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GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

VETCH

SECTION 5

NUTRITION AND FERTILISER

CROP REMOVAL RATES | SOIL TESTING | PLANT AND/OR TISSUE TESTING FOR NUTRITION LEVELS | NITROGEN | PHOSPHORUS | SULFUR | POTASSIUM | MICRONUTRIENTS

Nutrition and fertiliser

Key messages

- Vetch crops increase the amount of nitrogen in the soil, improving soil fertility for subsequent crops.
- The application of phosphorus (P), sulfur (S) and molybdenum (Mo) may be required to successfully establish vetch and promote vigorous growth.
- Phosphorus, potassium (K) and S requirements in vetch are similar to field peas.
- Additional nutrients are rarely required in vetch.

Fertiliser applications are the largest single variable expense for grain growers producing a crop but nutrition (e.g. nitrogen, phosphorus, potassium, sulfur and micronutrients) is a major determinant of profit. [1] Inefficient or incorrect use of fertiliser can be a substantial, but somewhat hidden, cost in the cropping operation.

However, the application of phosphorus, sulfur and molybdenum may be required to successfully establish vetch and promote vigorous growth. Soil tests are a guide to phosphorus requirements and will also give an indication of sulfur deficiency, as soils high in phosphorus will often respond to sulfur. Soils with a low pH are often deficient in molybdenum. [2]

Using good data to better understand your existing soil nutrient status before deciding on a fertiliser strategy can optimise expenditure on fertiliser and crop yields. Be sure to consider the following:

- Fertilisers are a major cost of growing a crop.
- Ensure your adviser has, or is working towards, the Fertcare Accredited Adviser standard.
- Be clear on fertiliser product choice and rate and timing of application.
- Soil testing is the only quantitative nutrient information that can be used to predict yield response to nutrients.
- Soil samples should be taken before sowing so that results and recommendations are available in time to order the right fertiliser product(s).
- Develop a strategy for deep sampling of nitrogen (N) and sulfur (S). For growers with a capacity to apply N either pre-sowing or at sowing, collect samples pre-crop (during fallow) with enough time to prepare N and S budgets and secure required fertiliser requirements.
- Choose a laboratory that has the Australasian Soil and Plant Analysis Council (ASPAC) certification for the tests they offer. National Association of Testing Authorities (NATA) accreditation is also desirable.
- Regular planned sampling of paddocks allows monitoring of fertility trends over time.

Crop production is becoming increasingly precise, but when it comes to fertiliser application, some growers often make decisions about type, time and rate based on incomplete information or a 'best guess'. Robust fertiliser decisions can be made by checking the 'four Rs' of plant nutrition, an approach developed by the International Plant Nutrition Institute that has become the cornerstone of nutrient stewardship in many countries. 4R Plant Nutrition is built around the right fertiliser source, applied at the right rate, at the right time, and in the right place. [3]

MORE INFORMATION

Better fertiliser decisions for crop nutrition

1 GRDC. More profit from crop nutrition. https://grdc.com.au/Research-and-Development/Major-Initiatives/More-Profit-from-Crop-Nutrition

2 NSW DPI. Namoi woolly pod vetch. http://www.dpi.nsw.gov.au/agriculture/pastures-and-rangelands/species-varieties/namoi-woolly-pod-vetch

3 GRDC (2013). Better fertiliser decisions for crop nutrition – Fact Sheet. https://grdc.com.au/resources-and-publications/all-publications/factsheets/2013/11/grdc-fs-bfdcn

5.1 Crop removal rates

When grain is harvested from the paddock, nutrients (phosphorus, nitrogen, zinc, etc.) are removed in the grain. If, over time, more nutrients are removed than are replaced (via fertiliser) then the fertility of the paddock will fall.

Fertiliser inputs must be matched to expected yields and soil type. The higher the expected yield, the higher the fertiliser input, particularly for the major nutrients, phosphorus, potassium and sulfur.

Vetch will remove some nutrients from the soil (Table 1). However, it can also increase soil nutrients, enough so that its contribution to paddock nutrition is beneficial (Table 2).

A balance sheet approach to fertiliser inputs is a good starting point in considering the amount of fertiliser to apply to your pulse crop. Other factors such as soil type, paddock history, soil test and tissue analysis results, as well as your own experience all affect the choice of fertiliser to be used. Table 1 shows the amount of nutrients removed in each tonne of seed. Nutrient budgeting is a simple way to calculate the balance between nutrient removal (via grain) and nutrient input (via fertiliser). [4]

Table 1: *Nutrient removal (kg/tonne-1) for vetch.* [5]

	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)
Vetch	26	7	22

Table 2: *Examples of net contributions of fixed N where the total amounts of N2 fixed by different legumes grown for forage, brown manure (BM) or grain have been compared to estimates of the amounts of N removed in either hay, wool, or grain, or lost by volatilization from urine patches from grazed pastures (Peoples et al. 2012 and unpublished data).*

Crop use	Total amounts of N2 fixed* (kg N/ha)	N Removed or lost (kg N/ha)	Net input of fixed N (kg N/ha)
Brown manure[A]	130	0	+130
Hay[A]	130	89 in hay	+41
Hay[B]	141	82 in hay	+59
Forage[C]	83	8 in wool + 23 lost	+52

*The amounts of shoot N fixed were adjusted to include an estimate of N contributed by the nodulated roots as described by Unkovich et al. (2010).

A = Hopetoun Vic, B = Yarrawonga Vic, C = Wagga Wagga NSW.

Source: GRDC

5.2 Soil testing

Key points:

- A range of soil test values used to determine if a nutrient is deficient or adequate is termed a critical range.
- Fertiliser decisions are in part based on where the soil test falls in relation to the critical range.
- Critical ranges for combinations of nutrient, crop and soil types are being established.

MORE INFORMATION

Legume effects on soil N dynamics - comparisons of crop response to legume and fertiliser N

4 J Walker, K Hertel, P Parker, J Edwards (2011) Lupin growth and development. NSW DPI. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/516183/Procrop-lupin-growth-and-development.pdf

5 Murrell, T.S. 2005. Average nutrient removal rates for crops in the Northcentral Region. Available at http://www.ipni.net/northcentral/nutrientremoval (accessed 4 Sep. 2007, verified 18 June 2008).

- Critical ranges are being established for topsoils (0 to 10 cm) and subsoils (10 to 30 cm in some cases, or to the depth of the crop root zone in others), depending on the nutrient.
- Deeper sampling is considered essential for understanding soil nutritional status and fertiliser requirement in Northern cropping systems.

The importance of subsoil layers for nutrients such as P and K is not yet reflected in the limited soil test-crop response data available. Researchers are currently using rough rules of thumb to help interpret P and K soil tests in terms of likely fertiliser responsiveness on Northern region Vertosols.

Tests for N and S provide information on nutrient supply, while P and K tests indicate nutrient sufficiency. If critical nutrient ranges for soil and crop species are available, the soil test information can be used to support decisions about fertiliser rate, timing and placement.

Appropriate soil tests for measuring soil extractable or plant available nutrients in the Northern cropping region are:

- bicarbonate extractable P (Colwell-P), to assess easily available soil P;
- acid extractable P (BSES-P), to assess slower release soil P reserves and the build-up of fertiliser residues (not required annually);
- exchangeable K; KCl-40 extractable S or MCP-S; and
- 2M KCl extractable mineral N, to provide measurement of nitrate-N and ammonium-N.

Other measurements that aid the interpretation of soil nutrient tests include:

- soil carbon/organic matter content;
- phosphorus buffering index (PBI);
- soil salinity measured as electrical conductivity; and
- chloride and other exchangeable cations including aluminium. [6]

5.2.1 Collecting soil samples for nutrient testing

The greatest source of error in any soil testing service comes from collection of the soil. Soil sampling does not have a single, definable strategy. The strategy needs to be closely aligned to the reasons for testing. The most stringent sampling requirement occurs when the reason for sampling is predicting crop response to added fertiliser.

How many cores should be taken to represent an area? The general rule is that the more variable crop growth is in the field the more sub-samples are required to produce a meaningful paddock average. If the objective of soil sampling is monitoring trends in paddock fertility or problem solving, the number of cores representing an area can be substantially reduced.

To ensure that a sample is representative:

- check that the soil type and plant growth from where the sample is collected are typical of the whole area to be treated;
- avoid areas such as stock camps, old fence lines and headlands where nutrient concentrations are often significantly higher than the rest of the paddock;
- ensure that each sub-sample is taken to the full sampling depth;
- do not sample in very wet conditions;
- avoid shortcuts in sampling such as taking only one or two cores or a handful or a spadeful of soil, which will give misleading results; and
- avoid contaminating the sample, the sampling equipment and the sample storage bag with fertilisers, other sources of nutrients or organic materials such as oils used to lubricate deep probes. [7]

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6 GRDC (2014) Crop Nutrition Factsheet: Soil testing for crop nutrition – Northern region. www.grdc.com.au/GRDC-FS-SoilTestingN

7 GRDC (2014) Crop Nutrition Factsheet: Soil testing for crop nutrition – Northern region. www.grdc.com.au/GRDC-FS-SoilTestingN

5.2.2 Sampling depth

The most common soil sampling depth for nutrient analysis is 0 to 10 centimetres for broadacre crops. This layer was chosen because nutrients, especially P, and plant roots are concentrated within this layer. To obtain more comprehensive soil data, including nutrient data, sampling below 10 cm should be considered for some nutrients.

Suggested sampling increments for key nutrients and salinity for northern cropping regions are:

- 0 to 10 cm (N, P, K and S);
- 10 to 30 cm (N, P, K and S);
- 30 to 60 cm (N and S, salinity, sodicity);
- 60 to 90 cm (N, S, salinity, sodicity); and
- 90 to 120 cm (optional) (N, salinity, sodicity).

Deeper sampling does raise issues of logistics and cost, which should be discussed with soil test providers. However, the additional information provides a clearer insight into nutrient status in the crop root zone. [8]

5.2.3 Critical values and ranges

A soil test critical value is the soil test value required to achieve 90% of maximum potential crop yield, while the critical range reflects the degree of uncertainty around the critical value. The narrower the range, the more reliable the prediction of a fertiliser response from the available data.

The critical range determines if a nutrient is likely to be deficient for crops based on whether the soil test value is greater than or less than the upper or lower critical range value (Table 3).

Table 3: *Adequate levels for various soil test results.*

Phosphorus			
	Colwell	Olsen	
Sand	20–30	10–15	
Clay	25–35	12–17	
Loam	35–45	17–23	
Potassium			
	Bicarb	Skene	Exchangeable K
Sand	50	50	Not applicable
Other soils	100	100	0.25 me/100 g
Sandy loam (field peas)	70–80	-	-
Sulfur			
	KCl		
Low	5 ppm		
Adequate	8 ppm		

Source: Grain legume handbook)

If the soil test value is less than the lower limit, the site is likely to respond to an application of the nutrient resulting in higher crop yields. For values within the range there is less certainty about whether a response will occur. Growers have to exercise judgement about the cost benefit of adding fertiliser in the coming season.

8 GRDC (2014) Crop Nutrition Factsheet: Soil testing for crop nutrition – Northern region. www.grdc.com.au/GRDC-FS-SoilTestingN

MORE INFORMATION

Soil testing for crop nutrition - Northern region Factsheet

Monitoring of soil phosphorus, potassium and sulfur to get the most out of your fertiliser dollar

If the soil test is above the critical range, fertiliser may be applied to maintain existing soil levels or a controlled rundown of nutrient reserves can be conducted until fertiliser applications become viable. Soil bulk density changes with texture and gravel content. As a rule, the bulk density of vertosols can range from 1.1 to 1.3 grams/cm3. [9]

The SoilMapp app provides details of soil bulk densities across Australia.

5.3 Plant and/or tissue testing for nutrition levels

Of the many factors affecting crop quality and yield, soil fertility is one of the most important. Producers can manage fertility by measuring the plant's nutritional status. Nutrient status is an unseen factor in plant growth, except when imbalances become so severe that symptoms appear on the plant.

Plant tissue testing is most useful for monitoring crop health, because by the time noticeable symptoms appear in a crop the yield potential can be markedly reduced. Several companies perform plant tissue analysis and derive accurate analytical concentrations however it can be hard to interpret the results and determine a course of action. As with soil tests, different plants have different critical concentrations for a nutrient. In some cases, varieties can vary in their critical concentrations (Table 4). Care should be taken to use plant tissue tests for the purpose for which they have been developed. Most tests diagnose only the nutrient status of the plants at the time they are sampled and cannot reliably indicate the effect of a particular deficiency on grain yield. [10]

Table 4: *Critical nutrient levels for lentil at flowering. These values can also be used in vetch. Any nutrient level below the critical range will be deficient; any level above will be adequate.*

Nutrients	Plant part	Critical range
Phosphorus (%)	Youngest mature leaf	0.3
Potassium (%)	Youngest mature leaf	1.8
Sulfur (%)	Youngest mature leaf	0.2
Boron (mg/kg)	Youngest mature leaf	20
Copper (mg/kg)	Youngest mature leaf	3.0
Zinc (mg/kg)	Youngest mature leaf	20

Source: Grain legume handbook

5.3.1 What plant-tissue analysis shows

Plant tissue analysis shows the nutrient status of plants at the time of sampling. This, in turn, shows whether soil nutrient supplies are adequate. In addition, plant tissue analysis will detect unseen deficiencies and may confirm visual symptoms of deficiencies. Toxic levels also may be detected.

Although usually used as a diagnostic tool for correction of future nutrient problems, plant tissue analysis from young plants will allow a corrective fertiliser application in the present season.

A plant analysis is of little value if the plants come from fields that are infested with weeds, insects and disease organisms, or if the plants are moisture-stressed or have some mechanical injury.

The most important use of plant analysis is as a monitoring tool for determining the adequacy of current fertiliser practices. Sampling of a crop periodically during the season or sampling once each year provides a record of nutrient content that can

9 GRDC (2014) Crop Nutrition Factsheet: Soil testing for crop nutrition – Northern region. www.grdc.com.au/GRDC-FS-SoilTestingN

10 Day, T., Day, H., Hawthorne, W., Mayfield, A., McMurray, L., Rethus, G., & Turner, C. (2006). Grain legume handbook. *GRDC: Canberra, ACT*. https://grdc.com.au/__data/assets/pdf_file/0026/209618/chapter-4-nutrition.pdf.pdf

be used through the growing season or from year to year. With soil-test information and a plant-analysis report, a producer can tailor fertiliser practices to specific soil–plant needs.

Sampling tips:

- Sample the correct plant part at the specified time or growth stage; i.e whole plant tops.
- Use clean plastic disposable gloves to sample to avoid contamination.
- Sample tissue (e.g. entire leaves) from vigorously growing plants unless otherwise specified in the sampling strategy.
- Take a sufficiently large sample (adhere to guidelines for each species provided).
- When troubleshooting, take separate samples from areas of good and poor growth.
- Where necessary, wash samples while fresh to remove dust and foliar sprays.
- After collection, keep samples cool.
- Refrigerate or dry if samples cannot be dispatched to the laboratory immediately for arrival before the weekend.
- Generally, sample in the morning while plants are actively transpiring.

Practices to avoid:

- sampling spoiled, damaged, dead or dying plant tissue
- sampling plants stressed by environmental conditions
- sampling plants affected by disease, insects or other organisms
- sampling soon after applying fertiliser to the soil or foliage
- contaminating samples with dust, fertilisers and chemical sprays or perspiration and sunscreen from hands
- sampling from atypical areas of the paddock, e.g. poorly drained areas
- sampling plants of different vigour, size and age
- combining samples from different cultivars (varieties) to make one sample
- placing samples into plastic bags, which will cause the sample to sweat and hasten its decomposition
- sampling in the heat of the day; i.e. when plants are moisture-stressed
- mixing leaves of different ages. [11]

5.4 Nitrogen

Key points:

- Nitrate ($NO3–$) is the highly mobile form of inorganic N in both the soil and the plant.
- To achieve maximum yields, common vetch requires 15–20 kg/ha nitrogen (N) [12] however as a legume it can produce it's own N needs if inoculated correctly.
- Woolly pod vetch has much slower initial growth than common vetch, so requires 25–50 kg/ha of nitrogen. [13]
- Sandy soils in high-rainfall areas are most susceptible to nitrate loss through leaching.
- Soil testing and N models will help to determine seasonal N requirements. [14]

11 SoilMate (2010) Guidelines for sampling plant tissue for annual cereal, oilseed and grain legume crops. Back Paddock Co., http://www.backpaddock.com.au/assets/Product-Information/Back-Paddock-Sampling-Plant-Tissue-Broadacre-V2.pdf?phpMyAdmin=c59206580c88b2776783fdb796fb36f3

12 R Matic (2015) GRDC Final Reports: DAS00013 – Vetch variety improvement for Australian field crop farming systems. https://grdc.com.au/research/reports/report?id=268

13 R Matic, S Nagel, G Kirby (2008) Woolly pod Vetch. Pastures Australia. http://keys.lucidcentral.org/keys/v3/pastures/Html/Woolly_pod_vetch.htm

14 D Herridge. (2013). Managing legume and fertiliser N for Northern grains cropping. http://www.ini2016.com/pdf-posters/Herridge.pdf

Symbiotic nitrogen fixation is the mutually beneficial relationship between the pulse (or any legume) host and Rhizobium bacteria. These bacteria colonise roots during seed germination then multiply rapidly to form root nodules within 4–10 weeks. They are dependent on the host plant for water, nutrients and energy, but in return supply the plant with nitrogen (ammonium, NH4+) for direct uptake. This 'fixed' nitrogen is derived from the enormous N_2 gas resources of the earth's atmosphere (around 80%) – the same source used by the Haber and Bosch process to manufacture compound N fertiliser.

Pulses (and pasture legumes) play an essential role in the nitrogen supply chain of field crops, especially since nitrogen is one of the most limited plant nutrients worldwide. By fixing their own nitrogen during growth, pulses become independent of soil mineral nitrogen and thereby conserve or spare it. When combined, these two sources (fixed and spared N) produce large amounts of residual nitrogen for following crops, boosting both their grain yield and grain protein. Compared to manufactured nitrogen fertiliser, biologically fixed nitrogen is:

- less volatile;
- more stable;
- 'slow release';
- environmentally sustainable;
- less energy demanding to manufacture;
- cost effective;
- not subject to supply restrictions or price fluctuations; and
- not subject to the challenges of application timing and utilisation efficiency. [15]

5.4.1 Nitrogen fixation

Legumes (crop and pasture combined) are estimated to fix almost 3 million tonnes of nitrogen each year in Australia, which is worth around $4 billion. This amount of fixed N makes a substantial (around 50%) contribution to the estimated 6 million tonnes of nitrogen that are required annually for grain and animal production on Australian farms.

Vetches are an economically viable option in rotation with cereal crops. The amount of nitrogen returned to the soil is between 50 and 63 kg per ha after grain production, and between 64 and 97.9 kg per ha after cutting for hay (see Table 3). Cereal crops in the paddocks where vetch was grown in the previous one to two years was significantly superior to crops which followed cereal or fallow. The high nutrient value of vetch hay and grain as well as the additional nitrogen added to the soil by growing vetch is the main reason for including vetch in crop rotation with the cereal crops.

The NSW Department of Agriculture reported that trials demonstrated the benefits of using vetch in crop rotations. Soil nitrogen is improved, weeds are decreased, and direct drilling is easier. Savings on fertiliser and herbicides for the following grain crop are two major incentives for using vetch in rotation with cereals. Wheat after vetch hay increased yield and protein by 25% and 1.8% respectively, compared with cereal on cereal. Table 5 presents the results of nitrogen fixation after vetch grain and hay crops from three sites by three years. [16]

Vetch has been found to increase nitrogen by 50–60 kg/ha which meant a 30–50% input reduction of mineral fertilisers to reach the same yields in cereals. [17]

15 E Armstrong, D Holding. (2015). Pulses:putting life into the farming system. NSW DPI. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/558958/Pulses-putting-life-into-the-farming-system.pdf

16 R Matic (2007) Improved vetch varieties for fodder production. Rural Industries Research and Development Corporation.

17 R Matic, S McColl (2013) Which vetch is my farming system? Online Farm trials. http://www.farmtrials.com.au/trial/16634

Table 5: *Nitrogen level before and after a vetch crop.*

Site	Soil texture	PH level (H_2O)*	Plant for	2003/04		2004/05		2005/06		Mean (kg/ha)**		Nitrogen Increase (kg/ha)
				A	B	A	B	A	B	A	B	
Blyth	Sandy loam	8.4	Grain	19	36	21	34	18	31	81.1	141.4	60.3
			Hay		42		40		43		175.1	94.0
Lameroo	Non-wetting sand	8.6	Grain	16	27	18	31	17	29	71.4	121.8	50.4
			Hay		30		34		33		135.7	64.3
Kingsford	Heavy loamy clay	7.4	Grain	25	38	27	42	22	39	103.7	166.6	62.9
			Hay		44		49		51		201.6	97.9

A = soil is taken before seeding vetch crop. B = soil taken from the same places just before seeding following crops. Nitrogen was calculated using q formula from SARDI, Soil and Plant Analysis to get total of nitrogen for 60 cm/ha: [(Nitrate Nitrogen + Ammonium Nitrogen) x 1.4] x 3. For example: Jamestown before vetch 29+6=35 x 1.4=49 x 3=147 kg; after grain vetch: 37+11=48 x 1.4=67.2 x 3=201.6; differences 201.6 – 147= 54.6 kg of Nitrogen increased.

Source: RIRDC

For more information on assessing nitrogen fixation, see Section 3: Planting, Assessing nodulation section.

5.4.2 Managing nitrogen

Topdressing pulses with nitrogen is not as effective as inoculation. Trials have shown that nitrogen topdressing of pulses results in little or no net growth or yield benefit. Inoculating pulses is most effective if the soil is moist and if residual soil nitrogen and soil rhizobia populations are low. [18]

High levels of nitrogen in the soil will inhibit nodulation and nitrogen fixation. Spreading nitrogen fertiliser may therefore reduce the amount of nitrogen fixed by the plant. [19]

'Starter' fertilisers such as MAP and DAP can be used on pulses. Some growers worry that using nitrogen on their pulse crop will affect nodulation. This is not the case with the low rates of nitrogen as supplied by MAP or DAP. A benefit from using the starter nitrogen is that early plant vigour is often enhanced and on low fertility soils, yield increases can be made. [20]

Soil testing for paddock nutrition prior to sowing is the best way to know whether crops may be at risk of nitrogen deficiency. For more information on soil testing, see Section 5.2 Soil testing, above.

MORE INFORMATION

The best return on investment: inoculating or topdressing pulses?

5.5 Phosphorus

Key points:

- Phosphorus (P) reserves have been run down over several decades of cropping.
- Testing subsoil (10 to 30 cm) P levels using both Colwell-P and BSES-P soil tests is important in developing a fertiliser strategy.
- Application rates on responsive soils should be similar to cereals to achieve optimum yields and maintain soil P levels.
- Applying P at depth (15 to 20 cm deep on 50 cm bands) can improve yields over a number of cropping seasons (if other nutrients are not limiting).

18 D Ferrier, M Peoples, L Watson (2013) The best return on investment: inoculating or topdressing pulses? Birchip cropping group. Online Farm Trials. http://www.farmtrials.com.au/trial/16655

19 P White, M Harries, M Seymour, P Burgess (2005) Producing pulses in the northern agricultural region. Department of Agriculture and Food, Western Australia, Perth. Bulletin 4656.

20 W Hawthorne (2007) Lupins in South Australia and Victoria. Pulse Australia. http://www.pulseaus.com.au/storage/app/media/crops/2007_Lupins-SA-Vic.pdf

- Phosphorus is very important to be added when sowing Woolly pod vetch, and generally provides a good start and growth. [21]

Reserves of mineral nutrients such as phosphorus (P) have been run down over several decades of cropping with negative P budgets (removing more P than is put back in by fertilisers or crop residues). This trend has accelerated as direct drill cropping has improved yields and crop frequency, removing even more P from the soil. Consequently, limited P is now constraining yields in parts of the northern grains region, particularly in the vertosols (black and grey cracking clays).

P is largely immobile in the soil, particularly in clay soils, so P applied to the topsoil (0 to 10 cm) layer will not penetrate into the subsoil. P is being removed from the deeper subsoil layers (10 to 30 cm) to meet crop demand, especially during dry periods when crop roots cannot access dry topsoil layers and the plant relies almost exclusively on stored subsoil water.

Crops must be able to access P (and potassium (K), another essential but immobile nutrient) from the subsoil. This supply is especially important in the post-seedling stage. P (and K) levels need to be adequate down to 30 to 40 cm to drought-proof cropping systems in the Northern region, which have a greater reliance on stored soil moisture rather than in-crop rainfall. [22]

5.5.1 Managing phosphorus

Most soils where pulses are grown are deficient in available P. Drill phosphate at seeding. Banding of phosphate below the seed can increase yields on some soils, particularly those with high phosphorous retention.

Phosphorus is very important to be added when sowing Woolly pod vetch, and generally provides a good start and growth. [23]

Deep placement of phosphorus and potassium fertilisers is increasingly required in Northern region cropping programs to address low subsoil reserves of these nutrients. Apply P at depths of 15 to 20 cm and in bands 50 cm apart, or closer if possible. If the bands are any wider than 50 cm there will not be enough plant roots to reach the high P zones and meet crop demand. Applying P in bands 25 to 50 cm apart produces stronger yield responses than bands 100 cm apart. This has been shown consistently across soil types and crops.

Increasing the volume of enriched soil is more effective than just increasing P rates. The key is placing bands in different positions each cropping season. The strategy of lower rates applied more frequently will eventually enrich enough of the soil volume to overcome P limitations, due to the excellent residual value of deep-placed P.

It is important to consider soil pH (e.g. acidic soils in the Northern region) when applying P. An interaction between soil pH and phosphorus fertiliser is most likely when: there are no other major nutritional constraints to crop growth; and a large change (>0.5 pH units) has been made to subsurface pH by lime application. When these two criteria have been met, an interaction between soil pH and phosphorus fertiliser can lead to greater availability of soil phosphorus. [24]

Soil testing

It is important to assess the P status of the subsoil periodically. Test the 10 to 30 cm layer using BSES-P as well as Colwell-P soil tests. Take the opportunity to test for K at the same time. Such testing will build a more complete picture of a soil's fertility and the values from the deeper layers can be used to refine your fertiliser strategy. P and K fertility in the subsoil changes more slowly than in the top 10 cm, where starter

21 R Matic, S Nagel, G Kirby (2008) Woolly pod Vetch. Pastures Australia. http://keys.lucidcentral.org/keys/v3/pastures/Html/Woolly_pod_vetch.htm

22 GRDC. (2012). Crop Nutrition: Phosphorus management Factsheet. https://grdc.com.au/resources-and-publications/all-publications/factsheets/2012/11/grdc-fs-phosphorusmanagements

23 R Matic, S Nagel, G Kirby (2008) Woolly pod Vetch. Pastures Australia. http://keys.lucidcentral.org/keys/v3/pastures/Html/Woolly_pod_vetch.htm

24 C Scanlan. (2016). GRDC Update papers: The interaction between soil pH and phosphorus fertiliser is dynamic. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/The-interaction-between-soil-pH-and-phosphorus-fertilizer-is-dynamic

fertiliser is applied and where nutrients are deposited via crop residues. Subsoil tests are an extra expense; however, they generally only need to be done once every four to six years. Analysing grain for nutrient content provides additional information when monitoring soil fertility by accounting for the amount of nutrient removed with each harvest.

Colwell-P

The Colwell-P test uses a bicarbonate (alkaline) extraction process to assess the level of readily available soil P. It was the original test for P response in wheat in northern New South Wales. It is used with the phosphorus buffering index (PBI) to indicate the sufficiency and accessibility of P in the soil.

BSES-P

The BSES-P test was developed for the sugar industry but is now an important tool in the grains industry. BSES-P uses a dilute acid extraction to assess the size of slower release soil P reserves. These reserves do not provide enough P within a season to meet yield requirements, but they partially replenish plant-available P. Because the P measured by BSES-P releases only slowly, changes in the test value of subsoil layers may take years. Therefore, this test needs to be done only every four to six years, and is most important in the subsoil layers.

MORE INFORMATION

Phosphorus management – Northern region

Sulfur in Northern Vertosols

PBI

The 'buffering capacity' of a soil refers to its ability to maintain P concentration in solution as the plant roots absorb the P. The phosphorus buffering index (PBI) indicates the availability of soil P. The higher the value, the more difficult it is for a plant to access P from the soil solution. Generally, a PBI value of less than 300 (a range that would include most northern vertosols) indicates that soil P, as assessed by Colwell-P, is readily available. Colwell-P and PBI values are needed in both 0 to 10 cm and 10 to 30 cm soil tests. BSES-P is optional in the 0 to 10 cm layer but essential in the 10 to 30 cm layer. [25]

5.6 Sulfur

Sulfur is an essential plant nutrient required by all crops for optimum production. After N, P and K, Sulfur (S) as a secondary nutrient element appears to be most important, as S concentration in legumes is almost double that of cereals. Plants take up and use S in the sulfate (SO4-S) form, which like nitrate (NO3-N), is very mobile in the soil and is prone to leaching in wet soil conditions, particularly in sandy soils. Sulfur must be present for good nodule development on pulse crop roots.

The key processes in the sulfur cycle in the Northern cropping soils are the reactions between soil solution sulphate and soil organic S, solution sulphate and adsorbed sulphate and loss of S by leaching. From a crop's point of view, the majority of the S it acquires early in the life cycle is most likely derived from immediate release of S from crop residues that remains in the surface soil, and mineralisation of S from organic matter over the fallow period. The move to stubble retention in no till systems has led to an increase in the amount of S mineralised.

5.6.1 Managing sulfur

Historically, S has been adequate for crop growth because S was supplied in superphosphate. It is recommended that growers use fertilisers blended with a sulfur component if soil tests show a deficiency in this nutrient

., vetch responds well to added sulfur in fertilisers when soils are low to moderate in fertility. Application practices are similar to those for field peas; i.e. top-dressing S sources such as gypsum will correct soil deficiency.

25 GRDC. (2012). Crop Nutrition: Phosphorus management Factsheet. https://grdc.com.au/resources-and-publications/all-publications/factsheets/2012/11/grdc-fs-phosphorusmanagements

Sulfur is a component of organic matter, and sulphate is adsorbed on to clay, iron and aluminium oxides. Sulfur leaches in high rainfall on sandy acidic soils. Cold, wet conditions slow S mineralisation and plant uptake. Root restricting constraints such as traffic pans, disease or soil acidity will worsen S deficiency. In areas close to the sea or industrial pollution, there can be significant input of S from the atmosphere.

S soil levels are easily managed due to the high availability of S products when applied in soil systems as most soil types have a limited ability to form unavailable S complexes. Some management practices are inadvertently supplying significant amounts of S through the application of gypsum to manage sodicity, application of ammonium sulphate as a source of N and even a standard application rate of 100 kg/ha of MAP/DAP will supply approximately 1.5 kg S/ha. [26]

5.7 Potassium

Potassium (K) is required by all plant and animal life. Adequate potassium results in superior quality of the whole plant due to the improved efficiency of photosynthesis, increased resistance to some diseases and greater Water Use Efficiency. Potassium helps maintain a normal balance between carbohydrates and proteins.

K is used in many plant processes (e.g. photosynthesis, sugar transport and enzyme activation). It is particularly important in regulating leaf stomata. Plants that have adequate levels of potassium are better able to tolerate drought and waterlogging than plants deficient in potassium.

5.7.1 Managing potassium

Potassium deficiencies are most common on well drained, coarse-textured soils e.g. sandy soils and deep grey sandy duplex soils. High rates of hay or grain removal and hay production can result in K deficiency.

K deficiencies can be corrected with potassium (potash) fertiliser (K20).

The right time and right place to give the best K response is at seeding rather than topdressing. Muriate of potash is a salt and can cause damage to sensitive seeds when place together in the sowing row. The amount of damage will depend on row width, seeding points, soil texture and moisture. Banding below the seed at planting has been shown to give much better results than topdressing or pre-spreading.

The right rate will need to be higher than replacement because K is relatively immobile. If the K buffering capacity is high, and the non-exchangeable K pool is strongly depleted, the competition between the soil and plant can mean minimum rates of 50 to 100 kg K/ha are needed to see responses. If using test-strips run out at seeding, use a high rate to see if K supply is adequate.

Another consequence of the low mobility, especially in alkaline soils, is that high rates can be used to cover two or three or even more crops. It is better to use higher rates less frequently than lower rates every year.

The right source is usually MOP, mainly because it is significantly cheaper than sulfate of potash, potassium nitrate or potassium magnesium sulfate (langbenite). All commercially available K fertilisers are imported, although there is one current development to exploit greensand deposits of glauconite in WA. Some growers are concerned about adding extra chloride, but the amounts added are of little agronomic or environmental significance in adding to salt loads. [27]

MORE INFORMATION

Do we need to revisit potassium?

26 S Mason (2016) GRDC Update Papers: Monitoring of soil phosphorus, potassium and sulfur in the southern region – how to get the most out of your fertiliser dollar. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Monitoring-of-soil-phosphorus-potassium-and-sulphur

27 R Norton (2014) GRDC Update Papers: Do we need to revisit potassium? https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2014/02/do-we-need-to-revisit-potassium

5.8 Micronutrients

Key points:

- Micronutrient deficiencies are best determined by looking at the overall situation: region, soil type, season, crop and past fertiliser management.
- Soil type is useful in deducing the risk of micronutrient deficiencies.
- When tissue testing, sample the appropriate tissues at the right time. Plant nutrient status varies according to the plant's age, variety and weather conditions.
- The difference between deficient and adequate (or toxic) levels of some micronutrients can be very small.
- When applying fertiliser to treat a suspected deficiency, leave a strip untreated. Either a visual response or tissue testing can allow you to confirm whether the micronutrient was limiting.
- Adequate trace element nutrition is just as important for vigorous and profitable crops and pastures as adequate major element (such as nitrogen or phosphorus) nutrition.

Micronutrients are essential for healthy plant growth. The key challenge is accurate identification of deficiencies and knowing your risk level. Unlike the macronutrients such as nitrogen (N), phosphorus (P), sulfur (S) and potassium (K) micronutrients are only needed in small quantities. Even so, they can limit production. The most likely limiting micronutrients to Australian cropping systems are boron (B), copper (Cu), manganese (Mn), molybdenum (Mo) and zinc (Zn). Iron (Fe) can be important, especially on strongly alkaline soils.

Traditionally, cultivation distributed these micronutrients through the topsoil but the introduction of no-till and one-pass seeding equipment has led to more limited physical distribution.

Many soils in Australia are deficient in trace elements in their native condition. Despite many decades of research into trace element management, crops can still be found to be deficient in one or more of these trace elements. Just because trace element deficiencies have not been prevalent in recent years, does not mean they will not return.

There is increasing concern in some districts that trace element deficiencies may be the next nutritional barrier to improving productivity. This is because current cropping systems are exporting more nutrients to the grain terminal than ever before.

Micronutrient deficiencies can be tricky to diagnose and treat. By knowing your soil type, considering crop requirements and the season, and supporting this knowledge with diagnostic tools and strategies, effective management is possible. [28]

Of the micronutrient listed above, Zn deficiency is probably the most important because it occurs over the widest area, particularly in south eastern Australia.

5.8.1 Micronutrients for vetch growth

There are few micronutrient recommendations available specifically for vetch cropping. Because vetch is often grown in rotation with cereals, the nutritional needs of cereals often provide adequate micronutrients for vetch. However, in molybdenum deficient soils, vetch can benefit from application. This is because Mo is required for effective nodulation and can also help to successfully establish vetch and promote vigorous growth.

In most soils, molybdenum present in an unavailable form will be released by applying lime or dolomite. The effect of liming on molybdenum availability is slow and it may take several months to correct the deficiency. The amounts of lime or dolomite needed may range from 2 to 8 tonnes per hectare, depending on initial pH of the

28 GRDC. (2013). Crop nutrition Fact Sheet. Micronutrients. www.grdc.com.au/GRDC-FS-CropNutrition-Micronutrients

soil and whether it is sandy or heavy textured. Unless lime is likely to be beneficial for other reasons, it is quicker and cheaper to apply a molybdenum compound to the soil or to the crop.

Where one of the molybdenum compounds is used, the quantities recommended vary from 75 g to 1 kg/ ha depending on the crop and the molybdenum material.

Molybdenum can be applied in the following ways:

- mixed with fertiliser; or
- in solution, to;
- seedlings in the seedbed before transplanting;
- the leaves of plants in the field; or
- the soil at the base of plants in the field. [29]

MORE INFORMATION

Crop nutrition - micronutrients

29 R Weir (2004) AGFacts: Molybdenum deficiency in plants. NSW DPI. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/166399/molybdenum.pdf