MORE INFORMATION

GRDC Tips and Tactics: Sunflower nutrition

Nutrition and fertiliser

Sunflowers require adequate nutrition yet have a significantly lower requirement for several of the major nutrients when compared to other crops. [1] The relationship between nitrogen (N), starting soil water and target yield is crucial in sunflower crops (Figure 1). [2]

Figure 1: *Nitrogen nutrition is important for healthy sunflower crops.*

Key points

- Sunflower are moderately tolerant to a range of soil constraints and prefer a friable soil surface for best crop establishment.
- Use soil tests to target nutrient management for both optimal oil and maximum grain yields.
- Nitrogen (N) is the nutrient taken up in the greatest quantities by sunflower and is essential for many plant processes.
- Excessive levels of N can reduce oil content while insufficient N will limit crop yields.
- Phosphorus (P) is the second most frequently limiting nutrient for sunflower crops.
- If arbuscular mycorrhizal (AM) fungi levels are low, supplying adequate P and zinc is very important.
- Germinating sunflower seed is very sensitive to fertiliser placed in the seed trench; growers should aim to limit the amount of fertiliser placed in close contact with the seed and use side banding to limit contact. [3]

1 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

2 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

3 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

Table 1 contains the amount of some of the nutrients removed in the largest quantity in seed, stubble and the plant total.

Table 1: *Nutrient uptake and removal at two levels of production.*

Yield	1 t/ha			2.5 t/ha		
Nutrient	Seed	Stover	Total	Seed	Stover	Total
N	26	14	40	60	35	95
P	4	1	5	9	3	12
K	8	22	30	18	55	73
S	1.7	3.0	4.7	4	8	12

Source: Australian Soil Fertility Manual

5.1 Soil requirements

Crop response to fertiliser can be limited by soil chemical factors such as pH, salinity, sodicity and their effect on nutrient availability and soil structure. The first step to developing a fertiliser plan is to understand soil background limitations. Establish a realistic yield target by allowing for their negative impacts on fertiliser performance. [4]

5.1.1 pH

Sunflowers grow best in neutral soils but a pH range from slightly acid to alkaline is suitable.

They are generally not tolerant of acidic soils with a pHCa of 5.0 or below. Sunflower are very sensitive to aluminium (Al) toxicity. In the field, sunflower commonly respond to liming on soils with surface Al saturation >5%. However, if the Al levels are high in the subsoil, limited options for amelioration are available. Aluminium toxicity is most evident in plant roots displaying distinct shortening and thickening, and a reduction in root hair density.

Despite sensitivity to Al, sunflowers tolerate high concentrations of manganese (Mn) in the root environment. Manganese availability can also increase with soil acidity.

5.1.2 Salinity

Sunflowers are moderately tolerant to salinity; they are less tolerant than cotton, wheat or sorghum but more tolerant than soybean or maize. The threshold soil salinity level for sunflowers is 4–5 dS/m (conductivity measure) and the rate of yield decline about 5% per dS/m above threshold.

Sunflowers affected by salinity display symptoms of stunting, thin stems, dull yellow-green leaves and look moisture stressed and wilted. Symptoms appear first on older leaves which appear dull and develop leaf tip margin necrosis, which spreads over the whole leaf surface. Under high levels of salinity, young leaves are also affected, causing browning off which may eventually lead to plant death.

Paddocks with salinity as a subsoil constraint should be identified and the depth to the subsoil constraint noted in order to calculate the reduction in plant available water and mineral N. Subsoil constraints effectively reduce the amount of soil water available and mineral N to the crop as the root exploration will be limited.

5.1.3 Soil cations and structural stability

In soils with high clay contents (i.e. greater than 15%), an excess of sodium, potassium or magnesium on cation exchange sites can result in surface soil dispersion and crusting. This structural instability commonly reduces crop establishment and can also

4 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

occur at depth, limiting root growth, which in turn inhibits the plants' access to water and nutrients.

In the absence of sodicity-driven soil structural effects, sunflower is categorised as having moderate tolerance to sodium (ESP 30–40%). High sodicity does not appear to affect oil content but may delay germination and flowering. [5]

MORE INFORMATION

RC Dalal, RJ Mayer (1986) Long term trends in fertility of soils under continuous cultivation and cereal cropping in southern Queensland. II. Total organic carbon and its rate of loss from the soil profile. Australian Journal of Soil Research 24, 265–279.

5.2 Declining soil fertility

The natural fertility of cropped agricultural soils is declining over time, and so growers must continually review their management programs to ensure the long-term sustainability of high quality grain production. Paddock records, including yield and protein levels, fertiliser test strips, crop monitoring, and soil and plant tissue tests all assist in the formulation of an efficient nutrition program.

Pasture leys, legume rotations and fertilisers all play an important role in maintaining and improving the chemical, biological and physical fertility of soils, fertilisers remain the major source of nutrients to replace those removed by grain production. Fertiliser programs must supply a balance of the required nutrients in amounts needed to achieve a crop's yield potential. The higher yielding the crop, the greater the amount of nutrient removed. Increasing fertiliser costs means growers are increasing pulses within their crop rotation and even the use of ley pastures to complement their fertiliser programs and possibly boost soil organic matter. [6]

5.2.1 Soil organic matter

Soil organic matter (SOM) is a critical component of healthy soils and sustainable agricultural production. Growers understand that crops grown in healthy soils perform better and are easier to manage. Soil organic matter is '*all of the organic materials found in soils irrespective of its origin or state of decomposition*' [7] that is anything in or on the soil of biological origin, alive or dead. It is composed mainly of carbon (approximately 60%) as well as a variety of nutrients (including nitrogen, phosphorus and sulfur). It is difficult to actually measure the SOM content of soil directly so we measure the soil organic carbon (SOC) content and estimate SOM through a conversion factor:

Soil organic matter (%) = organic carbon (%) × 1.72

It is important to understand the role of plants in the SOM cycle. Photosynthesis is the process by which plants take in carbon dioxide (CO_2) from the atmosphere, combine with water taken up from the soil, and utilising the energy from the sun, form carbohydrate (organic matter) and release oxygen (O_2). This is the start of the SOM cycle. When the leaves and roots (carbohydrate) die they enter the soil and become SOM. These residues are decomposed by soil organisms which provides them with the energy to grow and reproduce. The SOM cycle is a continuum of different forms (or fractions) with different time frames under which decomposition takes place. Over time SOM moves through these fractions; particulate, humic and resistant fractions. As SOM decomposes carbon is released from the system along with any nutrients that are not utilised by the microorganisms. These nutrients are then available for plants to utilise. Eventually a component of these residues will become resistant to further decomposition (resistant fraction Figure 2).

5 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

6 QDAF (2010) Nutrition management. Overview. Department of Agriculture, Fisheries and Forestry Queensland, https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/nutrition-management/overview

7 JA Baldock, JO Skjemstad (1999) Soil organic carbon/Soil organic matter. In KI Peverill, LA Sparrow, DJ Reuter (eds). Soil analysis: An interpretation manual. CSIRO Publishing, Collingwood Australia.

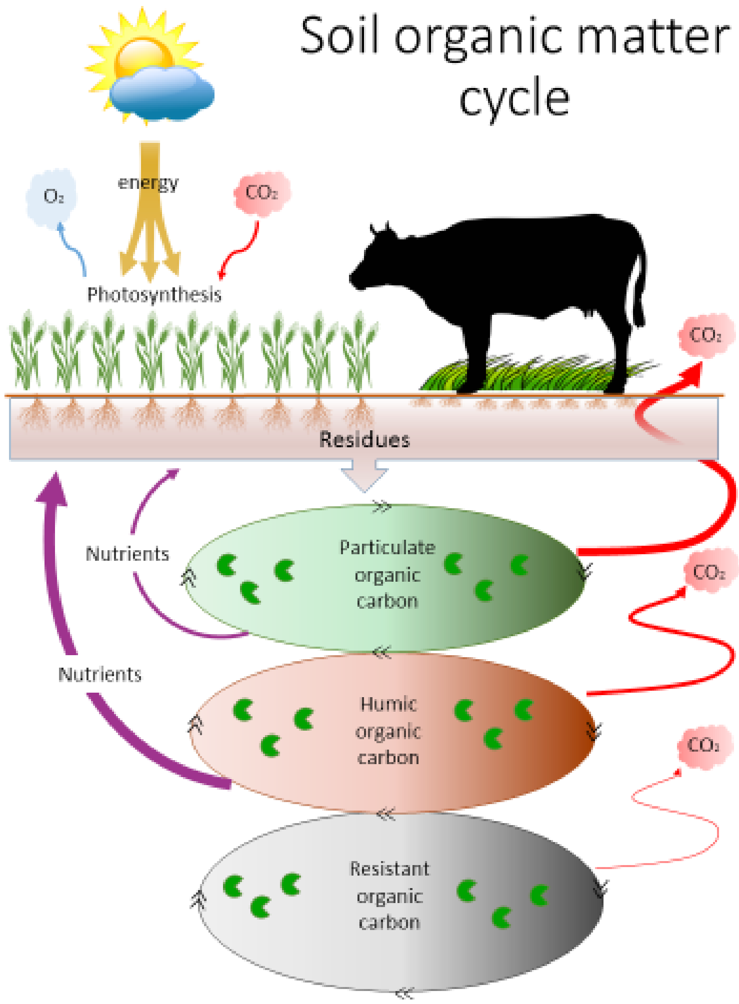

Figure 2: *Organic matter cycle.*

Source: J Gentry, QDAF

Organic matter is fundamental to several of the physical, chemical and biological functions of the soil. It helps to ameliorate or buffer the harmful effects of plant pathogens and chemical toxicities. It enhances surface and deeper soil structure, with positive effects on infiltration and exchange of water and gases, and for keeping the soil in place. It improves soil water-holding capacity and, through its high cation-exchange capacity, prevents the leaching of essential cations such as calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na). Most importantly, it is a major repository for the cycling of nitrogen and other nutrients and their delivery to crops and pastures.

Australian soils are generally low in SOM. Initial SOM levels are limited by dry matter production (and so climate) for each land type/location. SOM levels have declined under traditional cropping practices. On-farm measures (sampled 2012–15) from over 500 sites in Queensland and northern NSW confirm that soil organic matter, measured as soil organic carbon, declines dramatically when land is cleared and continuously cropped. This decline affects all soils and land types but is most dramatic for the brigalow–belah soils because their starting organic carbon levels are so high (Figure 3). [8]

8 QDAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112–117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

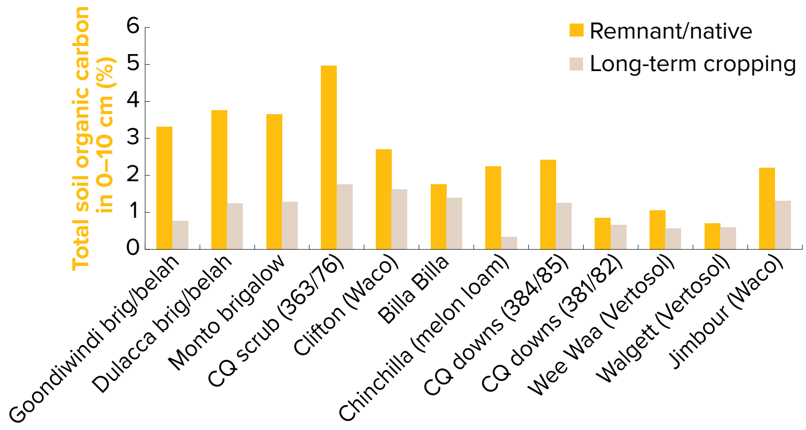

Figure 3: *The decline of soil organic carbon in long-term cropping systems.* [9]

Declining levels of SOM have implications for soil structure, soil moisture retention, nutrient delivery and microbial activity. However, probably the single most important effect is the decline in the soil's capacity to mineralise organic nitrogen (N) to plant-available N. Past research (1983) has shown that N mineralisation capacity was reduced by 39–57%, with an overall average decline of 52% (Figure 4). [10] This translated into reduced wheat yields when crops were grown without fertiliser N.

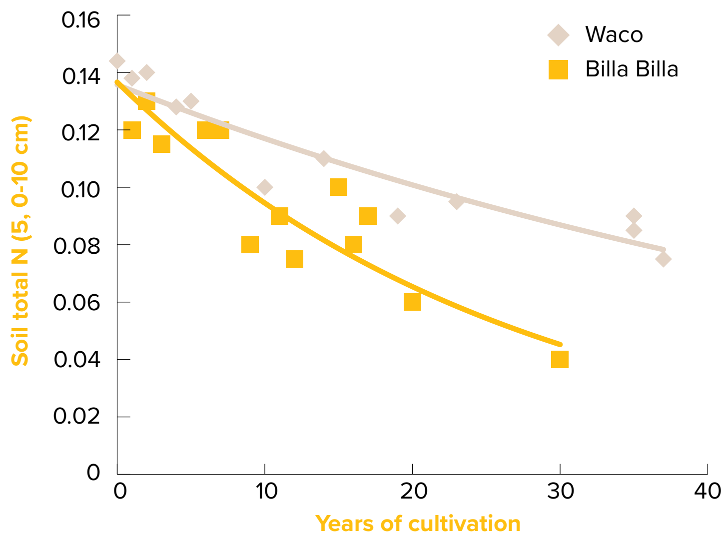

Figure 4: *Graph of decline in soil total N with years of cropping. The decline was greater for the Billa Billa soil (clay content 34%) than the Waco soil (clay content 74%).*

Source: based on Dalal & Mayer (1986a,b) [11]

9 QDAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112–117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

10 RC Dalal, RJ Mayer (1986) Long term trends in fertility of soils under continuous cultivation and cereal cropping in southern Queensland. II. Total organic carbon and its rate of loss from the soil profile. Australian Journal of Soil Research 24, 281–292.

11 RC Dalal, RJ Mayer (1986) Long term trends in fertility of soils under continuous cultivation and cereal cropping in southern Queensland. II. Total organic carbon and its rate of loss from the soil profile. Australian Journal of Soil Research 24, 281–292.

5.2.2 Current situation

Soil organic carbon levels are simply a snapshot of the current balance between inputs (e.g. plant residues and other organic inputs) and losses (e.g. erosion, decomposition) constantly happening in each soil and farming system. The decline over time is overwhelmingly driven by the extent of fallowing in our farming systems. Most fallow rain in the northern region (as much as 75–80% in a summer fallow) is lost as runoff or evaporation. This wasted rain does not grow dry matter to replenish the organic matter reserves in the soil. However, increasing moisture in the fallowed soil continues to support microbial decomposition. This helps accumulate available nitrogen for the next crop, but reduces soil organic carbon. The soil organic matter and carbon levels will continue to decline until they reach a new lower level that the dry matter produced by the new farming system can sustain. Put simply,

'Crops may make more money than trees and pastures, but do not return as much dry matter to the soil.'

Total soil organic carbon levels vary within a paddock, from paddock to paddock and from region to region. Comprehensive sampling was under taken throughout the northern region, with over 900 sites sampled and analysed for total organic carbon at 0–10 cm depth. These results varied enormously across sites. The average was 1.46% however it varied from under 0.5% to over 5% (Figure 5). [12] A selection of these data from representative soil types throughout the northern grains region clearly indicates how soil carbon levels can be significantly different due to soil type (Figure 6). [13]

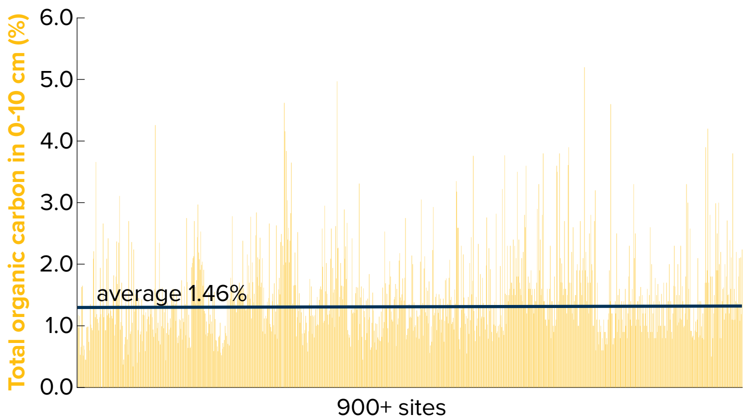

Figure 5: *Soil organic carbon levels on mixed farms within the GRDC Northern Region.* [14]

12 QDAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112–117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

13 QDAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112–117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

14 QDAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112_117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

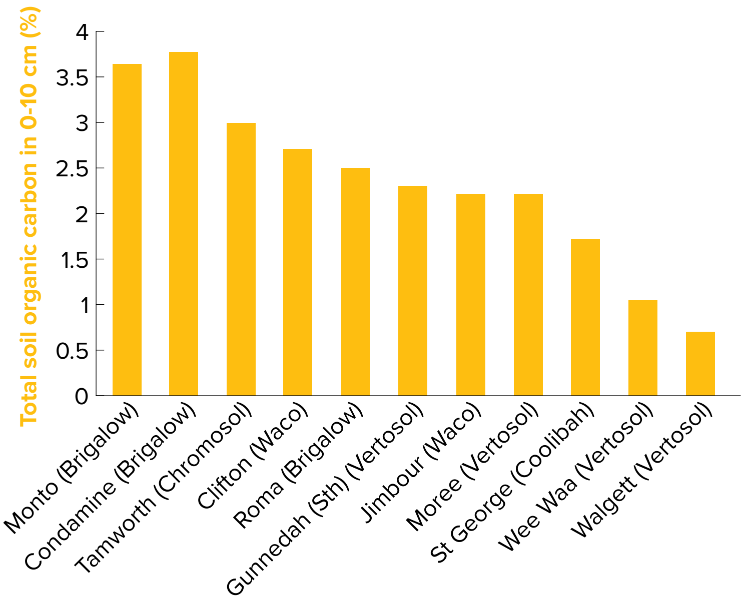

Figure 6: *Impact of land-type on total soil carbon levels (0–10 cm) across the northern region.* [15]

5.2.3 Options for reversing the decline in soil organic matter

Soil organic matter is an under-valued capital resource that needs informed management. Levels of SOC are the result of the balance between inputs (e.g. plant residues and other organic inputs) and losses (e.g. erosion, decomposition, harvested material) in each soil and farming. [16] So maximising total dry matter production will encourage higher SOC levels, and clearing native vegetation for grain cropping will typically reduce SOC and SOM levels. [17]

Modern farming practices that maximise Water Use Efficiency for extra dry matter production are integral in protecting SOM. Greater cropping frequency, crops with higher yields and associated higher stubble loads, pasture rotations and avoiding burning or baling will all help growers in the northern region to maintain SOM.

Research in the past has shown the most direct, effective means of increasing SOM levels is through the use of pastures, however these pasture have to be productive. A grass only pasture will run out of N especially in older paddocks, which is normally the reason why these paddocks are retired from cropping. As a result, a source of nitrogen is required to maximise dry matter production, this can be supplied via a legume or N fertiliser. The rotation experiments of I. Holford and colleagues at Tamworth, NSW and R. Dalal and colleagues in southeast Queensland provide good evidence of this (Table 2).

The greatest gains in soil carbon and nitrogen, relative to the wheat monoculture, were made in the 4-year grass–legume ley, with increases of 550 kg total N/ha and 4.2 t organic C/ha. The chickpea–wheat rotation fared no better than the continuous wheat system. The shorter (1–2-year) lucerne and annual medic leys resulted in marginal increases in soil organic C and N (Table 2).

15 QDAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112–117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

16 FC Hoyle, JA Baldock, DV Murphy (2011) Soil organic carbon: Role in rainfed farming systems. In PG Tow, I Cooper, I Partridge, C Birch (eds). Rainfed farming systems. Springer, pp. 339–361.

17 RC Dalal, RJ Mayer (1986) Long term trends in fertility of soils under continuous cultivation and cereal cropping in southern Queensland. II. Total organic carbon and its rate of loss from the soil profile. Australian Journal of Soil Research 24, 281–292.

MORE INFORMATION

SA Hossain, RC Dalal, SA Waring, WM Strong, EJ Weston (1996) Comparison of legume-based cropping systems at Warra, Queensland. 1. Soil nitrogen and organic carbon accretion and potentially mineralisable nitrogen. Australian Journal of Soil Research 34, 273–287.

MORE INFORMATION

SA Hossain, WM Strong, SA Waring, RC Dalal, EJ Weston (1996) Comparison of legume-based cropping systems at Warra, Queensland. 2. Mineral nitrogen accumulation and availability to the subsequent wheat crop. Australian Journal of Soil Research 34, 289–297.

Clearly, time and good sources of both carbon and nitrogen are required to build up SOM, which is exactly what the 4-year grass–legume ley provided. Nitrogen was supplied via N_2 fixation by the lucerne and annual medic in the pasture, with most of the carbon supplied by the grasses, purple pigeon grass and Rhodes grass. There were no inputs of fertiliser nitrogen in any of the treatments in Table 2. [18]

Table 2: *Effects of different rotations on soil total N and organic C (t/ha) to 30 cm and as gain relative to continuous wheat.*

Rotation	Wheat crops	Soil total N		Organic C	
		0–30 cm	Gain	0–30 cm	Gain
Grass/ legume ley 4 years	0	2.91	0.55	26.5	4.2
Lucerne ley (1–2 years)	2–3	2.56	0.20	23.5	1.2
Annual medic ley (1–2 years)	2–3	2.49	0.13	23.1	0.8
Chickpeas (2 years)	2	2.35	0.00	22.0	0.0
Continuous wheat 4 years	4	2.36	-	22.3	-

Source: Hossain et al. 1996a

Further research was initiated in 2012 to identify cropping practices that have the potential to increase or maintain soil organic carbon and soil organic matter levels at the highest levels possible in a productive cropping system. Paired sampling has shown that returning cropping country to pasture will increase soil carbon levels (Figure 7). However, there were large variations in carbon level increases detected, indicating not all soil types or pastures preform the same. Soil type influences the speed by which carbon levels change, i.e. a sandy soil will lose and store carbon faster than a soil high in clay. As too does the quality and productivity of the pasture, maximising dry matter production by ensuring adequate nutrition (especially in terms of nitrogen and phosphorus) will maximise increases in soil carbon over time. Current research in Queensland being undertaken by the Department of Agriculture, Fisheries and Forestry (QDAF) is indicating that the most promising practice to date to rebuild soil carbon stocks, in the shortest time frame, is the establishment of a highly productive pasture rotation with annual applications of nitrogen fertiliser, however, adding an adapted legume is also effective. [19]

18 D Herridge (2011) Managing legume and fertiliser N for northern grains cropping. Revised 2013. GRDC, https://grdc.com.au/uploads/documents/Managing-N-for-Northern-Grains-Cropping.pdf

19 QDAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112–117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

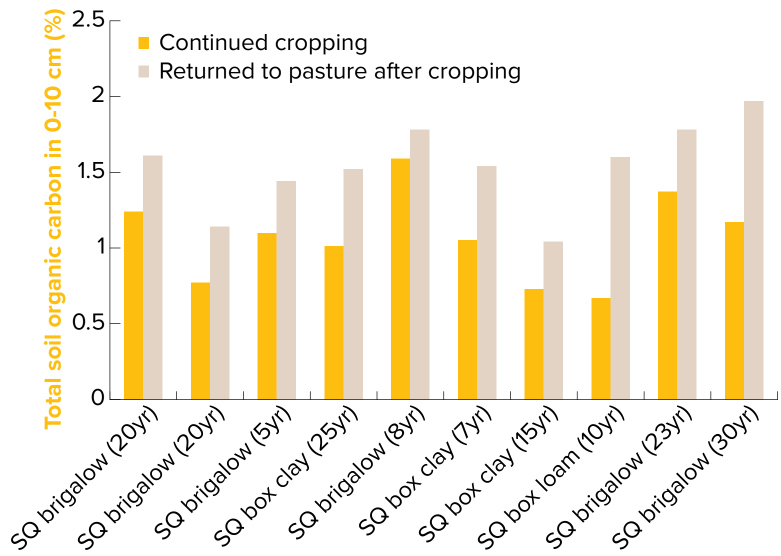

Figure 7: *Total organic carbon comparisons for croplands resown to pasture.* [20]

Impact of fertiliser N inputs on soil

If the rates of fertiliser N are sufficiently high, the effects can be positive. In the Warra experiments, both soil organic C and total N increased marginally (3–4%) over an 8-year period when no-till, continuous wheat, fertilised at a rate of 75 kg N/ha, was grown. This is in contrast with decreases of 10–12% in soil organic C and N in the non-fertilised, continuous wheat and chickpea–wheat plots. The result was much the same in NSW Department of Primary Industries experiments in northern NSW. At the Warialda site, for example, SOM increased during 5 years of cropping but only where fertiliser N had been applied to the cereals.

It is clear from the above examples that building SOM requires N. It works in two ways. First, the fertiliser or legume N produces higher crop/pasture yields and creates more residues that are returned to the soil. Then, these residues are decomposed by the soil microbes, with some eventually becoming stable organic matter or humus. The humus has a C/N ratio of about 10:1, i.e. 10 atoms of C to 1 atom of N. If there are good amounts of mineral N in the soil where the residues are decomposing, the C is efficiently locked into microbial biomass and then into humus.

If, on the other hand, the soil is deficient in mineral N, then more of the C is respired by the soil microbes and less is locked into the stable organic matter. [21]

5.3 Soil testing

Soil testing and professional interpretation of results should be an integral part of all management strategies. Soil tests estimate the amount of each nutrient available to the plant rather than the total amount in the soil. Valuable information obtainable from a soil test includes current nutrient status, acidity or alkalinity (pH), soil salinity (electrical conductivity, EC), and sodicity (exchangeable sodium percentage, ESP), which can affect soil structure.

20 QDAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112–117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

21 D Herridge (2011) Managing legume and fertiliser N for northern grains cropping. Revised 2013. GRDC, https://grdc.com.au/uploads/documents/Managing-N-for-Northern-Grains-Cropping.pdf

MORE INFORMATION

http://www.fertiliser.org.au/Fertcare

http://agronomycommunity.incitecpivotfertilisers.com.au/~/media/Files/IPL pdfs/Crop Soil Sampling Procedure1.ashx

http://www.backpaddock.com.au

http://www.afsa.net.au/index.php?action=content&page=11

http://www.aspac-australasia.com

Soil test information should not be used alone to determine nutrient requirements. It should be used in conjunction with test strip results and previous crop performance to determine nutrients removed by that crop, as well as previous soil test records, to obtain as much information as possible about the nutrient status of a particular paddock.

Figure 8: *Soil sampling: soils must be sampled to the correct depth.*

Soils must sampled to the correct depth (Figure 8). Sampling depths of 0–10 and 10–30 cm should be used for all nutrients. An additional sample at 30–60 cm is required for sulfur (S), and samples at 30–60, 60–90 and 90–120 cm (or to the bottom of the soil's effective rooting depth) are needed for N, pH, EC and chloride.

Care must be taken when interpreting soil test results; nutrients can become stranded in the dry surface layer of the soil after many years of no-till or reduced tillage, and deep nutrient reserves may be unavailable because of other soil factors, such as EC levels, sodicity or acidity. [22]

5.3.1 Test strips

Test strips allow you to fine-tune the fertiliser program. To gain the maximum benefit:

- Run them over a number of years, as results from any single year can be misleading.
- Obtain accurate strip weights.
- Oil-test a sample of grain from each strip.
- Harvest strips before your main harvest. Use yield monitoring if available.

When setting up a test strip area:

- Ensure that you can accurately locate the strips—a GPS reading is valuable.
- Repeat each fertiliser treatment two or three times (if comparing fewer than four treatments, more replication is needed).
- Change only one product rate at a time.
- Separate each strip of fertiliser by a control or nil-fertiliser strip.
- Ensure the tests are done over a part of the paddock with a uniform soil type.
- Keep clear of shade lines, trees, fences, headlands and any known anomalies in the field.
- Ensure that the test strip area is ~100 m long, with each strip 1–2 header widths.

A number of local Grower Solutions Groups, such as the Northern Grower Alliance (NGA) and Grain Orana Alliance (GOA), as well as NSW Department of Primary Industries (DPI) and Department of Agriculture, Fisheries and Forestry Queensland (QDAF) conduct nutrition trials in most years.

22 QDAF (2010) Nutrition management—Overview. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/nutrition-management/overview

MORE INFORMATION

www.nga.org.au

www.grainorana.com.au

MORE INFORMATION

http://www.aspac-australasia.com/index.php/component/labproficiency

http://www.grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-108-Jan-Feb-2014/Sunflowers-balancing-act

MORE INFORMATION

http://www.dpi.nsw.gov.au/agriculture/resources/soils/improvement/n-acidify

Colour photographs of nutrient deficiencies can be found in: 'Hungry crops: a guide to nutrient deficiencies in field crops' by NJ Grundon (1987) (Department of Primary Industries, Queensland Government, Information Series Q187002). [23]

5.3.2 Rules of thumb

1. Choose the same soil test package each year (including methods); otherwise, comparisons between years will be useless. For example, for phosphorus (P), do not use Colwell-P one year, then DGT-P the next; the two tests measure different forms of available P in the soil.
2. If you do not use a standard approach to sampling, a comparison of the data between different tests will not be reliable. Aim for data that have the best chance of representing the whole paddock, and mix the sample thoroughly.

For monitoring, sampling needs to cover roughly the same area each time to ensure meaningful comparisons between years. Permanent markers on fence posts to mark a sampling transect, or a handheld GPS or your smartphone, will serve this purpose.

Soil-testing laboratories should be able to provide information on appropriate soil sampling and sample-handling protocols for specific industries and crop types. Refer to the 'Australian Soil Fertility Manual' (see www.publish.csiro.au/pid/5338.htm) or download the GRDC Fact Sheet 'Better fertiliser decisions for crop nutrition' at http://www.grdc.com.au/GRDC-FS-BFDCN. [24]

Use an ASPAC- and NATA-accredited testing service. The results are more likely to be statistically valid and have reduced variation between tests.

5.3.3 Soil testing for N

The approximate amount of N available in the soil can be determined by soil testing. Soil tests should be taken at various places in each paddock to a depth of at least 90–120 cm. Primary roots grow to a depth of 2 m [25] and can extract N from this level. Test results are an indication only, so historical grain yield and protein levels from the paddock should also be used to determine N requirements. [26] Environmental conditions, including temperature, time and rainfall events, can affect starting levels of soil N; therefore, it is important to test later in the summer fallow or make adjustments to factor in mineralisation amounts as well as denitrification and leaching events.

Forms of N fertiliser

Nitrogen is available in four main forms:

1. Nitrate, e.g. ammonium nitrate, sodium nitrate, potassium nitrate
2. Ammonium, e.g. anhydrous ammonia, sulfate of ammonia, ammonium nitrate
3. Amide, e.g. urea
4. Organic, e.g. blood and bone, meat meal

It is important to choose the right product, as different compositions are more suited to certain conditions.

Calculating N fertiliser application

If N fertiliser is required, the calculation below can be used to obtain the quantity of fertiliser required. For example, if 40 kg N/ha is required, this rate of N can be supplied by applying 87 kg/ha of urea (46% N) (Table 3).

23 QDAF (2010) Nutrition management—Overview. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/nutrition-management/overview

24 GRDC (2013) Better fertiliser decisions for crop nutrition. Northern, Southern and Western Regions. GRDC Crop Nutrition Fact Sheet Nov. 2013, http://www.grdc.com.au/GRDC-FS-BFDCN

25 NSW DPI Agronomists (2007) Wheat growth and development. PROCROP Series, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/449367/Procrop-wheat-growth-and-development.pdf

26 QDAF (2010) Nutrition management—Overview. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/nutrition-management/overview

Fertiliser product required (kg/ha) = rate of N required kg N/ha × 100/(% N in fertiliser product) [27]

Table 3: *Nitrogen fertilisers commonly used in broad-scale farming.*

Fertiliser	% N	% P	% S
Urea	46		
Ammonium sulfate	21		24
Calcium ammonium nitrate	27		
Di-ammonium phosphate	17.5–18.0	20	
CSBP Agras No. 1®	17.5	7.6	17
CSBP Agyield®	17.5	17.5	4.5
CSBP Agrich®	12.0	11.4	12
CSBP Agstar®	15.5	12.8	11
Summit Easycrop 2®	31	9	4
Summit Canola 2®	33		12
Summit Topyield 3®	27.3	11.5	5
Summit Cereal®	18.5	11.0	14.4
Summit Canola 1 ®	18.5	11.0	14.4
Summit Croprich ®	18	14	11.5
Summit Sustain®	10.8	12	1
Summit Cropyield®	17.1	19.6	3.5
Summit DAPSZC®	17.1	18.3	8

Source: DAFWA.

'NBudget' calculator

'NBudget' is an Excel-based calculator for estimating the fertiliser N requirements of cereal and oilseed crops and N_2 fixation by legumes. It contains rule-of-thumb values for soil nitrate based on paddock fertility status and recent paddock history, with linked equations for calculating soil nitrate following crop growth and post-crop fallow.

Other key calculations in NBudget determine: soil water at sowing based on fallow rainfall or depth of wet soil; biomass and grain yields of the different crops based on water-use efficiencies; N_2 fixation of legumes based on crop biomass and soil nitrate effects; and production of crop residues and the net release or immobilisation of nitrate-N from those residues as they decompose in the soil.

Input data to develop NBudget were sourced from published and unpublished experiments conducted principally by the farming systems and plant (N) nutrition programs of the NSW and Queensland agricultural agencies during the past 30 years. The data required to run NBudget include: location and description of the paddock as very low, low–medium, medium or high fertility; tillage practice; yield and protein level (for cereals) of the previous crop; fertiliser N applied to previous crop; simple assessment of risk of crown rot for the winter cereals; and fallow rainfall or depth of wet soil.

For a detailed guide to use of NBudget and N management, download Dr David Herridge's publication, 'Managing legume and fertiliser N for northern grains

27 QDAF (2012) Wheat—nutrition. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/nutrition

cropping': https://grdc.com.au/uploads/documents/Managing-N-for-Northern-Grains-Cropping.pdf. [28]

5.3.4 Soil testing for P

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 NSW. It is used with the P 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 and is now an important tool in the grains industry. BSES-P uses a dilute acid extraction to assess the size of slow-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 4–6 years, and is most important in the subsoil layers.

P buffering index

The 'buffering capacity' of a soil refers to its ability to maintain P concentration in solution as the plant roots absorb the P. The 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 <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 0–10 and 10–30 cm soil tests.

BSES-P is optional in the 0–10 cm layer but essential in the 10–30 cm layer. [29]

Traditionally when testing to determine a crop's P requirement, a soil sample from 0–10 or 0–15 cm was taken and analysed for Colwell-P and PBI. According to recent work into depletion and stratification of P, as well as the existence (or otherwise) of additional slow-release P reserves that can be detected using the BSES-P test, Colwell-P alone is unlikely to provide all of the information to make an informed decision. Of particular note is the lack of correlation between the two soil P tests, with this most obvious in samples from below 10 cm.

Although data are still being collected on the rates at which these BSES-P reserves can become available to plants (i.e. over days, weeks or long fallows), current observations suggest that subsoils with quite low BSES-P levels (i.e. <25–30 mg/kg) are still able to meet the demands of a well-developed root system (i.e. a trickle of P from many roots accessing a large soil volume).

However, there are many subsoils across the region where soil P (both Colwell and BSES) is low. For example, grain P data from wheat, barley and sorghum collected across the region in the GRDC-funded project '*Toward a better P nutrition package: diagnosing P status and application strategies to improve fertiliser*' (DAQ00084) suggest that 20–25% of all crops were marginal–low in P, whereas the proportion of marginal–low-P chickpea crops was much higher. Early results suggest that some significant yield gains may be possible on these soils. [30]

MORE INFORMATION

GRDC Update Papers

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/05/Toward-a-Better-P-Nutrition-Package-Diagnosing-P-Status-and-Application-Strategies-to-Improve-Fertiliser-Response

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/Nutritional-interactions-of-N-P-K-and-S-on-the-Darling-Downs

GRDC Podcast
http://www.grdc.com.au/Media-Centre/GRDC-Podcasts/Northern-Weekly-Update/2013/11/21-north

28 D Herridge (2013) Managing legume and fertiliser N for northern grains cropping. Revised version. GRDC, http://www.grdc.com.au/~/media/6E5659619C7C4063AB3C8E58A4DE39E7.pdf

29 GRDC (2012) Northern region—phosphorus management. GRDC Crop nutrition Fact Sheet Nov. 2012, http://www.grdc.com.au/~/media/578CC7FEE649428D9C4C90B7461537D0.pdf

30 M Bell, D Lester, P Moody, C Guppy (2010) New ways to estimate crop needs and deliver P to improve the return on fertiliser investment. GRDC Update Papers 17 Sept. 2010

5.4 Plant tissue sampling

Plant tissue testing is an underused crop nutrition management tool. It is more reliable than soil testing for nutrients where local soil test calibrations are not available, or when checking on the effectiveness of a change to a fertiliser program (Figure 9).

For these reasons, critical tissue concentrations should be associated specifically with defined stages of plant growth or plant part rather than growth periods (i.e. days from sowing). Growers are advised to follow laboratory guides or instructions for sample collection.

Plant nutrient status varies according to plant age, variety and weather conditions. The difference between deficient and adequate (or toxic) levels of some micronutrients can be very small. Agronomists consider one test alone not enough; several tissue tests need to be done over time throughout the growing period to establish whether the crop is tracking according to the season at hand.

The key to successful plant tissue testing is ensuring the crop is sampled when actively growing, and the sample is collected from the appropriate plant part, at the correct growth stage and time. For example, time of day and soil moisture availability are important for some nutrients for consistency of results when doing consecutive tissue tests. Some plant tissue diagnostic values are presented in Table 4. [31]

Table 4: *Plant tissue sampling guidelines for top 1 to 3 mature leaves of sunflower at bud stage.*

Nutrient	Sufficient range
Nitrogen (%)	2.0–3.4
Phosphorus (%)	0.25–0.49
Potassium (%)	1.5–2.9
Sulfur (%)	0.2–0.39
Calcium (%)	0.3–1.9
Magnesium (%)	0.2–1.4
Zinc mg/kg	15–69
Copper mg/kg	6.24
Iron mg/kg	20–249
Manganese mg/kg	15–99
Boron mg/kg	35–150

Source: Reuter and Robinson, 1996

When applying fertiliser to treat a suspected deficiency, leave a strip untreated. Use a visual response (where a 20% yield difference is not evident) or plot harvesting of the strips can allow you to confirm limiting micronutrients. [32]

31 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

32 GRDC (2013) Micronutrients. Northern, Southern and Western Regions. GRDC Crop Nutrition Fact Sheet Nov. 2013, http://www.grdc.com.au/GRDC-FS-CropNutrition-Micronutrients

PODCAST

http://www.grdc.com.au/Media-Centre/GRDC-Podcasts/Driving-Agronomy-Podcasts/2010/06/Plant-Tissue-Testing-uncovering-hidden-hunger

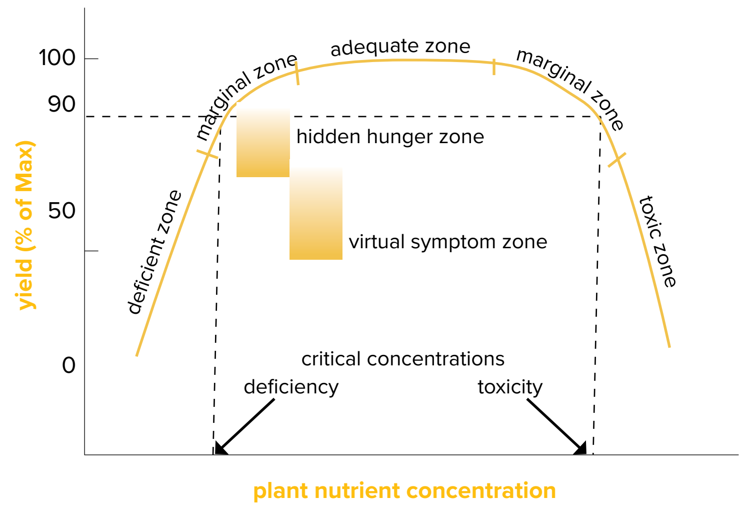

Figure 9: *Generalised grain yield response curve.*

5.5 Hierarchy of crop fertility needs

Current research by QDAF on the Darling Downs confirms a hierarchy of crop fertility needs. There must be sufficient plant-available N to get a response to P, and there must be sufficient P for S and/or potassium (K) responses to occur. [33]

Additive effects of N and P appear to account for most of the aboveground growth and yield response. [34]

Liebig's law of the minimum, often called Liebig's law or the law of the minimum, is a principle developed in agricultural science by Carl Sprengel (1828) and later popularised by Justus von Liebig. It states that growth is controlled not by the total amount of resources available, but by the scarcest resource (i.e. limiting factor) (Figure 10). [35]

Figure 10: *Leibig's law, or law of the minimum.*

33 D Lester, M Bell (2013) Nutritional interactions of N, P, K and S on the Darling Downs. GRDC Update Papers 7 March 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/Nutritional-interactions-of-N-P-K-and-S-on-the-Darling-Downs

34 D Lester, M Bell (2013) Nutritional interactions of N, P, K and S on the Darling Downs. GRDC Update Papers 7 March 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/03/Nutritional-interactions-of-N-P-K-and-S-on-the-Darling-Downs

35 Anon. Liebig's law of the minimum, http://en.wikipedia.org/wiki/Liebig's_law_of_the_minimum

5.6 Nitrogen

Nitrogen (N) is the major nutrient required by sunflowers and has the greatest impact on characteristics such as the size and number of leaves, seed size and weight, yield and oil content. There is an interaction between S and N for many of these factors as well. Excess N causes a reduction in oil contents, whilst insufficient N will limit crop yield. The challenge is targeting the optimum level. An N budget helps target optimal yield and oil contents. [36]

Sunflower has a lower requirement for N than sorghum and winter cereals. However, N is the nutrient required in the greatest quantity by a sunflower crop. Cropping history, years of cropping, fallow conditions and yield potential determine the quantity of N fertiliser needed. [37]

As a guide, for high-yielding crops on the Liverpool Plains, use 60–100 kg N/ha. In the Moree and Narrabri districts, little N is usually used, but on responsive paddocks up to 50 kg N/ha should be applied. Irrigated crops need 100–140 kg N/ha depending on target yields. [38]

Nitrogen budgeting can be used to help determine the N requirements of a crop by using the following calculations. The quantity of N removed in 1 tonne of grain is ~40 kg, of which 26 kg is in the seed and 14 kg in the stover. The quantity of N required to grow the crop is ~1.7 times the amount removed in the seed. [39]

N removed in seed (kg/ha):
Target yield (t/ha) × N removed (kg/t)

N required for crop (kg/ha):
N removed in seed × 1.7

Example calculation:
2 t/ha (target yield) × 26 (kg N removed/t seed) × 1.7 = 88 kg N/ha

Fertiliser required = N required for crop (88 kg/ha) – soil N reserve – expected soil N mineralisation
= 88 kg/ha – 50 kg/ha – 10 kg/ha (1% organic carbon × 5% × 200 mm of rainfall)

Total fertiliser requirement = 28 kg/ha (in some regions, some loss figures may need to be accounted for)

Nitrogen taken up by a crop comes from the available soil nitrate-N and from fertiliser-N. Soil nitrate-N is estimated by soil testing (preferably to 120 cm depth) or by reviewing the previous crop history, in particular the grain yield and protein content of the previous crop. [40] It is reasonable to expect sunflowers to extract N to at least this depth unless there are subsoil constraints. [41]

Pre-plant application of N fertiliser or banding of fertiliser 5 cm below and to the side of the seed is recommended. Germinating seed is very susceptible to N fertiliser burn if sown in close contact. [42]

Sunflower roots are able to extract water and N from depths of 1.5 m or greater in the soil profile so can be a useful crop in tapping deep N bulges.

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36 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

37 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

38 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

39 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

40 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

41 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region–northern NSW and southern Qld. Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

42 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

For monounsaturated sunflower markets, a bonus/discount system applies for oil content above or below 40%. Protein and oil content of grains are inversely related, therefore too much N can reduce oil content.

The relationship between soil nitrate-N and soil water (0–120 cm) has been found useful in managing oil content. Limited studies in NSW suggested that matching nitrate:water at ratios 0.5–1.0 optimised oil content above the required industry standard of 40%, as well as grain yield. Oil contents were, on average, less than 40% when the nitrate: water ratio was more than 1.0 (Figure 11). [43]

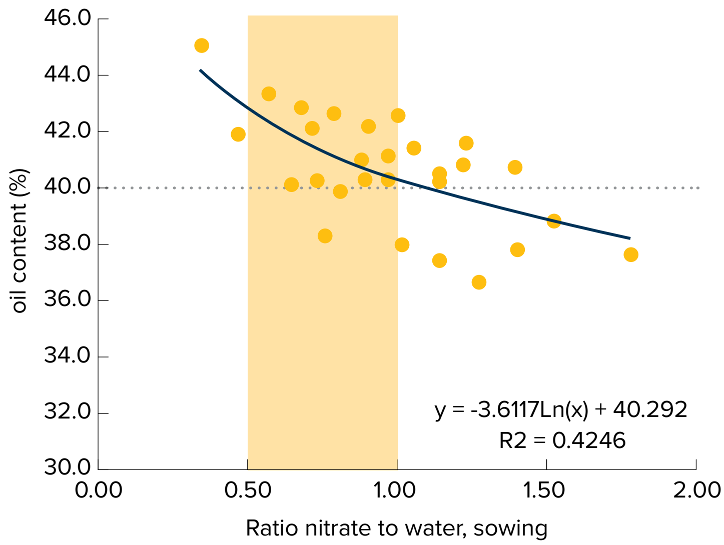

Figure 11: *The relationship between the starting soil nitrate:water ratio and oil content of sunflower.* [44]

Source: Serafin, Belfield & Herridge, 2010

Benchmarking project

In the 'Sunflowers in Northern NSW and Southern Qld—Tools for Success' benchmarking project, N fertiliser rates were consistently low in the Moree district, averaging 23 kg N/ha over the 3-year project. These rates fell well short of those required to meet the district average of 1.4 t/ha. By contrast, N rates in the Gunnedah district were consistently high. Southern Queensland crops received, on average, enough N for yields of 1.1 t/ha, close to the average yield.

The supply of adequate nutrition to a sunflower crop is of great importance; however, in the northern grains region, the type and amount of nutrition supplied is highly variable (Table 5).

43 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

44 L Serafin, S Belfield, D Herridge D (2010) Managing Nitrogen to optimise sunflower yield and oil content. Proceedings of the 1st Australian Summer Grains Conference, Gold Coast, Australia, https://grdc.com.au/uploads/documents/2010ASGCEditedPapersPDF/Serafin_ManagingNitrogen_edited_paper.pdf

Table 5: *Sunflower nutrition and average fertiliser application in the northern grains region.*

Benchmarking year	Average yield (t/ha)	N (kg/ha)	P (kg/ha)	S (kg/ha)	Zn (kg/ha)	% of paddocks not fertilised
Moree						
2003–04	1.18	7.0	3.2	0.4	0.40	50
2004–05	1.57	15.2	3.6	0.6	0.42	15
2005–06	1.41	31.6	2.2	0.3	0.35	17
Gunnedah						
2003–04	1.66	68.1	2.7	2.7	0.30	10
2004–05	2.22	69.3	7.4	2.8	0.68	5
2005–06	1.47	71.0	4.6	15.3	0.51	6
Southern Queensland						
2003–04	1.58	60.0	6.5	0.7	0.83	0
2004–05	1.01	36.9	2.8	0.8	0.25	10
2005–06	1.25	43.6	3.2	0.9	0.43	20

Replicated trials

The effect of N on yield and oil content was evaluated over two seasons at sites in northern NSW. Trials conducted at Pine Ridge on a site with high starting levels of soil N demonstrated the effects of excessive N (Figure 12).

The starting soil N level at this site was 143 kg N/ha, sufficient to achieve 3.3 t/ha. Most of this N had accumulated as a bulge at 60–120 cm soil depth.

This amount of N was in excess of that required for dryland yields. Hence, a decline in yield and oil content resulted from additional N applied.

The relationship between N, starting soil water and target yield is crucial to yield and oil content.

The relationship between optimum yield and oil content was also demonstrated at the Gurley trial site (Figure 13). Starting soil N levels were measured as 52 kg N/ha, sufficient to achieve a yield of 1.2 t/ha.

The maximum yield achieved at this site was with the addition of 125 kg N/ha (1.7 t/ha), whereas the maximum oil content was achieved with no additional N. Nitrogen application needs to be balanced; at this site, 60 kg/ha of additional N would have optimised yield and oil content.

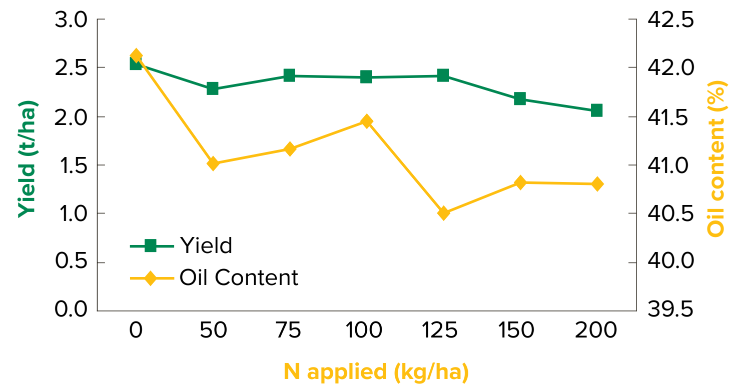

Figure 12: *Relationship between nitrogen, oil content and yield of sunflowers, Pine Ridge–Gunnedah, 2005–06.*

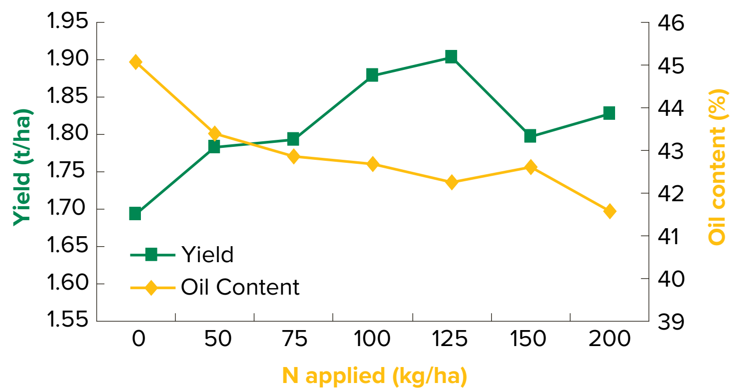

Figure 13: *Relationship between nitrogen, oil content and yield of sunflowers, Gurley–Moree, 2005–06.*

Benchmarking paddocks

Thirty-two paddocks were sampled to determine starting soil nitrate levels in 2004–05 and 2005–06. One-fifth of paddocks sampled had starting nitrate levels >200 kg/ha, enough N to produce 4.6 t/ha, an unattainable yield under dryland conditions.

As N costs rise, awareness of N quantity and distribution through the soil profile and crop requirements become increasingly important. Not only does too much N negatively affect oil contents and yields, the gross margin declines. [45]

5.7 Phosphorus

Phosphorus (P) is the second most frequently limiting nutrient for sunflower production. Sunflowers respond to P deficiency by flowering and maturing faster.

The quantity of P removed in 1 tonne of grain is approximately 5 kg, of which 70–80% is in the seed and 20–30% in crop residues. Phosphorus fertiliser needs are best

45 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

determined by soil tests, soil type, test strips, consideration of likely arbuscular mycorrhizal (AM) fungi levels, paddock history and local experience. In paddocks where P is needed, apply at least 10 kg P/ha or at a rate to match P removal. In southern NSW at least 20 kg P/ha is usually required, increasing to 40–50 kg P/ha if sunflowers follow a rice crop. At high rates, alternative application methods to sowing with the seed may need to be considered to prevent fertiliser burn.

The value of deep application of P and potassium (K) has been demonstrated on a range of cereal crops in Vertosol soils. To date there is little research data to demonstrate responsiveness in sunflower as measured in other tap-rooted crops such as chickpea and mungbean. If AM fungi levels are low—such as after a long fallow canola or rice—supplying adequate phosphorus and zinc fertiliser is very important (Figure 14). [46]

Figure 14: *Dark green healthy leaf (right) compared with P-deficient leaf showing dull yellow chlorosis and dark grey necrotic lesions (left).*

Photo: NJ Grundon

5.8 Sulfur

Sulfur (S) forms important partnerships with N during sunflower production. Together, they determine leaf area, which provides photosynthates to developing florets and seeds, following through to yield and seed size. Deficiency when combined with N reduces yield as seed weight and the number of seeds per plant declines.

The amount of S removed in the seed of a 1-t crop is 5 kg/ha, with uptake highest between budding and anthesis; a large proportion is also taken up post-anthesis (Table 6). [47]

Table 6: *Sulfur uptake by sunflower.*

Growth stage	% Uptake
Emergence – budding	20
Budding – anthesis	45
Post-anthesis	35

Sulfur has not been identified as a problem to date on the cracking clay soils of northern NSW and Queensland, which usually contain ample amounts of S as gypsum in the subsoil. Responses are most likely on shallow soils, deep sands and where sunflowers are double cropped.

If N is adequate but S is deficient:

- sulfur stress at budding will decrease oil yields by 30% due to lower single seed weight and less seeds per plant
- sulfur stress at anthesis will produce a 17% decrease in oil yield due to reduced seeds per plant due to floret abortion.

46 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

47 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

Sulfur deficiency can be corrected before anthesis, which will increase seed weight, providing N is adequate. [48]

5.9 Potassium

Potassium (K) is required for stalk and tissue strength. Sunflowers have a high requirement for K, with every 1 t/ha of yield removing 30 kg K/ha. [49] This is removed as 8 kg K/ha in the seed, and the remaining 22 kg K/ha in the stover. Responses to K are unlikely if soil test levels are >0.25 meq/100 g. [50] It becomes more critical when soil sodium levels rise; the plant requires more K in the soil than Na, otherwise the crop will take up too much Na and reduce yields (Figure 15).

There are anecdotal reports that sunflower stalks release K slowly during breakdown, having a beneficial effect on following crops such as cotton. [51]

While low K has been associated with increased crop lodging in other countries, K responses are generally not seen in sunflowers in Australia. [52]

Figure 15: *Potassium-deficient leaf showing marginal and interveinal chlorosis and necrosis.*

Photo: NJ Grundon

5.10 Boron

Sunflower is a crop that has a high boron (B) requirement and is very sensitive to boron deficiency. Despite the majority of sunflowers being grown on alkaline calcium rich soils which lower B availability, B deficiency is rare. Transitory B deficiency may occur as a result of climatic conditions that limit uptake and translocation of B from soil to plant structures undergoing rapid growth.

Boron content of many soils increases with depth, making deep soil sampling and plant tissue analysis necessary after root extension has reached at least 60 cm. Sunflower is tolerant of high soil B. [53]

Classical boron (B) deficiency symptoms and some others suspected to be caused by B deficiency have become more common over the past 5–7 years. Symptoms generally show up at or near flowering and include malformed upper leaves, which may show purplish or bronze-coloured patches.

The growing point may become necrotic, plants are stunted, internodes shortened and root development poor. Older leaves may have necrotic patches and

48 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

49 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and southern Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

50 L Serafin, D McCaffery, S Thompson (2014) Sunflower. Summer crop production guide 2014. pp. 80–92. NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre-crops/guides/summer-crop-production-guide

51 L Serafin, S Belfield (2008) Sunflower production guidelines for the northern grains region—northern NSW and souther Qld. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/249779/Sunflower-production-guidelines-for-the-northern-grains-region.pdf

52 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

53 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

discoloration and be thick and leathery. Flowers may be deformed and seed-set poor. Boron deficiency can also cause weakening of the stalk, resulting in lodging or head loss as the weight of the developing flower puts stress on the weakened stem. Black lesions are sometimes seen on the stem and deterioration of the pith is common.

Boron deficiency is commonly associated with moisture stress and need not be due to low levels of B in the soil. Instead, the ability to uptake and translocate B may be affected by stress. For example, B deficiency has been reported when good growing conditions are abruptly followed by hot dry conditions. Boron-deficient plants often show up in patches, particularly in shallow soils on ridgelines. [54]

5.11 Zinc

Fertiliser responses to zinc (Zn) often occur on heavy alkaline soils. However, they are more easily detected in crops such as maize and sorghum. Plant tissue analysis is a more reliable indicator of sunflower responsiveness than soil testing. Using starter fertilisers containing Zn or using foliar Zn applications can assist in addressing deficiencies. [55] Zinc can be broadcast at 10–20 kg Zn/ha and worked into the soil well before sowing. Banding Zn-compound fertilisers (rather than zinc-blended fertilisers) with the seed at planting is an effective way of applying zinc. Alternatively, when crops have 8–10 leaves, apply two foliar sprays of zinc sulfate heptahydrate solution (1 kg/100 L water) at 150–200 L/ha, 7–10 days apart. [56]

5.12 Fertiliser application guidelines

Germinating sunflower seed is very sensitive to fertiliser placed in the seed trench, and fertiliser should therefore be placed away from the seed, or consideration given to the amount and type of fertiliser placed in close contact with the seed (Table 7).

If sunflowers are planted using row crop equipment, the majority of the P and K should be side-banded 5 cm beside and 5 cm below the seed during planting. Some or all of the N can also be applied pre-plant or side-banded, provided that the total amount of fertiliser material (NPKS) side-banded does not exceed 330 kg/ha of product. Nitrogen can also be side-dressed before the plants are 30 cm tall (6–8 leaf stage).

If applying some starter fertiliser in the seed trench, the rates in Table 7 provide guidelines (kg/ha) for two common seedbed utilisation (SBU) factors for a light clay soil with good soil moisture in the seed zone. SBU is the opener width divided by row spacing times 100. For example, 2.5% SBU is 2.5 cm opener with 100 cm row spacing. [57]

Table 7: *Starter fertiliser rates based on common sunflower seedbed utilisation factors for a light clay soil with good soil moisture.*

Product (kg/ha)	Seedbed utilisation (%)	
	2.5%	3.3%
MAP	11.5	15
DAP	14	18

Source: Seed-Placed Fertilizer Decision Aid, International Plant Nutrition Institute

54 Australian Sunflower Association (2004) Boron deficiency. The New Big Black Sunflower Pack. p. 29. Australian Oilseeds Federation

55 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

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57 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

5.13 Nutritional disorders

Diagnosing sunflower nutrient deficiencies or toxicities can be confusing as symptoms may appear similar to other environmental or disease conditions. Use soil and plant tissue testing as a guide as well as consulting with reference literature and industry resources to assist in correct identification. Table 8 contains a guide to some nutrient deficiencies and toxicities. [58]

Table 8: *Symptoms of nutrient deficiency and toxicity in sunflowers.* [59]

Deficiencies	Symptoms	Occurrence	May be confused with...	Management
Nitrogen	Pale older leaves, stunting, less leaves, thin stems	Sandy soils, low organic matter, long history of cropping, incorrect N budgeting, waterlogging.	S deficiency (first displays on new growth) which is opposite to N deficiency.	N budget before sowing to ensure adequate N applied at or before sowing for target yield. Foliar in crop if deficient before bud initiation
Phosphorus	Lack vigour, smaller plants and heads; slow maturity, thin stems, older leaves - grey necrosis initially on leaf tip margins. Water soaked necrotic concentric circles	Low organic matter, highly acidic or alkaline soils where P is more strongly adsorbed, long cropping history, low VAM, eroded topsoil	Reduced plant growth is very difficult to diagnose; leaf necrotic symptoms may be confused with Alternaria or Septoria	Preferably apply P at sowing banded below the seed as starter fertiliser also containing zinc
Potassium	Stunted plants, poor vigour, delayed maturity, oldest leaves interveinal chlorosis that develops necrosis. Leaves point down and may be cupped up or down.	Low organic matter, long history of cropping or haymaking, sandy low K soils - leached soils.	Mg deficiency	K fertiliser at or before sowing, not in contact with seed. Foliar spray possible but not usually requ1ired
Sulfur	Chlorosis of young leaves	Low organic matter, acid sandy soils, long cropping history	N deficiency; Mb deficiency	No field reports known but suspected. Apply gypsum or sulfate of ammonia pre sowing.
Calcium	Stunted plants, short thick stems; emerging leaves crinkled. Top leaves and head bracts may have interveinal necrosis or die if severe. Lower leaves may have mottled chlorosis and necrosis.	Acid sandy soils where Ca leached. Strongly alkaline or sodic soils; high Al and low exchangeable Ca levels	Cu deficiency {leaf crinkling). B deficiency (also affects growing point). However B deficiency causes thickening, cupping, bronzing.	Unlikely to occur. If it does apply lime or dolomite in acid soils or gypsum in alkaline soils.
Magnesium	Stunted plants, shortened internode length, thin stems. First notice mottled, interveinal chlorsis of lower leaves. Severe deficiency may cause leaf downward cupping and bronzing.	Acid sandy soils. Soils over fertilised with Ca or K.	K deficiency	No field reports known. If concerned could apply dolomite in the fallow prior to sowing or Magnesium sulfate at or before sowing.
Zinc	Stunted plants, young leaves narrow, wavy leaf margin, leaf wilting , brown spot necrosis on leaves	Highly alkaline soils, leached sandy soils, loss of topsoil, low arbuscular mycorrhiza soils	Moisture stressed - wilting	Starter fertiliser with P and Zn banded at sowing; foliar Zn chelate in crop
Boron	Youngest leaves and bud leaves pale yellow. Bud ceases to expand, develops grey necrotic area near leaf base, yellow mid leaf, green leaf tip	Leached sandy soils;alkaline soils with free lime; low organic matter	Ca or Cu deficiency in vegetative state	Chelated B sprays in crop

58 GRDC (2016) Sunflower nutrition. GRDC Tips and Tactics, http://www.grdc.com.au/TT-SunflowerNutrition

59 Australian Oilseeds Federation (2012), Better Sunflowers Agronomy Training Package (Big Yellow Sunflower Pack), Agronomy https://bettersunflowers.com.au/bysp/surveyinfo.aspx?sid=5

Deficiencies	Symptoms	Occurrence	May be confused with...	Management
Iron	Younger leaves have pale yellow interveinal chlorosis, plant stunting, spindly stems. Severe cases develop brown necrosis	Alkaline soils as iron is less available at high pH. Waterlogged soils, acid soils with excess Mn, Zn, Cu, Ni	Zinc toxicity	Foliar spray of iron chelate
Molybdenum	Older leaves are pale yellow; leaves may become cupped with necrotic leaf margins. Reduced establishment, seedling death.	Acid soils especially under irrigation	N and S but they usually occur later than Mb symptoms and Mb more distinct	Apply sodium molybdate before sowing, or as an in crop foliar spray. Alternatively use a Mb seed dressing.
Toxicities	**Symptoms**	**Occurrence**	**May be confused with...**	**Management**
Aluminium	Roots discoloured, multiple short, thick lateralroots. Poor seedling emergence, stunted plants, low vigour and yield	Highly acidic soils (pH<5)	P and Mg deficiency on leaves	Lime acid soils to raise pH.
Manganese	Brown/black spots on lower stem, petioles, leaf blade hairs; severe symptoms are interveinal chlorosis upper leaves , white necrotic patches, leaf crinkling.	Highly acid soils or poorly drained soils high in Mn	Distinctly individual except petiole necrosis may look like Ca deficiency or disease	Lime acid soils, improve drainage. Don't grow sunflower in poorly drained soils

Source: Big Yellow Sunflower Pack 2015