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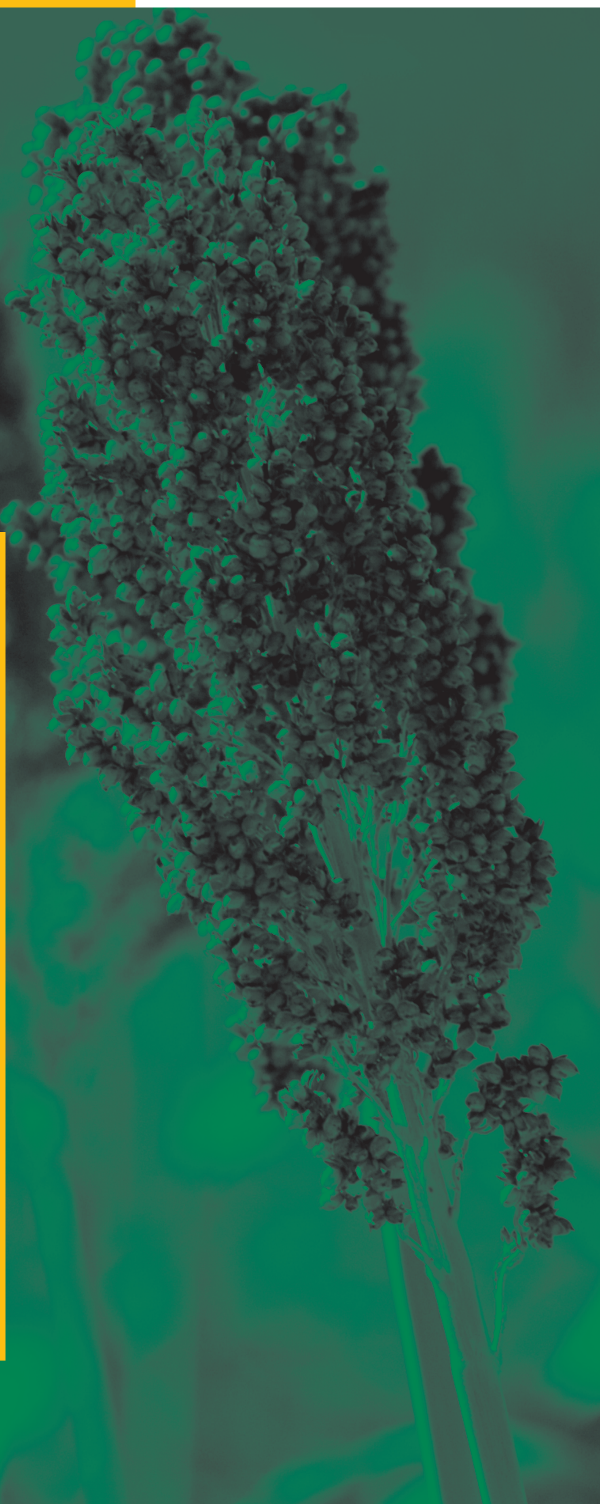

SORGHUM

SECTION 5

NUTRITION AND FERTILISER

DECLINING SOIL FERTILITY | CROP REMOVAL RATES | SOIL TESTING | NITROGEN | PHOSPHORUS | ZINC | POTASSIUM | SUBSOIL CONSTRAINTS

Nutrition and fertiliser

A balance of soil nutrients is essential for profitable yields. Fertiliser is commonly needed to add the essential nutrients phosphorus (P), potassium (K), sulfur and zinc. Lack of other micronutrients may also limit production in some situations.

Knowing the nutrient demand of crops is essential in determining nutrient requirements. Soil testing and nutrient audits assist in matching nutrient supply to crop demand. [1]

5.1 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.[2]

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.

5.1.1 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'* [3] 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

1 P Matthews, D McCaffery, L Jenkins (2013) Winter Crop Variety Sowing Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/aboutus/news/all/2013/2013-wcvsg

2 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

3 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.

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 1).

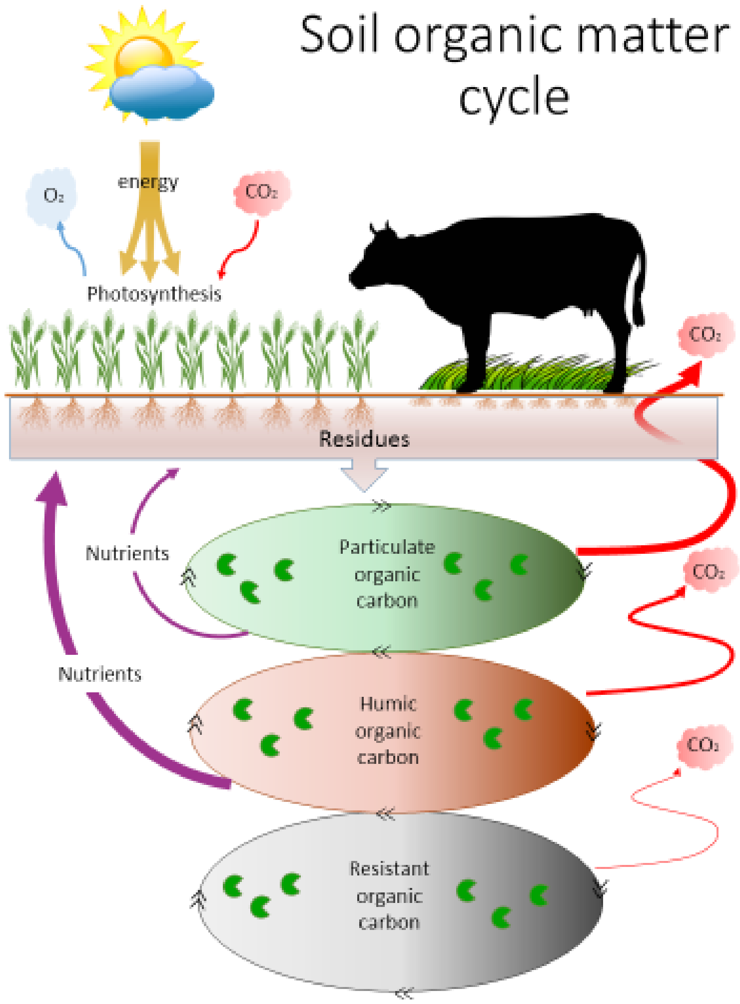

Figure 1: *Organic matter cycle.*

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 2). [4]

4 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

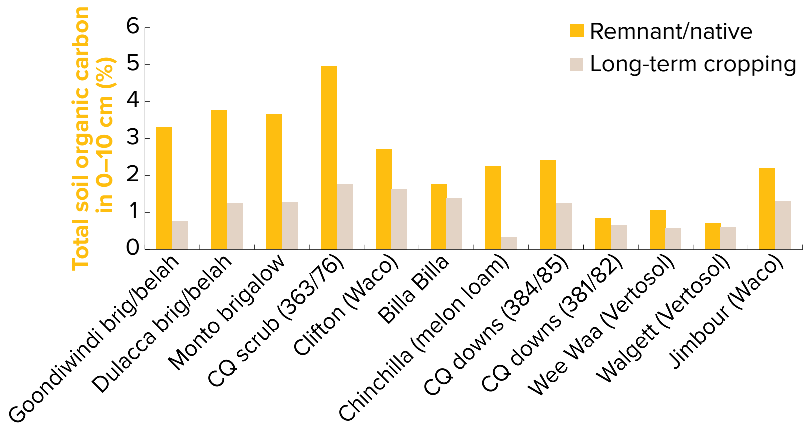

Figure 2: *The decline of soil organic carbon in long-term cropping systems.* [5]

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 3). [6] This translated into reduced wheat yields when crops were grown without fertiliser N.

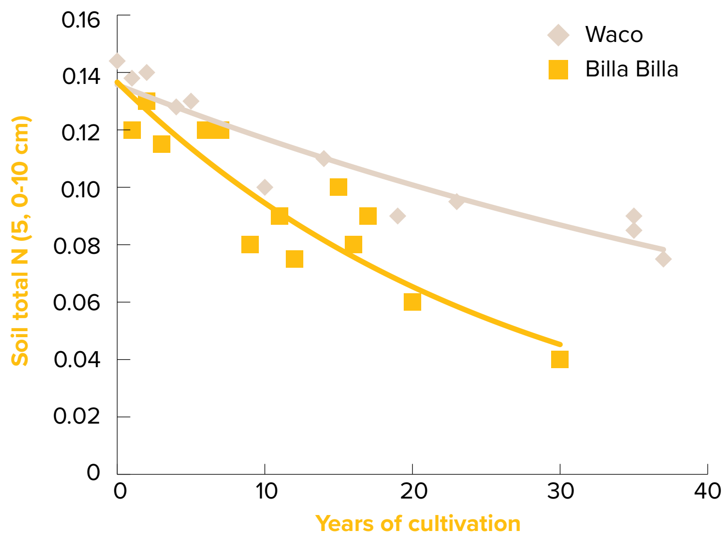

Figure 3: *Graph of decline in soil total N with years of cropping. The decline was greater for the Billa Billa soil (clay content 34%) than the Waco soil (clay content 74%).*

Source: based on Dalal & Mayer (1986a,b) [7]

5 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

6 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.

7 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.

5.1.2 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 4). [8] 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 5). [9]

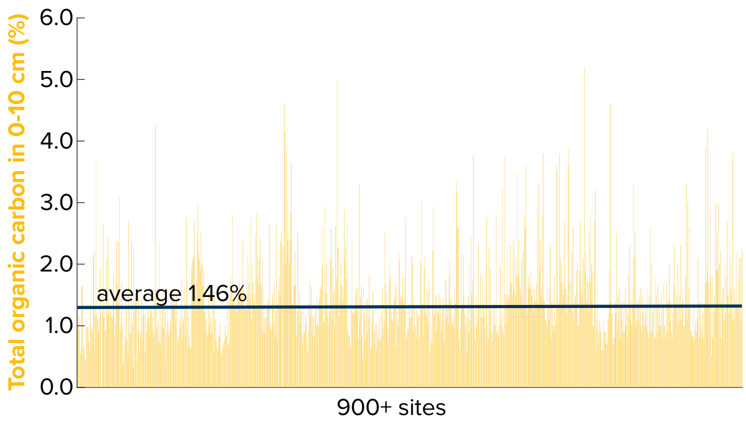

Figure 4: *Soil organic carbon levels on mixed farms within the GRDC Northern Region.* [10]

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

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 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

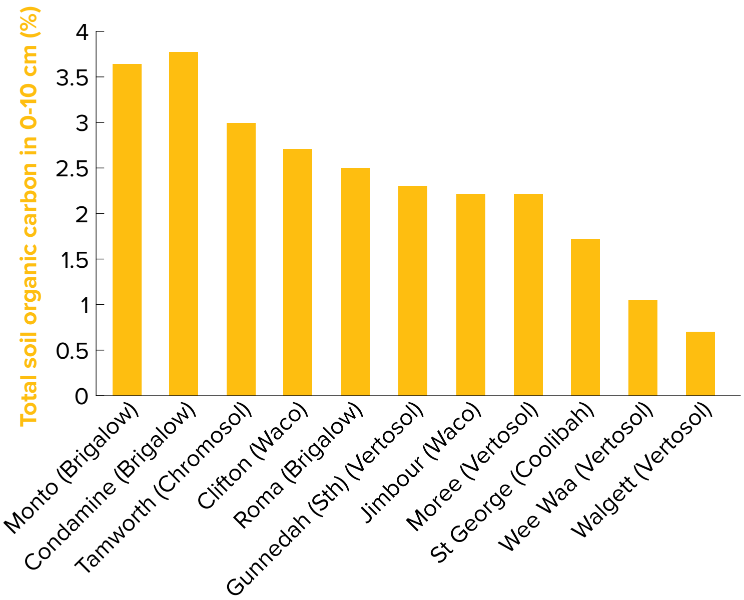

Figure 5: *Impact of land-type on total soil carbon levels (0–10 cm) across the northern region.* [11]

5.1.3 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. [12] 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. [13]

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 1).

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 1).

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.

11 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

12 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.

13 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.

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 1. [14]

Table 1: *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 6). 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. [15]

14 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

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

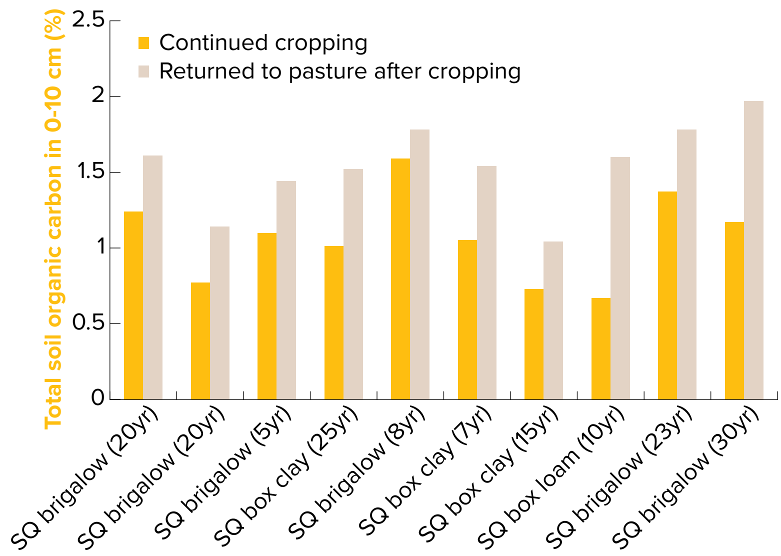

Figure 6: *Total organic carbon comparisons for croplands resown to pasture.* [16]

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. [17]

5.2 Crop removal rates

Nitrogen (N) is the main nutrient required for good sorghum yields, with total requirements of 85 kg N for a yield of 3.5 t/ha, 130 kg N/ha for a yield of 5.2 t/ha, and 150 kg N/ha for a yield of 6 t/ha.

Phosphorus removed in grain for a 5.2 t/ha crop is in the vicinity of 12 kg of P, which equates to 60 kg of mono-ammonium phosphate (MAP). In practice, such a high rate may not be needed. The recommended rate will depend upon the soil test level and the recent history of P application.

16 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

17 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

If the soil test (bicarbonate-extractable or Colwell P) is >15, then there is a low probability of sorghum responding to P fertiliser. This critical value is half that of wheat, reflecting the efficiency with which sorghum is able to extract P from the soil. Sometimes there is an early response to P, but as the root system and arbuscular mycorrhizae (AM) develop, this can disappear.

In a mixed sorghum and wheat cropping system, it may be worthwhile fertilising the wheat crop and not the sorghum, depending on the nutrient status and removal.

The use of P fertiliser is also recommended under cold-start conditions if soil phosphate levels are marginal.

Phosphorus fertiliser is usually applied with the seed, but the suggested maximum rate of MAP on sorghum planted on clay soils in 1-m rows is 35–40 kg/ha. This 'safe' rate should be reduced on loamy soils. If more P needs to be applied than this, it should be put on away from the seed, either in a separate mix with the N fertiliser or in a separate band.

One of the most economical and effective ways to supply P to sorghum crops is to use feedlot manure (Figure 7). One tonne of aged manure contains about 7 kg of P, which means that an application of 8 t/ha will supply 56 kg P/ha, enough for four or five crops of sorghum, and more if the soil P levels are reasonably high and the strategy is to apply about 7–10 kg P/ha.year.

Feedlot manure also applies large quantities of potassium (K) and sulfur (S), which will ensure that there are no deficiencies relating to these nutrients. The N component of the feedlot manure adds to the value. In a good summer season, about half of the total N should be released during the first crop. If 8 t/ha of manure is applied, this means that, of the 128 kg of N in this manure, about 64 kg should be available to the sorghum crop and could be deducted from the fertiliser requirement.

Figure 7: *Feedlot manure supplies large quantities of potassium and sulfur.*

In subsequent years, the extra N release should be considered a bonus, which may boost yields in a good year. In this way, manure applications can provide a little extra reserve of N in an organic form, which can help boost yields in a wet summer. Nitrogen removal at given target yields in northern grains districts is shown in Table 2.

For farms within 60 km of a feedlot, the cost of manure is typically about $22–25/t spread on the paddock, which makes manure good value compared with the equivalent cost of N and P (total $43). If K is of use, the value of nutrients in manure is >$50/t. [18]

MORE INFORMATION

S Simpfendorfer & L Serafin (eds) (2016) Northern grains research results 2016. Research & Development – Independent Research for Industry, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/679102/Northern-grains-research-results-2016.pdf

MORE INFORMATION

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https://www.pioneer.com/home/site/ca/template.CONTENT/products/sorghum/production-manual/guid.AE3799A5-A380-492A-B5DF-1D49E8B1735B

18 P Wylie (2008) Managing sorghum for high yields—a blueprint for doubling sorghum yields. GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Sorghum_HY.pdf

MORE INFORMATION

GRDC Update Paper: The what where and why of soil testing in the northern region

MORE INFORMATION

http://www.grdc.com.au/Media-Centre/GRDC-Podcasts/Northern-Weekly-Update/2014/01/024

MORE INFORMATION

https://grdc.com.au/Media-Centre/Media-News/North/2013/11/In-crop-nitrogen-key-to-summer-sorghum-yields

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Agronomic-and-economic-responses-of-sorghum-to-nitrogen-nutrition

Table 2: *Yield targets and nitrogen removal for grain sorghum*

	Soil moisture (mm)	In-crop rainfall (mm)	Water Use Efficiency	Target yield (t/ha)	kg N/ha removed
Cool areas, better soils (Darling Downs–Liverpool Plains)	160	250	15	6.15	102
In-between areas with brigalow and box soils	150	250	13	5.20	87
Hotter areas, Moree, Condamine, Roma	130	205	10	3.35	61

5.3 Soil testing

Soils should be tested every 3–5 years as part of a nutrient-monitoring program. Actual fertiliser usage should be determined using soil testing, in conjunction records of grain production and grain quality for individual paddocks. Soil test results should be interpreted by experienced, accredited specialists. [19]

Always carry out N tests to the estimated rooting depth of the crop in question. [20]

5.4 Nitrogen

Sorghum responds to the application of N fertilisers. Numerous trials across northern NSW have demonstrated the likely yield benefits, on average 1.8 t/ha, from the application of 80 kg N/ha at or prior to sowing and in short fallow situations; in sorghum following sorghum this was up to 2.9 t/ha.

Research by NSW DPI and the Northern Grower Alliance (NGA) has evaluated the effect of applying N in crop. Results from the 2007–08 season showed that crop yield could be maintained if N is applied post emergence up to the 7-leaf stage.

The contribution of a pulse crop or pasture to soil N largely depends on the quantity of dry matter produced and levels of nodulation. However, as a guide, compared with a previous sorghum crop, cowpea and mungbean crops may leave up to an additional 40 kg/ha of soil N, whereas soybeans and pigeon peas may leave 25–50 kg N/ha.

Nitrogen budgeting can also be used to determine the N requirements of a crop and can be calculated as described below (see section 5.4.3 'Crop nitrogen requirements'). The quantity of N required to grow the crop is about twice the quantity removed in the grain. [21]

5.4.1 Nitrogen supply

The crop N requirement can be supplied from the following sources:

- N in the soil as nitrate
- N mineralised through the growing season
- N applied as fertiliser

Mineralisation rates will depend on age of cultivation, soil organic matter status (see section 5.1.1) and seasonal conditions. Consult your advisor to gain a mineralisation estimate.

The crop N requirement not supplied by the soil from either soil nitrate reserves or mineralisation should be applied as fertiliser (Table 3).

19 QDAF (2011) Sorghum—nutrition, irrigation and harvest issues. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/sorghum/nutrition,-irrigation-and-harvest

20 N Moore, L Serafin, L Jenkins (2014) Grain sorghum. Summer crop production guide 2014, pp. 5–16, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

21 N Moore, L Serafin, L Jenkins (2014) Grain sorghum. Summer crop production guide 2014, pp. 5–16, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

Where a grain legume was the previous summer crop

The contribution of previous summer grain legumes to soil N levels is very erratic, ranging from actual depletion to an increase of up to 40 kg N/ha. Growers are advised to adopt a conservative approach and treat as for other summer crops unless previous experience shows otherwise. With good plant growth but little removal of N in grain (i.e. with low yield), the loss of soil N under cropping will be less with a grain legume than with other crops. [22]

Soil nitrate-N is estimated by soil testing to 100 cm depth and from the cropping history, especially the grain yield and protein content of the previous crop. Using the above example, if only 80 kg/ha of nitrate-N was available in the soil, then a further 80 kg N/ha would be needed. The protein content of grain is a good indicator of the adequacy of N supply to a crop, as shown in Table 4. [23]

Table 3: *Nitrogen rates (kg N/ha) for sorghum, as influenced by crop rotation, on the Liverpool Plains.*

	Dryland sorghum target yield		
Previous crop	**4 t/ha**	**6 t/ha**	**Irrigated sorghum**
Sorghum, sunflower, cotton	100	140	180
Cowpea, mungbean	60	120	–
Soybean	–	–	100
Long fallow, winter cereal	80	120	150
Long fallow, faba beans	30	90	120
Long fallow, chickpeas	45	100	–
Lucerne (good stand)	0	0	–

Nitrogen-fertiliser application rates should be based on your target yield, seasonal expectations and previous paddock history. Application rates will vary considerably from area to area. On the Darling Downs, higher rates are generally used than on the Western Downs or in central Queensland, because the country has been farmed considerably longer, the soils are capable of storing more plant-available moisture, and yield expectations are generally higher. However, the same principles apply in all areas—if the available N is low at planting then adequate N fertiliser must be applied to achieve your yield goal. [24]

5.4.2 Low grain protein, the signal of nitrogen deficiency

The grain protein content of sorghum can be used as a reliable indicator of the N supply available for that particular sorghum crop. Table 4 summarises the relationship between grain protein and N supply. [25]

22 QDAF (2011) Sorghum—nutrition, irrigation and harvest issues. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/sorghum/nutrition,-irrigation-and-harvest

23 N Moore, L Serafin, L Jenkins (2014) Grain sorghum. Summer crop production guide 2014, pp. 5–16, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

24 QDAF (2011) Sorghum—nutrition, irrigation and harvest issues. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/sorghum/nutrition,-irrigation-and-harvest

25 QDAF (2011) Sorghum—nutrition, irrigation and harvest issues. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/sorghum/nutrition,-irrigation-and-harvest

Table 4: *Using sorghum grain protein as an indicator of season nitrogen (N) supply.*

Sorghum grain protein (@13.5% moisture)	Indicated N supply
<9.0%	Acute N deficiency. Grain yield would almost certainly increase with increased N supply (e.g. N fertiliser). Protein percentage will also increase if N supply is adequate for optimum season yield.
9.0–10.0%	Marginal N deficiency. Grain yield may increase and protein will increase with increasing N supply.
>10.0%	Nitrogen not limiting yield this season. Higher N supply may increase grain protein. Producing higher protein percentage by adding extra N is only economical if high protein premiums exist.

5.4.3 Crop nitrogen requirements

The amount of N removed from the paddock in harvested grain can be calculated as:

N removed (kg N/ha) = yield (t/ha) × protein (%) × 1.6

As a rule, twice this amount of N is required to grow the crop. The following formula that can be used to estimate the N requirement of a sorghum crop:

N required (kg N/ha) = yield goal (t/ha) × protein (%) × 3.2

The N supply required to produce a range of yield and protein levels is given in Table 5.

Table 5: *Available soil nitrogen (N) needed for expected yield and grain protein levels.*

Yield (t/ha)	Grain protein				
	8%	9%	10%	11%	12%
2.0	51	58	64	70	77
2.5	64	72	80	88	96
3.0	77	86	96	106	115
3.5	90	101	112	123	134
4.0	102	115	128	141	154
4.5	115	130	144	158	173
5.0	128	144	160	176	192
6.0	154	172	192	212	230
7.0	180	202	224	246	268
8.0	204	230	256	282	308

Available soil N = current soil N (soil test) + estimated mineralisation between the time of testing and harvest

5.4.4 Nitrogen fertiliser application

Nitrogen fertiliser can be applied in a number of forms, the most common being anhydrous ammonia (82% N) and urea (46% N). The choice usually depends on price, availability, and ease and convenience of use.

Care must be taken when applying nitrogenous fertilisers at planting. Release of ammonia from the fertiliser can damage the germinating seedling if applied with the seed at planting. Table 6 details the safe rates for application with the sorghum seed at planting.

MORE INFORMATION

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Agronomic-and-economic-responses-of-sorghum-to-nitrogen-nutrition

https://grdc.com.au/Media-Centre/Media-News/North/2013/11/In-crop-nitrogen-key-to-summer-sorghum-yields

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

Table 6: *Safe rates (kg/ha) of some nitrogen (N) fertiliser products sown with sorghum seed at planting.*

Row spacing (cm)	N applied	Urea	DAP	MAP Starterfos
18	25	54	130	200
25	18	39	90	138
50	9	20	45	69
75	6	13	30	46
100	4.5	10	23	35

Rates should be reduced by 50% for very sandy soil and may be increased by 30% for heavy-textured soils or where soil moisture conditions at planting are excellent.

Rates should be reduced by 50% when planting equipment with narrow slit openers is used (the fertiliser concentration is increased around the seed).

Rates may be increased by 50% when airseeders are used and operating at high pressures with wide openers. Airseeders spread the fertiliser bands when operating at high pressures, reducing the fertiliser concentration around the seed. [26]

5.5 Phosphorus

Sorghum is much more tolerant of low soil P levels than is wheat or barley. Soils with <10 µg/g (ppm) of bicarbonate-extractable P are likely to respond to P. Responses to starter fertilisers are likely in Moree, Tamworth and parts of the Liverpool Plains. [27]

Summer cereal crops generally are not as responsive to P as are wheat and barley. Soil P levels need to be quite low (<15 mg/kg of bicarbonate-extractable P on the Darling Downs, <10 mg/kg on the Western Downs and central Queensland) before consistent responses to P fertiliser occur. Deficiency symptoms include stunted plants and reddening of lower stems. Using a BSES-P test in addition to the traditional bicarbonate-extractable P test will improve the accuracy of identifying P responsive sites.

Fertiliser placement in a band with the seed is important because P movement in the soil is very limited. Application rates vary from 5 to 10 kg P/ha depending on soil type and district.

Research on the Western Downs suggests the strongest responses to deep P in grains (wheat and sorghum) occurred when post-planting rainfall allowed the establishment of secondary roots and tillers, which are the main pathways to plant P uptake and increased yields. In wet years when the topsoil was readily accessible, or in extremely dry years, responses were more limited. [28]

Applying phosphate fertiliser can induce zinc (Zn) deficiency, either by interference with Zn uptake or by relative dilution of Zn concentration in the plant by the large increase in production caused by phosphate application. A small amount of Zn applied with the phosphate overcomes the problem.

Phosphorus deficiency is more likely to occur after a long fallow due to low numbers of AM fungi in the soil. AM fungi are the beneficial soil fungi that help plant roots to take up both P and Zn. [29]

MORE INFORMATION

GRDC Update Paper: Phosphorus and potassium nutrition

MORE INFORMATION

GRDC Update Paper: A calculator to assess the economics of deep placement P over time

MORE INFORMATION

http://www.grdc.com.au/GRDC-FS-PhosphorusManagement

MORE INFORMATION

GRDC Update Paper: Changing nutrient management strategies in response to declining background fertility

26 QDAF (2011) Sorghum—nutrition, irrigation and harvest issues. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/sorghum/nutrition,-irrigation-and-harvest

27 N Moore, L Serafin, L Jenkins (2014) Grain sorghum. Summer crop production guide 2014, pp. 5–16, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf

28 M Bell, D Lester (2015) Improving fertiliser decisions for P on the Western Downs, GRDC Update Papers 31 July 2015, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Improving-fertiliser-decisions-for-P-on-the-Western-Downs

29 QDAF (2011) Sorghum—nutrition, irrigation and harvest issues. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/sorghum/nutrition,-irrigation-and-harvest

5.6 Zinc

Sorghum frequently responds to Zn on the heavy alkaline clay soils. Good yield responses have been obtained in northern NSW from starter fertilisers containing 2.5% Zn applied at 40–100 kg/ha. For longer term responses lasting 5–6 years, Zn oxide should be applied at ~15 kg/ha and incorporated into the seedbed well before sowing. Foliar sprays have also become a popular option for applying Zn. [30]

Yield responses to Zn from trial work and grower experience are common in many areas (i.e. the Darling Downs and Liverpool Plains). Zinc plays a vital role in a plant's ability to use N and transform it into yield and protein. Zinc is, therefore, a vital element to the plant and it should not be overlooked in a balanced crop-nutrition program.

Zinc deficiency is not easy to detect, but response to Zn fertiliser occurs frequently on old cultivation on heavy clay soils with high soil pH and/or high P levels. Soil erosion, soil structural problems (e.g. hardpans) and root diseases can all increase the likelihood of Zn deficiency. The availability of Zn to many crops is increased by the presence of AM in the soil. Crops grown after long fallows or other events that deplete soil AM population will be most at risk of suffering Zn deficiency. [31]

5.6.1 Critical levels for zinc

Soil pH <7.0: 0.4 mg/kg (DTPA-extractable Zn)
Soil pH >7.0: 0.8 mg/kg (DTPA-extractable Zn)

On the Western Downs, the deficiency is usually associated with low soil Zn test (<0.4 mg/kg), high soil pH (>8) and low organic carbon (<0.7%).

Zinc can be applied directly to the soil (Zn sulfate monohydrate), as a component of a starter fertiliser, as a foliar spray (Zn sulfate heptahydrate) or as a seed dressing. Zinc sulfate monohydrate should be applied at least 4 months before planting at 10–20 kg/ha, which will provide enough Zn for 5–8 years. [32]

5.6.2 Sulfur

Sulfur responses are widespread on the eastern and southern Darling Downs. Deficiencies have also occurred on the Anchorfield and Haselmere soil types of the central Darling Downs and in areas of the Jimbour plain. It is prevalent on basaltic black earth soils that have been intensively farmed for ≥20 years, particularly if they have been eroded, waterlogged or irrigated, and especially where double-cropping is practiced. Soil S levels in the intensively farmed districts east of the range tend to be low, especially where gypsum and/or S-containing fertilisers have not been used regularly.

Soil test levels <4 mg S/kg (0–10 cm) are indicative of likely S response. A rate of 8–10 kg S/ha is normally adequate. A deep soil test to 120 cm may give a better indication of profile S supply.

Gypsum at the rate of 200–400 kg/ha every 3 years is the cheapest source of S. [33]

5.7 Potassium

Potassium deficiency rarely occurs in the sorghum-growing areas of Queensland except in the South Burnett. However, there is the potential for the deficiency to occur on some of the older farming soils, particularly on the Darling Downs.

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30 QDAF (2011) Sorghum—nutrition, irrigation and harvest issues. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/sorghum/nutrition,-irrigation-and-harvest

31 QDAF (2011) Sorghum—nutrition, irrigation and harvest issues. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/sorghum/nutrition,-irrigation-and-harvest

32 QDAF (2011) Sorghum—nutrition, irrigation and harvest issues. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/sorghum/nutrition,-irrigation-and-harvest

33 QDAF (2011) Sorghum—nutrition, irrigation and harvest issues. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/sorghum/nutrition,-irrigation-and-harvest

Because of the gradual decline in soil K levels with crop removal and historically low fertiliser application rates, some situations (particularly red soils) require K fertiliser applications. However, crops also vary in their response to improved soil K levels. Generally, winter cereal responses have been low to moderate unless gross deficiencies occur. Yields of rain-grown cereals such as maize and sorghum are less likely to respond to K applications than yields of grain legumes (soybeans and navy beans) and peanuts under conditions of marginal soil K status.

Potassium fertilisers cannot be placed in direct contact with seed at rates required. Fertilisers should be applied by side-banding at planting, combine-drill pre-plant in fallow, or broadcast and cultivated in fallow or prior to preceding crop. [34]

5.8 Subsoil constraints

Subsoil salinity is quite common in the brown, grey and black clay soils in northern NSW. Salinity is the salt concentration in the soil solution. Whereas previous research from experimentally imposed salt levels had indicated that grain sorghum is tolerant of salinity, more recent research in northern NSW indicates that grain sorghum is much more sensitive to salinity.

The recent research showed a rapid decline in plant growth and yield as soil salinity increased, i.e. when electrical conductivity (EC, saturated extract) increased from 2 to 5 dS/m. Anecdotal reports from growers and agronomists agree with these experimental results that where there is subsoil salinity, root exploration by grain sorghum into these saline layers is greatly reduced.

In addition to subsoil salinity, subsoil sodicity is reasonably common in northern NSW. A sodic soil has an excess of exchangeable sodium ions attached to clay particles. This excess of ions affects the physical characteristics of a soil by causing dispersion. When a clay soil disperses with water, the clay particles swell, as they are no longer bound together, and this minimises drainage through the soil pores (spaces). A dispersive soil sets hard when dry.

Subsoil sodicity restricts rooting depth. It therefore restricts crop access to water and nutrients. Surface sodicity results in surface sealing and reductions in water infiltration and may cause waterlogging on the surface or inhibit emergence. [35]

34 QDAF (2011) Sorghum—nutrition, irrigation and harvest issues. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/sorghum/nutrition,-irrigation-and-harvest

35 N Moore, L Serafin, L Jenkins (2014) Grain sorghum. Summer crop production guide 2014, pp. 5–16, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/303485/Summer-crop-production-guide-2014.pdf