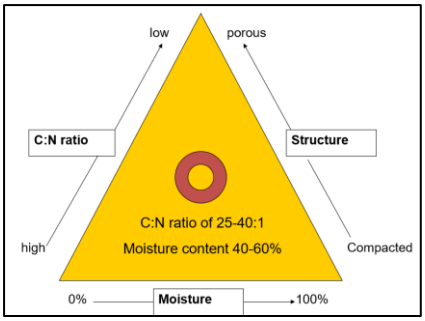
Composting: how does it work?

Composting is a *highly* complex process which is totally dependent on microorganisms that live naturally in the environment and on organic materials.

Provided there is enough moisture and oxygen, these microorganisms will begin to break down the organic materials in a newly formed compost heap. In the process, these microorganisms produce heat as they respire and multiply. ***The natural heating in a compost pile or windrow is vital*** to the process as it:

- kills plant, animal and human pathogens;
- kills weed seeds and weed propagules;
- denatures viruses;
- helps break down pesticides and other organic contaminants.

The proportion of moisture, carbon and porosity across raw materials is key: therefore, to find the right balance, fleshy, wet, green material needs to be mixed with chunky, woody material; and "high carbon" feedstocks need to be mixed with "high nitrogen" materials.



Material	C:N ratio	Moisture content	Structure
Manure	19:1	80%	Dense
Straw	80:1	12%	Weak
Mixed garden wastes	25:1 to 40:1	50 - 60%	Needs shredding
Vegetable waste	12:1	75%	dense

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Compost systems

There are a variety of composting systems, for example, fully contained "in-vessel" systems for food and garden wastes (legal requirement for food wastes); or open-air windrows systems.

For crofters and small-scale horticulture, the best will usually be three or four simple turned or unturned piles or windrows of garden wastes only (usually covered and party or fully enclosed).

Making good compost:

To make good compost you have to be prepared to put in time and effort: making good compost does not happen by accident!

First, choose feedstocks carefully, using a blend of high carbon (wood/ paper/cardboard) and low carbon (fleshy/soft/green) wastes. To be able to integrate hedge and tree/shrub prunings in your compost, consider buying a top-class shredder.

Once you have the raw materials in place, ensure these wastes are moist but not wet: to avoid rain over them, cover the heap with waterproof, breathable membrane in wet areas or wet spells: a gortex cover, or a piece of carpet which breathes work well: or waxed cotton, as the team from Campy Growers who have sourced the material from a local cloth factory rejects. If material is too wet and airless, introduce coarser material and/or make the heap smaller.

During the process, it is all about balance! Ensure enough air gets in but not too much.

How to test it: the squeeze test. Squeeze the material in your hand: if when doing so you get more than one drip, it is too wet. Be aware, in East of Scotland, most compost heaps in most years are too dry on top and most in West are too wet throughout.

Once the process is underway, turn regularly (at least twice) usually over a period of several weeks or even months, measuring temperatures in the pile and **aiming for temperatures of around 60 to 65°C in the centre of the pile**: over 70°C beneficial microbes start dying. You should compost all materials for at least 6 months, and ideally a year or more; and **do not to add new material to the heap in (at least) final 6 months.**

Using your compost

Your compost is ready! Do keep in mind that for some applications you might need to sieve the compost before use. A good alternative is the motorised Scheppach compost turner which sieves to 0 – 10 mm and 0 – 20 mm size fractions (costs around £400 and is cheaper than hand operated machines available).

Depending on its characteristics compost has many uses:

- **Fertiliser** (great source of P, K, Mg, S, trace elements);
- **soil conditioner** (organic matter builder, soil structure improver);
- if it is sieved compost (0 – 10 mm), it can be used as a **great lawn top-dressing;**
- coarser compost can be **good mulch**, helping prevent weeds and conserving moisture around trees/shrubs;

- and it can also be a **constituent of growing media**, especially for growing nutrient-hungry vegetable and salad crops including potatoes and well-grown vegetable transplants. In this case, you should dilute it with other, low-nutrient materials.

Caveat: real compost & garden compost as growing medium

While compost can be used as part of growing media, manufactured growing media are a different thing.

Manufactured growing media are manufactured by blending several constituents to get tailor-made products for specific uses. Some of these constituents can be: peat (formerly the main bulk constituent); coir (wastes from coconut production); composted bark; composted wood fibre; sterilised, heat-treated wood fibre; and to a lesser extent top-quality-PAS100-accredited green compost, sterilised loam (a mixture of sand, silt and clay), coarse sand and gravel, unsterilised loam/natural topsoil, perlite or vermiculite, biochar.

Although these manufactured growing media/garden compost and "true compost" might look the same, you should not use them interchangeably as garden composts are very variable, can be too salty and nutrient-rich for young developing roots; often contain too much ammonium-N; can sometimes have a high C:N ratio; are physically unsuitable for use alone (i.e. they drain too quickly/don't hold enough water or not quickly enough/hold too much water); and usually contain weed seeds, plant pests and pathogens.

Useful resources:

- FAS website https://www.fas.scot/
- Horticulture: a handbook for crofters (https://www.crofting.org/enterprise/books-and-cards/horticulture-handbook/)
- RHS webpage on peat-free growing media (https://www.rhs.org.uk/advice/profile?pid=441)

ANNEX 1: Measuring your pH and nutrients

Basic measurements don't have to be expensive. Test kits are easily available and cheap, but they are less precise and accurate, and their interpretation and comparison with published information can be difficult.

Instead, the recommendation is to do ***lab analysis*** (you might need helping to interpret them, but they are worth it!)

If you are taking samples, how you take them is important. They must be representative of area of interest, at right depth and at right time. Here are some suggestions:

- Run a W pattern and take 10 sub-samples per unit area → bulk
- Prepare a bulked sample for each block in rotation
- Test normally twice per rotation

20 cm depth cultivated land, 7.5 cm grassland, 15 cm deep on untilled/no-dig land.

More info here (SRUC testing), or here (NRM testing) .