GREATSOILS

A fresh look at soil testing for carrot production

Case Study 2 – Martin Wood, Earthcare Technical

AHDB
AGRICULTURE & HORTICULTURE DEVELOPMENT BOARD

Fresh Growers Ltd pioneered the return of Chantenay carrots

Action points

Soil tests and the recommendations associated with them are an important tool but they need to be used by farmers and advisors along with other information to make the best decision on how much fertiliser or other amendments to apply to a particular crop in a particular field in a particular year. So it's important to use common sense when interpreting soil test results (Magdoff and van Es, 2009)[1].

- **Yearly soil testing can be useful for intensive vegetable production on light soils**
- **Analysing for additional nutrients as well as the standard nutrient analysis can indicate further requirements for fertilisers**
- **The balance of nutrients can be important for intensive vegetable production on light soils**

Background

Martin Evans is CEO of Fresh Growers Ltd, a cooperative formed in June 1998 by 10 farmers, which pioneered bringing back Chantenay carrots to the UK. It's now the world's leading supplier, supplying over 90% of the UK market for Chantenay, a small but sweet variety that thrives in the sandy soils of central Nottinghamshire. Fresh Growers Ltd has a farming base of 8,000ha (around 50% owned, 50% rented land), growing and marketing both conventional and organic vegetables (including conventional carrot varieties other than Chantenay), and also producing piccolo parsnips, asparagus and other root crops. It has 1ha of factory space, which serves all the major UK retailers.

One key to this success story lies in the soil: the underlying sandstone, which runs north-south in a narrow belt through the Sherwood region, gives rise to well-drained sandy loam soils, ideally suited to growing carrots. However, production of high value vegetable crops such as carrots is only possible in this region with intensive use of fertilisers and irrigation. There is

Martin Evans, Fresh Growers Ltd

also a need to balance production interests with environmental considerations (the Sherwood sandstone aquifer serves as an important source of drinking water). A further key, according to Martin, is the matching of fertiliser with crop variety.

Fresh Growers Ltd approach to soil management

Soil testing

Soil testing underpins soil management decisions, with every field in the cooperative being analysed each year for pH, phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), boron (B), copper (Cu) zinc (Zn), manganese (Mn), iron (Fe) and molybdenum (Mo) in order to come up with what Martin terms 'an audit of the chemistry'. Organic matter content and cation exchange capacity are also measured. With only around 7% clay and 2.5% organic matter, these sandy loam soils have a very low cation exchange capacity, and so getting the right balance of nutrients applied as well as the right amount of fertiliser is considered important. With carrots, sodium (Na) is an important nutrient to take into account (as well as the usual ones listed above) as shown in the following data[2] (Table 1).

Table 1: Nutrients removed in a crop of carrots yielding 125 tonnes/hectares

Nutrient	Amount of nutrient in raw carrots (g/tonne)	Amount of nutrient removed in 125 tonnes of carrots (kg)
P	350	44
K	3,200	400
Ca	330	41
Mg	120	15
Na	690	86

Soil management

Martin started to develop his ideas on soil health during his time as Farms Director at Bomfords. He saw adjacent fields with similarly high P and K indices producing very different yields of vegetables, but equally good subsequent yields of cereals. Standard nutrient indices alone did not seem to hold the answers for optimising fertiliser use in vegetable production. During one of his regular visits to the US he was introduced to the ideas of William A. Albrecht (1888–1974) one of the pioneering soil scientists in the USA[3].

William A. Albrecht and the Base Cation Saturation Ratio system

William Albrecht's ideas have helped Martin Evans to match fertiliser recommendations to particular crop needs. Making decisions on whether or not to add nutrients to the soil should ideally be based on results of soil tests.

Albrecht's early work at the University of Missouri was on nitrogen fixation by soybeans, during which he discovered the importance of calcium in maintaining nitrogen fixation by legumes. Calcium was important to both the microbial partner and the plant partner in this symbiotic relationship, particularly in soils that were acidic. By the 1950s, Albrecht had come to the conclusion that when lime is applied to acid soils it is the supply of Ca that is more important than the change in pH. This led to an interest in the role of Ca in animal and human nutrition, which he explored during his retirement, travelling widely in order to promote his ideas on balanced nutrition of plants and animals based on balanced ratios of exchangeable cations (Marshall, 1977).

The concept of ideal ratios of nutrients such as Ca and Mg in soil has been around for over 100 years but the evidence directly relating specific cation ratios to crop productivity is inconsistent (Kopittke and Menzies, 2007; Johnston, 2011)[4,5]. In the 1940s, scientists (Bear and Toth, 1948)[6] defined what they thought of as the ideal soil in terms of the balance of exchangeable Ca, Mg, K and H ions. This notion, which emphasised the importance of the ratio of cationic nutrients rather than the total amounts present, ended up being formalised as the Base Cation Saturation Ratio system and became associated with the name of Professor Albrecht.

However, research indicates that plants do well over a broad range of cation ratios, as long as there are sufficient supplies of K, Ca and Mg. These positively charged cations are held in soil on negatively charged sites on the surfaces of clay minerals and also organic matter. Soils containing more clay will have higher amounts of exchangeable cations and have the potential to hold greater reserves of nutrients such as Ca and Mg, but on light sandy soils, which have fewer cation exchange sites, more frequent, smaller additions of fertilisers will be required to maintain yield. Standard soil tests for cations in the UK measure the exchangeable K and Mg and express this as a Soil Index (England and Wales) or Soil Status (Scotland). There are some situations where the ratios of cations are important: for example The Fertiliser Manual (RB209) highlights the importance of K:Mg ratios in fruit, vines and hops (the recommendation is that the ratio of exchangeable K to exchangeable Mg should not be greater than 3:1 to avoid the risk of Mg deficiency).

Calcium should not be limiting if Ca-containing liming materials are used to correct soil acidity (Ca is progressively leached from the soil by rainfall and irrigation water over time). In certain parts of the country dolomitic limestone (which has a high Mg content) has been used resulting in high soil Mg levels.

There is no evidence that the balance between cations has any significant impact on soil biology such as earthworm activity or on weeds.

Martin acknowledges that the Albrecht approach has its limitations but, for him, it provides a framework into which he has incorporated his own knowledge to come up with bespoke fertiliser recommendations for each variety grown by the co-operative members in each particular field. He looks at what the soil analysis tells him about what's in the soil, considers specific crop requirements, and then comes up with a fertiliser recommendation using straights (no compound fertilisers). An example of this approach is given in Table 2.

Soil analysis results: pH, organic matter, P, K, Ca and Mg were by standard analysis (BS 3882:2015), available S was measured using potassium phosphate extraction, cation exchange capacity was estimated by summing the exchangeable K, Ca and Mg, expressed as cmolc/kg (formerly meg/100g), and extractable micronutrients were measured using EDTA extraction. All results are expressed as air-dry soil. Standard soil analysis results were converted to an estimated amount per hectare to a depth of 15cm using a standard soil bulk density value of 1.3g/cm^3.

Chantenay carrots being sorted

Table 2. Example soil analysis results of a sandy loam soil in Warwickshire used to grow vegetables and salads and Martin's approach to managing it for carrot production

Measurement	Unit	Result
pH	no unit	6.6
Cation exchange capacity (CEC)	cmolc/kg	13
Organic matter (loss-on-ignition)	%	2.0
Available P (measured)	mg P/kg	63
Available P (calculated from the measured value)	kg P_2O_5/ha	233
P index	no unit	4
Exchangeable K (measured)	mg K/kg	199
Exchangeable K (calculated from the measured value)	kg K_2O/ha	390
K index	no unit	2+
Exchangeable Ca (measured)	mg Ca/kg	1,804
Exchangeable Ca (calculated from the measured value)	kg Ca/ha	2,932
Exchangeable Ca (calculated)	% of CEC	71
Exchangeable Mg (measured)	mg Mg/kg	85
Exchangeable Mg (calculated from the measured value)	kg MgO/ha	229
Exchangeable Mg (calculated)	% CEC	5
Mg index	no unit	2
Ratio of exchangeable Ca to exchangeable Mg (calculated)	no unit	71:5
Available S (measured)	mg S/kg	29
Available S (calculated from measured value)	kg SO_3/ha	118
Extractable B	mg/kg	1.0
Extractable Cu	mg/kg	3.6
Extractable Zn	mg/kg	8.7
Extractable Mn	mg/kg	49
Extractable Fe	mg/kg	957
Extractable Na	mg/kg	62
Extractable Mo	mg/kg	0.1

The ratio of exchangeable Ca to exchangeable Mg for this soil was 71:5, Martin considers this satisfactory for carrot production.

The Mg value of 85mg/kg (Mg index 2) was converted into an equivalent value for one hectare using a standard bulk density value. The calculated value of 229kg MgO/ha was lower than the ideal value considered by Fresh Growers Ltd to be 404kg MgO/ha, so Mg fertiliser was recommended in the form of 100kg/ha kieserite.

Prior to purchase in 2003 Inkersall Grange Farm was an egg and poultry enterprise so the soil had high P status (Index 6) but very low K status (Index 0–1) with a very high Mg status (Index 7) from the use of dolomitic limestone. In order to balance the Ca and Mg in the soil Martin introduced the use of gypsum (calcium sulphate, in the form of flue gas desulphurisation gypsum) which has the added benefit of supplying S. In addition, the soluble Ca supplied from gypsum helps to control cavity spot (*Pythium violae*). Another benefit of gypsum as a source of Ca (unlike ground limestone, which has a liming value) is that where potatoes are also grown soil pH can be maintained at pH <5.2 thereby reducing the risk of common scab (*Streptomyces scabies*).

Traditionally, the management of the Sherwood sands involved the regular application of farmyard manure to increase organic matter, but with the demise of mixed farming other methods are needed. In other areas of the country green manures are used, but that isn't possible with strawed carrots due to the lack of time to establish the manure crop after late-harvested carrots. However, the use of around 100 large bales of straw per hectare leads to around 70 tonnes/ha of organic matter being added to the soil. This brings benefits in terms of improved infiltration of water and water-holding capacity, a reserve of slowly released macronutrients and micronutrients, and enhanced biological diversity and activity.

Conclusion

The addition of organic matter to the soil together with careful matching of fertilisers to the soil and crop variety provides the strategy for soil health management by Fresh Growers Ltd, which contributes to a profitable and sustainable business.

References

[1] www.sare.org/Learning-Center/Books/Building-Soils-for-Better-Crops-3rd-Edition

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[4] Kopittke, P. M., & Menzies, N. W. (2007) A review of the use of the basic cation saturation ratio and the "ideal" soil. *Soil Science Society of America Journal*, 71(2), 259–265.

[5] Johnston, J. (2011) Assessing soil fertility: the importance of soil analysis and its interpretation. Potash Development Association. http://www.pda.org.uk/technical-potash-notes/assessing-soil-fertility-the-importance-of-soil-analysis-and-its-interpretation

[6] Bear, F. E., & Toth, S. J. (1948) Influence of calcium on availability of other soil cations. Soil Science, 65(1), 6–74.

Further information

In addition, a range of resources to help you with soil management is available on the AHDB Great Soils website: horticulture.ahdb.org.uk/great-soils

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