CANOLA NUTRITION

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SUMMARY

- Canola is grown on a wide range of soil types in Australia, and consequently growers have experienced a variety of nutritional problems with the crop. A nutrient such as Mn may be deficient on one soil type, but toxic on another.
- A concerted effort by public institutions, grower-supported funding bodies and the fertilizer industry has provided solutions to many of the nutritional problems confronting Australian canola growers. However, computer-based decision support tools for canola nutrition need to be developed for specific regions of Australia.
- Genetic engineering of canola for specific nutritional traits such as increased tolerance to high levels of Al and Zn deficiency will be an important future development.

INTRODUCTION

Australia has some of the most infertile soils in the world, as a consequence of the antiquity of the continent and extensive weathering of soils. Many agricultural soils are deficient in both macronutrients (particularly N, P and S) and micronutrients. Canola growers have experienced a variety of nutritional problems with the crop because it is grown on diverse soil types including deep, leached, sandy soils in Western Australia, highly calcareous soils in South Australia, and hard-setting acidic soils in New South Wales. To minimize nutritional disorders and other problems, growers are advised to use only their best fields for canola. The dramatic expansion of canola in Australia has depended in part on overcoming many regional nutritional problems, and this has been achieved through the co-operative efforts of public sector institutions, grower-supported funding bodies, fertilizer companies and grower groups such as 'TopCrop'.

FERTILIZER USE

The expansion of canola in Australia over the last decade has had a significant impact on the use of fertilizer. For example, the application of urea N fertilizer to canola increased from about 5,000 t in 1988 to over 150,000 t in 1998. In addition, it is estimated that the break-crop benefits of canola in improving the yield and protein content of following wheat crops is worth the equivalent of another 100,000 t of urea.

Compared to most other grain crops in Australia, canola has a greater requirement for nutrient inputs to achieve high yields. Canola needs about 25% more N, P and K, and up to five times more S than Australian Standard Wheat to balance fertilizer inputs with nutrient removal in grain. However, across Australia there is considerable variation in fertilizer use on canola due to climate and soil factors, and the N contribution from pasture and grain legumes. In estimating the fertilizer requirements for canola, growers use soil tests, field cropping history, balance sheets based on estimated nutrient removal, plant testing to assess crop nutrient status and test strips in fields to see if adequate fertilizer has been applied.

NITROGEN

In southern Australia, canola was traditionally grown after a legume-based pasture as a break crop for wheat and because of the high mineral N status of the soil. However, there is an increasing trend to grow canola more frequently in longer cropping sequences when soil mineral N is low, so that large applications of N fertilizer are required for high yields. When canola follows a cereal crop of 3 t/ha or more, 75-100 kg N/ha should be applied for a 2-3 t/ha canola crop. Suggested N fertilizer rates for southeastern Australia are shown in Table 2.

Table 2. Suggested rates of N fertilizer for canola in southeastern Australia

Situation	Suggested rate
Canola after dominant legume pasture	nil to 40 kg N/ha
Canola later in cropping rotation	
- high rainfall (>500 mm)	50 to 100 kg N/ha
- low rainfall	25 to 50 kg N/ha
Irrigation and continuous cropping	50 to 120 kg N/ha

Growers usually apply most of the N fertilizer as urea or anhydrous ammonia up to 4 weeks before sowing, plus a portion of the N at sowing in compound 'starter' fertilizers such as mono-ammonium phosphate (MAP; 10%N:22%P:0:1%S) or di-ammonium phosphate (DAP; 18%N:20%P:1%S) banded beside or below the seed to avoid damage during germination. When all the N is applied at sowing, it is banded between the rows for safety. Compounded ammonium phosphate sulphate (15%N:13%P:11%S) and granulated ammonium sulphate are also used to provide N and S. There is little difference in yield response to the various forms of fertilizer N, and price (including transport and application costs) is the dominant factor in determining the N source.

There appears to be little or no yield penalty from split N fertilizer applications to canola. The second N application is usually made at the flower buds visible stage. Split N applications to canola are useful if N fertilizer rates need to be varied according to seasonal conditions on difficult soil types or where yield potentials are high; for example, when canola is grown in the high rainfall zones, or under irrigation. Split N applications are also made where there is a high risk of leaching if all the N is applied before or at sowing. Urea is normally used, and it is topdressed either by a ground spreader or airplane, preferably just before rain.

Nitrogen fertilizer can increase the water use-efficiency of early-sown canola. The additional N enables the crop to cover the ground quicker and develop a dense leaf canopy, resulting in reduced soil evaporation and better water use-efficiency. However, because the N promotes vegetative growth, there is a risk that the crop could become water-stressed during pod filling if soil moisture reserves have been depleted and there is little rainfall.

The N fertilizer rate is usually determined by considering the cropping/pasture history of the field in conjunction with a soil test for mineral N. Growers are advised to use a deep (60 cm) soil test for mineral N close to sowing for calculating N fertilizer requirements. The deep soil test can detect any nitrate-N accumulated at depth. Values for mineral N in soils are typically 30-140 kg N/ha, and canola on sites with over 100 kg/ha mineral N usually has a low response to fertilizer N. Early application of excessive N fertilizer may induce rank growth and subsequent lodged crops that are difficult to harvest.

A range of plant tests based on critical nitrate-N and total N concentrations at defined growth stages are available to assist growers in monitoring the N status of their crops. The nitrate-N concentration in the petiole of the youngest mature leaf or the total N concentration in the whole shoot are generally used to assess the likelihood of a response to additional N fertilizer. With the increasing release of new canola cultivars in Australia, it may become difficult to calibrate robust plant N tests.

'Best practice' rates of N fertilizer usually have little effect on seed oil concentration, although high rates may increase seed protein and reduce the oil concentration (Figure 4).

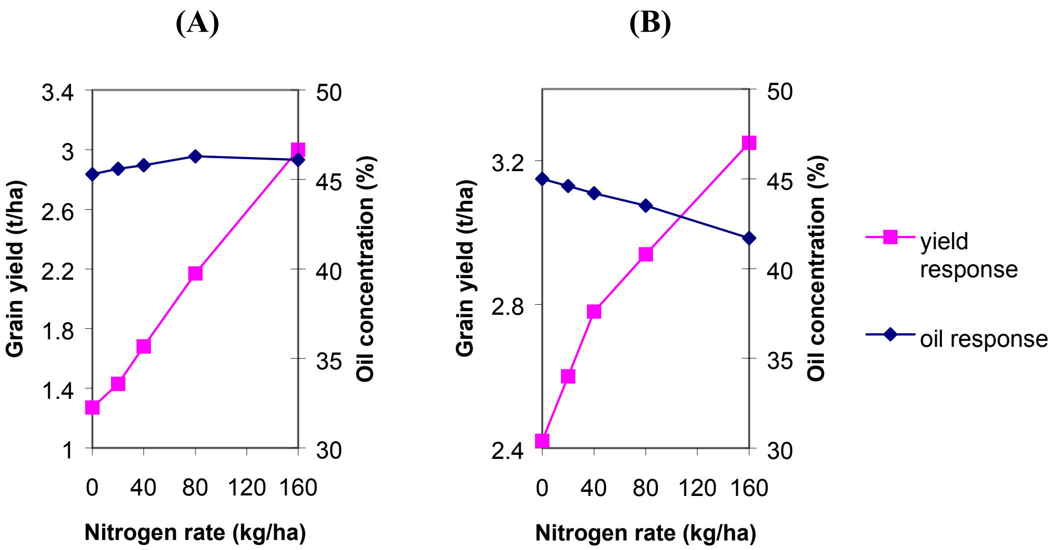

Figure 4. Effect of N fertilizer on seed yield and oil concentration at (A) Wellington and (B) Parkes in central New South Wales. In (A) N fertilizer increased yield but had no effect on oil concentration, whereas in (B) the N increased yield but decreased oil concentration at the higher rates

However, in most cases the increased seed yield due to N fertilizer more than compensates for any decrease in oil concentration. Although there are a few reports of N affecting glucosinolate levels in seed meal, they are inconsistent and it is likely that any effect of N on glucosinolate level is related to S supply.

PHOSPHORUS

Most Australian soils are naturally low in plant-available P, and the application of P fertilizer to canola is routine. The application rate varies from 10-15 kg P/ha in low rainfall regions where yield expectations are 1.0-1.5 t/ha, to 20-30 kg P/ha in high rainfall regions where yields of 2.5-3.5 t/ha are expected. Where the soil pH is below 5.0, P fixation can become significant and P fertilizer rates may be increased. Although the P requirement of canola is high, maximum yield responses on calcareous soils are sometimes attained at P rates similar to those for wheat. It appears that on these soils, canola roots secrete organic acids into the rhizosphere that dissolve some of the P fixed as calcium phosphates, making it available for plant uptake.

With the move to higher N and P fertilizer rates, and the rapid expansion of canola in Australia, many growers have changed from superphosphate to high analysis fertilizers such as MAP or DAP to reduce transport costs and facilitate application. The P fertilizer is usually banded beside or below the seed at sowing to avoid chemical injury during germination.

A number of soil tests are used to estimate P fertilizer rates for canola. The three common tests for so-called plant available P are the two bicarbonate extractions (Colwell- and Olsen-P), and the dilute acid-fluoride Bray 1-P extraction. These tests are reasonably reliable at predicting P responsiveness on acidic soils. However, on highly calcareous soils such as those of Eyre Peninsula in South Australia, the tests may be unreliable for estimating P fertilizer rates for canola. Future research aims to develop a more reliable soil P test for such soils, and to evaluate the effectiveness of acidic liquid P fertilizers on these soils to increase P availability in the early stages of crop growth.

Phosphorus fertilizer applied at commercial rates does not appear to have any effect on canola oil concentration.

SULPHUR

Many Australian soils are inherently low in top-soil S, and derive only a few kg S/ha/year from atmospheric accessions, unlike some European countries that used to receive up to 80 kg S/ha/year from this source. In the past, the low S status of Australian agricultural soils was masked by the use of superphosphate (11% S) to correct widespread P deficiency.

Sulphur deficiency in canola was first recognized in the late 1980s in central and southern New South Wales, and was subsequently identified in canola from all states of southern Australia. This situation arose because of the increased use of high analysis N and P fertilizers containing little S, a reduction in soil organic matter on many farms, and higher yields due to improved cultivars and better crop management. In addition, the higher rates of N fertilizer applied to canola sometimes induced or exacerbated S deficiency on soils of low S status.

Often there are no symptoms of S deficiency at the rosette stage, then a rapid appearance of quite severe symptoms after flower buds become visible. This is probably due to sufficient S being available from mineralized organic matter early in the season to support rosette growth. However, stem elongation occurs during late winter when mineralization of S is low and cannot meet crop demand. Although the symptoms of S deficiency may abate during flowering as S mineralisation increases, yields are reduced. With severe S deficiency, the flower petals are pale yellow to cream and most flowers fail to form pods (Figure 9). Losses of up to 80% of seed yield plus a 20% reduction in seed oil concentration have occurred in central and southern New South Wales due to S deficiency.

Many Australian growers now use pre-sowing soil testing (particularly the KCl-40 test), and plant testing to detect low S soils and incipient S deficiency in canola. The KCl-40 test measures the level of sulphate-S and a proportion of the mineralizable S. Plant tests are based on the concentration of total S in the youngest mature leaf or whole shoot, usually sampled just before stem elongation. Field experiments have shown that S-deficient canola responds to sulphate-S topdressed at the start of stem elongation, giving up to 100% recovery of seed yield and oil concentration. Economic responses to topdressed sulphate-S have been recorded as late as flowering in salvage situations.

Canola requires about 10 kg of sulphate-S per tonne of grain. The standard recommendation in southern New South Wales is to routinely apply 20-30 kg/ha sulphate-S. Lower rates are applied to soils that have naturally occurring gypsum at depth, or where sulphate-S has accumulated deeper in the profile. This can be detected by deep (60-90 cm) soil testing. The S is usually applied pre-sowing as gypsum, or in sulphate-S fortified fertilizer blends or superphosphate at sowing. In general, the cropping history of the field has not proved a reliable guide to the likelihood of S deficiency in canola. Elemental S applied at sowing has been ineffective at overcoming S deficiency because the S is oxidized too slowly during winter to meet crop demands later on.

Although field trials have shown that S fertilizer can increase glucosinolate levels, Australian canola cultivars have such low glucosinolate levels that the increase is insignificant.

OTHER NUTRIENTS

Other nutrient deficiencies have been reported for canola in Australia, but they tend to be limited in distribution and can be rectified through routine applications of either micronutrients or soil ameliorants.

Calcium, magnesium and potassium

Calcium deficiency occurs occasionally in early spring, particularly on acidic soils when plants are waterlogged, and weather conditions are cold and cloudy. Symptoms of the disorder (called ‘withertop’) are the collapse of the stalk tissue in the upper part of the inflorescence and subsequent withering of the flower head above the damaged zone. However, the disorder is transient and patchy within a field, so it is considered to be of little economic significance. Liming to raise the pH increases Ca availability and helps reduce the incidence of ‘withertop’.

There have been no documented reports of Mg deficiency for canola in Australia. However, wheat grown in fields in southern New South Wales that are also used for canola production sometimes shows transient Mg deficiency in winter before the roots reach Mg further down the soil profile. Clearly, the situation for canola requires monitoring.

There are a few reports from Western Australia of K deficiency in canola, but most Australian soils are well supplied with this nutrient. Potassium deficiency in canola is only likely when it is grown on deep sandy acidic soils in high rainfall regions, particularly if a heavy hay crop has been removed the previous season. Rates of 40-80 kg/ha of muriate of potash are recommended in suspected deficient situations.

Micronutrients

There are reports of deficiencies of B, Mn, Mo and Zn for canola in Australia, and it is expected that Cu and Fe deficiencies could also occur. Toxicity from high levels of Al and Mn is a problem on the more acid soils, and B toxicity is a potential problem on some soils derived from marine sediments.

Most canola growers in regions with actual or potential micronutrient deficiencies routinely apply rates recommended for wheat. Canola has a high requirement for Zn, particularly on alkaline soils high in carbonates, and Zn is applied adjacent to the seed at sowing. Molybdenum deficiency is a potential problem on acidic or basaltic soils with low Mo levels, and growers in these regions usually apply sodium molybdate before sowing as a precaution. Manganese deficiency in canola is likely on highly calcareous soils in South Australia and some deep sandy soils in Western Australia.

Canola has a high demand for B, and B deficiency has been reported for canola grown in a field trial on acidic soil near Canberra. The crop failed to set seed without the application of supplementary B at the start of stem elongation. Boron deficiency may become a problem as canola expands onto the acidic soils of the high rainfall tablelands of southern New South Wales. Many of these soils have low B levels, and liming to increase the pH to a level suitable for canola could induce or exacerbate B deficiency.

Sub-soil B toxicity is a major problem of barley and wheat on some soils derived from marine sediments in South Australia and Victoria. It is a potential problem for canola, although anecdotal evidence suggests that canola tolerates considerably higher levels of sub-soil B than barley or wheat. Canola quality Indian mustard (*Brassica juncea*) may be an alternative to *B. napus* canola on high B soils.

Deficiencies of micronutrients are usually addressed by the application of supplemented fertilizer or a form of the element at sowing. Although the response of canola to foliar applied micronutrients is quite good, this method is more expensive and inconvenient.

Soil acidity and liming

In Australia, canola is not recommended for soils below pH 4.5 (in $CaCl_2$), and preferably not below 4.7 if exchangeable Al levels exceed 3%. Many soils where canola is grown have a pH less than 5.0, with some as low as 4.0. Although most of these soils were naturally acidic, their acidity has been increased by agricultural activities. The acidity may occur in either the surface or sub-soil zones, or in both. Soil tests for pH are recommended before growing canola. Samples are taken from the surface (0-10 cm) as well as at depth (10-30 cm) to check for sub-soil acidity.

Where the soil is below pH 5, Al and Mn toxicites can be a problem for canola. Aluminium is much more detrimental than Mn because it kills root tips, the sites of root growth. Plants with Al toxicity have a shallow stunted root system that is unable to exploit soil moisture at depth. The crop does not respond to available nutrients, and seed yield is drastically reduced. Severe Mn toxicity reduces yield because entire leaves become chlorotic and distorted (Figure 10), but the effect on yield of mild Mn toxicity which causes a yellowing of the leaf margins has not been studied.

The most effective treatment for Al and Mn toxicity is liming to raise the soil pH above 5.0. Lime rates depend on the pH to depth and the cation exchange capacity of the soil. Microfine lime is usually applied at 2.5-4.0 t/ha. Shallow incorporation of lime is sufficient to ameliorate surface soil acidity, but deep ripping is required to incorporate the lime, reduce soil strength and improve drainage where there is the more serious problem of sub-soil acidity. In many respects, the sensitivity of canola to soil acidity has had beneficial spin-offs in that it forced Australian growers to implement liming programs before their soils became too acidic for less sensitive crop and pasture species.

There are breeding programs to improve the Al and Mn tolerance of Australian canola, using both conventional technology and genetic engineering. The rationale for increasing the tolerance of canola to soil acidity is to broaden management options for growers while they implement liming programs.

FUTURE DIRECTIONS

Overcoming nutritional constraints to yields will continue to be a priority for the Australian canola industry as yields increase, agronomic practices change and new growers include canola in their farming systems. A major challenge will be to ensure that information on the nutrition and fertilizer requirements of canola is disseminated to growers. It is likely that this will be achieved in two ways: firstly by the development of 'best management practice' packages for canola nutrition for specific regions of Australia, and secondly through the development of computer-based decision support tools for canola nutrition.

Future work will be directed to developing tests for problem soils, such as a more reliable P test for highly calcareous soils. In addition, a national survey of the nutrient status of canola crops would help identify and assess the magnitude of nutritional limitations to yield.

There is considerable effort in Australia to develop other *Brassica* species such as Indian mustard (*B. juncea*) to canola standard. Although it is not anticipated that the nutrition of these alternatives will differ much from that of *B. napus* canola, this should be verified.

Finally, it is likely that genetic engineering of canola will play an importance role in developing new Australian cultivars for increased tolerance of specific nutritional conditions such as high Al in acid soils, and greater tolerance of both high and low levels of micronutrients such as B and Mn.

FURTHER READING

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