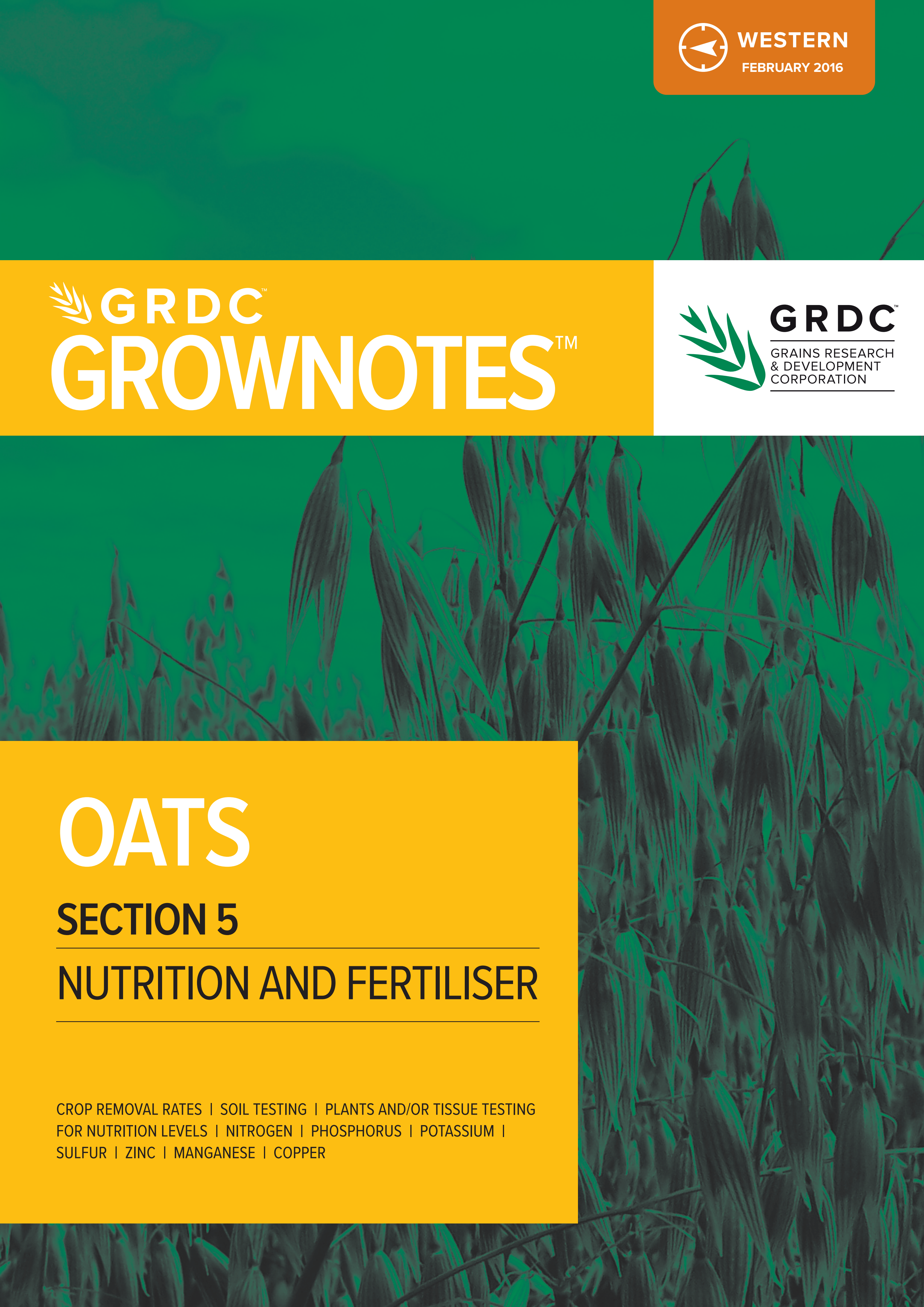

WESTERN
FEBRUARY 2016

GRDC GROWNOTES™

GRDC™ GRAINS RESEARCH & DEVELOPMENT CORPORATION

OATS

SECTION 5

NUTRITION AND FERTILISER

CROP REMOVAL RATES | SOIL TESTING | PLANTS AND/OR TISSUE TESTING FOR NUTRITION LEVELS | NITROGEN | PHOSPHORUS | POTASSIUM | SULFUR | ZINC | MANGANESE | COPPER

SECTION 5

Nutrition and fertiliser

FAQ

Oats have traditionally been considered a low input crop and have generally been grown on paddocks with lower soil fertility. The development of higher yielding grain and hay varieties combined with greater emphasis on grain and hay quality from both export and domestic markets means that nutrient management has to be more carefully considered when growing oats.

Most oat varieties grown on poor soil (e.g. low in nitrogen) could develop red-tipping on the leaves and this may result in below-optimum yields.

Nutrition requirements for nitrogen (N), phosphorus (P) and potassium (K) in oat grain crops are similar to those recommended for wheat or barley.

It is important for growers to use both soil testing and tissue testing to ensure the crop nutrient status is adequate for plant growth. As per other cereals, nutritional inputs should be based on soil test data and yield potential of the crop.[1]

Apply fertiliser at above the normally recommended rates to crops used for grazing and grain, as they have a longer productive period than grain-only crops.

5.1 Crop removal rates

Table 1: Nutrients removed (kg) per tonne of grain production [2]

Crop type	Nitrogen	Phosphorus	Potassium	Sulfur
Wheat	21	3.0	5	1.5
Triticale	21	3.0	5	1.5
Barley	20	2.7	5	1.5
Oats	17	2.5	4	1.5

5.2 Soil testing

Soil test information can be used to support decisions about fertiliser rate, timing and placement. Soil testing is the only quantitative nutrient information that can be used to predict yield response to nutrients.

Soil samples should be taken before sowing so that results and recommendations are available in time to order the right fertiliser product(s). Crop nutrition can be monitored by tissue testing to check the availability of soil and applied nutrients.

Choose a laboratory that has the Australasian Soil and Plant Analysis Council certification for the tests they offer. National Association of Testing Authorities accreditation is also desirable.

1 DAFWA (2015) Oats: fertilisers and plant nutrition, https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition

2 Agriculture Victroia (2008) Establishing forage cereals, http://agriculture.vic.gov.au/agriculture/dairy/pastures-management/forage-cereals/establishing-forage-cereals

More information

Soil testing for crop nutrition (Northern Region)

Better fertiliser decisions for crop nutrition

Regular soil testing using the same GPS locations in paddocks (e.g. every three years) allows monitoring of fertility trends over time. [3]

The most common soil sampling depth for nutrient analysis is 0 to 10 cm for broadacre crops. This layer was chosen because nutrients, especially P, and plant roots are concentrated within this layer. To obtain more comprehensive soil data, including nutrient data, sampling below 10 cm should be considered for some nutrients. [4]

5.3 Plants and/or tissue testing for nutrition levels

Figure 1: Oats crops remove significant quantities of all major nutrtients. (Photo: DAFWA)

The agricultural areas of Western Australia are dominated by sandy soils. They contain low amounts of organic matter and are poor at retaining water and nutrients. As with wheat and barley crops, oat crops grow poorly if nutrients aren't added. The major nutrients required for healthy growth are N, P, K and S; and the micronutrients Cu, Mn, Mo and Zn.

Oat crops, particularly oaten hay, remove significant quantities of all the major nutrients. It is, therefore, important for growers to use both soil testing and tissue testing to ensure the crop nutrient status is adequate for plant growth. Application of nutrients is required to optimise production either on an annual basis for nutrients like N and P or less frequently for the micronutrients like Cu and Zn.

The continued loss of nutrients from paddocks without replacement becomes particularly important when the soils are already marginal or deficient in nutrients. Continually depleting nutrients, particularly K, from soil with adequate amounts of that nutrient will eventually reduce soil K supply and decrease the productivity and quality of produce. Removing nutrients from the soil may also reduce its pH. As the plant material is removed from the paddock, there is a net export of alkalinity which leaves residual hydrogen ions in the soil to maintain electrical balance. As this process is repeated over time the soil becomes acidic. [5]

More information

CSBP Soil and Plant Analysis Laboratory

While oats have a higher tolerance to acidic soil and high aluminum levels than barley and wheat, economic responses to liming are still achieved. Therefore it is important to monitor top- and sub-soil pH levels to determine if liming is required.

[3] GRDC (2013) Better fertiliser decisions for crop nutrition, http://grdc.com.au/Resources/Factsheets/2013/11/Better-fertiliser-decisions-for-crop-nutrition

[4] GRDC (2014) Soil testing for crop nutrition (Northern Region), http://grdc.com.au/Resources/Factsheets/2014/01/Soil-testing-for-crop-nutrition-North

[5] DAFWA (2015) Oats: Fertilisers and nutrition, https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition

5.4 Nitrogen

5.4.1 The importance of N management

Nitrogen is largely responsible for setting up the yield potential of the crop. Nitrogen is required for tiller development and required by plants to create protein. The N for plant growth is supplied from both the soil and from N fertiliser application. Nitrogen is taken up by the oat plant when it is in an inorganic form (as either ammonium or nitrate). In the soil over 98% of the N is in an organic form which cannot be taken up by the oat plant until it is mineralised. A large proportion of the oat plant's requirement for N is supplied by the soil. Where the available N supply from the soil is inadequate for optimum yield and quality, N fertiliser is required. Soil testing helps estimate the amount of N already available in the soil. Soil type, cropping history, yield potential and the season are important factors to consider in N management decisions.

The amount of N fertiliser required to grow a grain or oat hay can be estimated from your fertiliser decision support programs. As a rule of thumb, N fertiliser at 40 to 80 kg per hectare (N/ha) has been found ideal for most growing conditions in Western Australia. The amount of N required will be modified by seasonal conditions and the oat variety. Dwarf varieties have a higher N requirement; it is suggested that the N application rate used be increased by about 20% above that recommended for non-dwarf varieties.

Oat hay and grain yield response to applied N depends on the soil moisture available during the season. In a dry season there is usually a poor crop response to applied N due to water being more limiting to yield than N supply. Poor finishes to the season also reduce crop yield and grain quality irrespective of how much N is applied.

Nitrogen can leach in wet seasons, particularly in sandy soils. In leaching situations, the N requirement for oats can be delayed and/or split to reduce the N lost by leaching. In waterlogged soils, applying UAN can achieve better responses than urea. To maximise hay quality, any late N should be applied between tillering (Z25) and stem elongation (Z31). Applying N too late (later than Z33) causes nitrates to accumulate in the plant dry matter, reducing hay quality. For grain yield, profitable responses to N application have been found up to 10 weeks after sowing. There is generally little chance of a profitable yield increase to N fertiliser occurring if the N is applied later than 10 weeks after seeding. [6]

Increasing N supply:

- may increase hay yield
- increases hay greenness
- increases stem fibre levels (acid detergent fibre and neutral detergent fibre)
- decreases water-soluble carbohydrates (WSC)
- may increase in-vitro digestibility and metabolisable energy slightly
- may sometimes lead to high nitrate N levels – unacceptable in many hay markets
- interacts with variety for fibre and WSC

The method of N application needs to be considered. Split applications of N appear important, particularly for hay.

- For hay production, do not apply excessive levels of N as it may decrease hay quality by increasing stem fibre levels and decreasing WSC. Varieties may differ in their response to the amount and method of applied N.

[6] DAFWA (2015) Oats: Fertilisers and nutrition, https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition

Interaction with seeding rates

- Increasing the seeding rate will increase oat grain and hay yields irrespective of N fertiliser levels. Higher seeding rates can increase grain screenings and reduce leaf greenness in hay. However, higher N fertiliser rates will increase yields.

Research has shown the response of oat grain yields to seeding rate is independent of the N application rates. High seeding rates and high N fertiliser rates increase screenings but no other quality parameters. Hay yield response to seeding rate was independent of the level of applied N.

Leaf greenness was the only aspect of hay quality that decreased as seeding rate and N levels increased. At low levels of N there was a larger drop in upper canopy leaf greenness as the number of plants sown increased, compared to greater amount of N applied. Stem thickness of oats decreased as seed rate increased irrespective of N fertiliser which improves hay quality.

Interaction with potassium

- Maintaining adequate amounts of N and K nutrition are necessary for optimum grain and hay yields. Supplying adequate rates of K resulted in better grain and hay quality

Trials have shown that both N and K are important to optimise yield and quality of oat hay and grain. When soil test K levels are low (Colwell K soil test of less than 80 mg/kg) the response of oat plants to fertiliser N can be affected by K deficiency. To optimise the response to fertiliser N, adequate K fertiliser has to be applied.

Results suggested that both oat hay and grain yields were governed mainly by applied N but required at least 70 kg K/ha to achieve their optimum levels.

Whilst N and K interact to influence hay yield, they do not interact to influence hay quality. On K-deficient soils, increasing K (regardless of N supply) reduces NDF and crude protein and increases WSC of the hay.

Grain yield increases as combined N and K fertiliser rates increase. The relationship suggests that it would not be economical to add K without an adequate amount of N fertiliser.

As with grain yield, N and K can also interact to influence grain quality. Grain quality is also affected by combined N and K fertilisers. Under low N supply, K provides little benefit, but if N supply is high, a lack of K can affect quality. [7]

N-deficiency symptoms

Nitrogen-deficiency symptoms of oats appear in the early growth stages and become more severe as the plant grows. When the crop is young, stems are short and thin; leaves and stems are pale green. At flowering, N-deficient plants are stunted, have fewer tillers and smaller heads than N-adequate plants. At maturity, the crop is multicoloured with upper leaves pale green and middle leaves yellow to pale green with red tips. The oldest leaves may have died, turned brown and fallen onto the soil. Grain yield is reduced primarily due to there being fewer kernels per head and lower head density. [8]

5.5 Phosphorus

Phosphorous is important for oat production. Adding P fertiliser can increase both hay and grain yield, depending on the soil test P. The optimum P requirements for hay and grain appear to be different. Oat varieties may differ in their P requirements.

7 DAFWA (2015) Oats: Fertilisers and nutrition, https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition

8 DAFWA (2015) Oats: Fertilisers and nutrition, https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition

Phosphorus is a major nutrient for improving oaten hay and grain production. Phosphorus is a vital component of adenosine triphosphate (ATP), the 'energy unit' of plants. ATP forms during photosynthesis and is used from the beginning of seedling growth through to the formation of grain and maturity. Deficiencies result in slow growth, decreased hay and grain yields, inferior quality and subsequently lost income.

It is suggested that P can be applied at crop establishment as an adequate supply is critical for rapid development. Phosphorus is needed during early growth for plant root development and elongation, so P fertilisers are drilled with the seed during sowing. An economic response is unlikely if the application is delayed for more than 10 days after sowing.

The oat crop response to P will be influenced by the level of Colwell P and the ability of the soil to retain P (Phosphorous Retention Index – PRI). On low P-fixing soils (PRI < 2 mL/g, reactive Fe < 280 mg/kg and Phosphorous Buffering Index < 15), P is held very loosely, making it more available to plant roots and potentially reducing the amount of P required for maximum economic yield. On medium and high P-fixing soils (PRI 2 –15 mL/g and >15 mL/g, reactive Fe 280–1000 mg/kg and > 1000 mg/kg, respectively), P is held more tightly with less available to plant roots. A better response to applied P is expected where soil Colwell tests are low. Soil testing is therefore required before deciding what rate of P to apply. [9]

P-deficiency symptoms

Phosphorus deficiency results in poor seedling establishment and root development. The deficiency symptoms usually only occur if the deficiency is severe and are more noticeable in young plants as they have a greater relative demand for P than more mature plants. The tips of the old leaves become dark orange-yellow and this colour moves towards the base, usually along the leaf edges. The affected leaves often have green bases, orange-yellow mid-sections and bright red or purple tips and the edges of the leaves are rolled inwards. In severe deficiency, affected areas die and turn red and purple. [10]

5.6 Potassium

Potassium is an important nutrient for oat production. Hay crops remove large amounts of K. Potassium is required for photosynthesis, transport of sugars, enzyme activation and controlling water balance within plant cells. A deficiency of K results in poor root growth, restricted leaf development, few grains per head and smaller grain size which affects yield and quality.

Potassium deficiency is more common on lighter textured soils where there is less clay and organic matter to retain the K in the root zone. The deeper sands on coastal plains, which are peaty and occur on the south coast, are the most prevalent K-deficient soils of the high rainfall zone of Western Australia. Potassium deficiency is likely to occur if the soil has less than 60 mg/kg of K in the topsoil.

Potassium deficiency can reduce the tolerance of plants to environmental stresses such as drought, frost and waterlogging, as well as pests and diseases. Potassium deficiency can reduce straw or stalk length leading to lodging problems.

Crop requirements for K change during the growing season. Potassium uptake is low when plants are small and increases during late vegetative and flowering stages. Research in Western Australia has shown that oat yield response to added K depends on the soil extractable K (Colwell K) and environmental conditions. Adding K has a positive effect on quality for hay and grain where soil K levels are low to deficient.

9 DAFWA (2015) Oats: Fertilisers and nutrition, https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition

10 DAFWA (2015) Oats: Fertilisers and nutrition, https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition

Symptoms of K deficiency progress slowly and can be costly if not detected in time. Regular soil and plant analysis and nutrient budgeting can ensure that K deficiency does not occur. Muriate of potash (KCl) is the cheapest form of K. It is applied by top dressing either before seeding or up to 5 weeks after seeding. If K deficiency is diagnosed in the soil by Colwell-extractable soil tests, applying 20–40 kg K/ha as muriate of potash (40–80 kg/ha) may give an economic yield increase. Potassium at low rates can be banded below or with the seed at sowing, with sulfate of potash safer than muriate of potash. Higher amounts of K drilled with seed can decrease seedling germination, mainly due to salt effect. Western Australian research has shown that banded K is twice as efficient as top-dressed K. In other words, applying 10 kg of K in the furrow achieves an equivalent plant response of top-dressing 20 kg/ha of K.

Hay crops remove greater amounts of K (about 10 kg K/t) compared to K losses in grain. The removal of nutrients in hay has to be considered when planning fertiliser requirements for following crops. Practices such as swathing of canola and concentrating and burning of windrows can have significant effects on the spatial distribution of K across the paddock. For these reasons growers should use soil test results in conjunction with plant tissue testing and visual symptoms to determine application rates for paddocks. Decision support tools relate soil test values and other soil characteristics to yield potential to five recommended K application rates. [11]

K-deficiency symptoms

Potassium is very mobile in plants. In deficient plants, K is redistributed to the new growth and the deficiency symptoms first appear in the older leaves, which turn pale green and bronze with yellow areas developing in the mid-section of the leaf between the edge and mid-vein. These areas quickly extend towards the leaf tip until the top two-thirds of the leaf is bronze-yellow. Grey-brown spots develop within the bronze-yellow areas. Typically, the deficient plant develops a three-tone appearance with green younger leaves, green with yellow to bronze colours on the middle leaves and brown older leaves. [12]

5.7 Sulfur

Sulfur has an important role in forming proteins and is essential for producing chlorophyll. Crops that have a high N requirement must have adequate S to optimise N utilisation and protein synthesis.

Sulfur deficiency in oat crops is rare in Western Australia, mainly because of the widespread use of superphosphate (11% S). As with N and P, most of the S in the soil is in organic form. Soils with low amounts of organic matter are prone to S deficiency. Sulfur in organic matter must be mineralised to sulfate before being taken up by roots. Sulfate is mobile in soils and can be leached out of the rooting zone during winter. Deficiencies therefore most often occur in wetter years. On duplex soils, deficiency symptoms may be only temporary as roots grow into the deeper soil layers where more S is available.

Sulfur deficiency is expected to increase in oat crops in the future as more compound fertilisers containing lower S are used in oat production. Hay production, particularly on sandy soils is expected to increase the risk of S deficiency as hay crops remove about 1.5 kg S/ha per tonne of hay.

A soil test value of less than 10 mg/kg in the soil surface (0–10 cm) indicates likely S deficiency. However, S in the soil frequently increases down the soil profile, so knowledge of the distribution of S in the soil profile is required. This may involve deeper soil sampling to know the S supply in the soil. Applying P as superphosphate and

11 DAFWA (2015) Oats: Fertilisers and nutrition, https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition

12 DAFWA (2015) Oats: Fertilisers and nutrition, https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition

compound fertilisers that apply S at 5 to 10 kg/ha can avoid S deficiency. Similarly sulfate of ammonia can be a cost-effective source of N and S.

S-deficiency symptoms

The youngest leaves of S-deficient plants are pale green and then pale yellow across the whole leaf (no striping). Under severe deficiency the entire plant becomes a lemon-yellow colour with red stems.[13]

5.8 Zinc

Zinc is a component of many plant enzymes and essential for healthy plant growth and leaf formation. Oats are highly susceptible to deficient levels of Zn in the soil. After the initial recommended application, most micronutrients have a long residual value in the soil. Tissue testing is the only effective way to determine if there is adequate plant-available Zn in the soil.

Although plant symptoms may be sufficient to diagnose Zn deficiency, a tissue test may also be required. Zinc concentrations in the young leaves of less than 14 mg/kg indicate that the plant is Zn deficient.

An initial application of 1 to 2 kg/ha zinc oxide (75% Zn) will correct a deficiency for many years. A foliar spray of 1 kg/ha zinc sulfate (23% Zn) in 50–100 L of water should be applied as soon as Zn deficiency is detected to prevent grain and hay yield losses.

Zn-deficiency symptoms

Zinc deficiency causes patchy growth, with plants in poor areas stunted with pale green leaves and yellow or orange-red tips. Youngest leaves usually remain green, middle and older leaves turn pale green and pale yellow areas develop between the leaf edge and mid-vein at the tip. Brown spots occur in the affected areas, increasing in size until the leaf tip dies, often turning red-brown to black.

With severe deficiency the stem remains very short and youngest leaves have difficulty emerging fully. The symptoms can be mistaken with that of *Barley yellow dwarf virus* and severe P deficiency. [14]

5.9 Manganese

Oats can be found to be highly susceptible to Mn deficiency which can cause significant yield losses. In severe cases, the crop may die.

Tissue tests and visual symptoms can be used to help diagnose Mn deficiency. Mn concentrations less than 20 ppm (mg/kg) in whole shoots indicate Mn deficiency. The concentrations of Mn in tissues vary across oat varieties.

If manganese sulfate (25% Mn) is applied as a foliar spray at a rate of 4 kg/ha (1 kg Mn/ha in 50 to 100 L of water) when symptoms first appear it is usually effective in correcting Mn deficiency; however, a repeat spray a few weeks later may be necessary.

Applying ammonium sulfate and ammonium nitrate can markedly reduce Mn-deficiency symptoms. Drilling fertilisers enriched with Mn can reduce the risk of crop damage from Mn deficiency. However, even where an ammonium-enriched fertiliser has been used, severely deficient patches may still require a foliar Mn spray.

One of the side effects of correcting an acidic soil with lime is that higher soil pH levels reduce the availability of manganese. This is most common on gravely soils.

13 DAFWA (2015) Oats: Fertilisers and nutrition, https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition

14 DAFWA (2015) Oats: Fertilisers and nutrition, https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition

A 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

Mn-deficiency symptoms

In oats, Mn deficiency produces a condition called 'grey speck' which occurs in patches. Oats become pale green and young leaves have spots or lesions of grey/brown necrotic tissue with orange margins. These lesions will coalesce under severe Mn-deficient conditions. Plants are weak, stunted, floppy and pale green-yellow and appear water-stressed even when adequate soil moisture is available.

Close examination of the leaf may show slight interveinal chlorosis. The distinction between green veins and yellow interveinal areas is poor. Symptoms can be confused with red leather leaf, which is favoured by prevailing high humidity in high rainfall areas. Symptoms can also be mistaken for take-all. [15]

5.10 Copper

Oats are less susceptible to copper deficiency when compared to wheat and barley; however, Cu is essential for growth and development. Plants need Cu to produce new cells and for pollen development (sterile pollen), and hence Cu deficiency severely affects grain yield. Deficient plants that apparently look healthy can produce shrivelled grain, reducing both grain yield and quality.

Tissue tests using the youngest emerged leaf can help diagnose Cu deficiency. Tissue tests with Cu concentrations < 1.3 mg/kg indicate the plant is severely Cu deficient. Applying 3 to 9 kg/ha of copper sulfate (25% Cu) with fertiliser at seeding in areas suspected to be deficient in Cu correct the deficiency. Copper fertiliser has a long residual in the soil, and a single Cu application at recommended rates can last 20–30 years.

Intermittent tissue testing of the youngest leaves can help monitor the plant-available Cu in the soil.

If a deficiency is detected in a tissue test, it can be corrected with a foliar application of Cu sprayed on the crop up to booting stage. This is relatively inexpensive and very effective at correcting a deficiency and optimising yield.

Cu-deficiency symptoms

Copper-deficient crops have a patchy appearance. Plants in poor areas are stunted, pale green and look limp and wilted even with ample soil water. Late tillers may develop at nodes or joints above ground. Young leaves turn pale green whereas old leaves remain green. Under conditions of severe deficiency, plants may have leaves which die back from the tip and twist into curls.

The ears of Cu-deficient plants are shrunken with gaps such as 'frosted heads'. The heads of Cu-deficient plants have poor seedset from sterile pollen which results in 'white heads', similar to the ear heads affected by drought, heat stress and frost. [16]

Cereal grain yield can often be severely limited by Cu deficiency without showing any previous visual symptoms until there is a failure to form grain. That is why tissue testing earlier in the season is so valuable in areas where Cu deficiency may occur.

15 DAFWA (2015) Oats: Fertilisers and nutrition, https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition

16 DAFWA (2015) Oats: Fertilisers and nutrition, https://www.agric.wa.gov.au/oats/oats-fertilisers-and-plant-nutrition