PHENOLOGY, PHYSIOLOGY AND AGRONOMY

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SUMMARY

- Canola in Australia is mostly grown in winter-dominant rainfall environments with spring type varieties which do not need vernalisation (winter chilling) to flower although vernalisation speeds up flowering.
- The aim of breeders has been to retain just enough of the responses delaying the onset of flowering to produce a leaf canopy intercepting most of the incoming solar radiation to give a yield potential to match the environmental resources.
- Rain-fed crops are sown usually after the first significant rains in April or May, the growth and yield is then determined by the amount of water available.
- The water use efficiency for potential seed yield is usually between 10-12 kg/ha/mm.
- The key agronomic factors in canola production are linked with increasing whole-farm profitability and sustainability using canola in rotations with cereals and pulses.

INTRODUCTION

Canola in Australia is rather different to crops in most other countries. Here, the crop is usually sown in autumn, but with spring type varieties which do not need vernalisation (winter chilling) to flower although vernalisation speeds up flowering. Crops ripen in late spring or early summer, after a 5-7 month growing season. This compares to the situation in Europe, where most of the crop is of winter varieties which require vernalisation, are sown in early autumn, and harvested late in the following summer, nearly 12 months after sowing. In Canada, by contrast, early maturing varieties are sown in spring, and develop rapidly in the long days to be harvested before the onset of winter, with less than a 4 month growing season. Perhaps the nearest equivalent to the Australian crop is that in the Indian subcontinent, where early maturing varieties are grown over the cooler winter period.
The early rapeseed crops in Australia (1960s and 1970s) were Canadian varieties, which were poorly adapted to the short days of our winter-spring season. Australian researchers have therefore been at the forefront of work to understand flowering responses, and in tailoring the new varieties to our environment. The aim of breeders has been to retain just enough of the responses to delay the onset of flowering to produce a satisfactory leaf canopy. This interception of most incoming solar radiation gives a yield potential to match the environmental resources available. The growth of canola and its seed yield in Australia is almost always limited by the amount of water available to the crop, at least during maturation. The development of ways to measure and improve water use efficiency has therefore been critical in making the most of our environment.

CROP CANOPY DEVELOPMENT AND PHOTOSYNTHETIC EFFICIENCY

The growth rate of the crop is closely related to the amount of solar radiation captured by the leaves. Depending on variety and sowing date, between 9 and 30 leaves are produced on each main stem. The maximum size of individual leaves on the plant in the absence of stress is around 200 cm^2.

Initially, LAI increases slowly in the autumn and winter, then increases rapidly in spring to a maximum just after flowering commences. A leaf area index of about 4 is required for the crop canopy to intercept about 90% of the incoming solar radiation. Leaves senesce and are shed rapidly from late flowering onwards. At full flower, the canopy of flowers can intercept or reflect up to 60% of the incoming radiation, causing potential shortages of photosynthate to the early developing pods underneath. After flowering, a dense layer of green pods provides a photosynthetic canopy up to mid pod filling. Researchers in Australia and Britain have explored ways of improving the structure and efficiency of the crop from flowering onwards. Limiting the number of branches, flowers and pods set can improve the radiation environment and hence rate of seed retention. Removing the petals from flowers (apetalous types) has been shown to also allow more radiation into the crop canopy, to prolong leaf life and improve seed retention. Different pod types, including fewer but longer pods, and more acute angles of insertion on the stems, can also play a role in more efficient crop canopies for photosynthesis in the same way that narrow, upright leaves improve canopies in rice and wheat.

Figure 1.

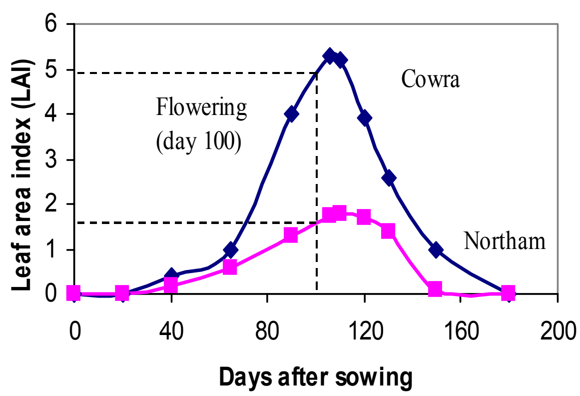

Figure 1. Leaf area index of a canola crop at Northam, Western Australia, and at Cowra, New South Wales

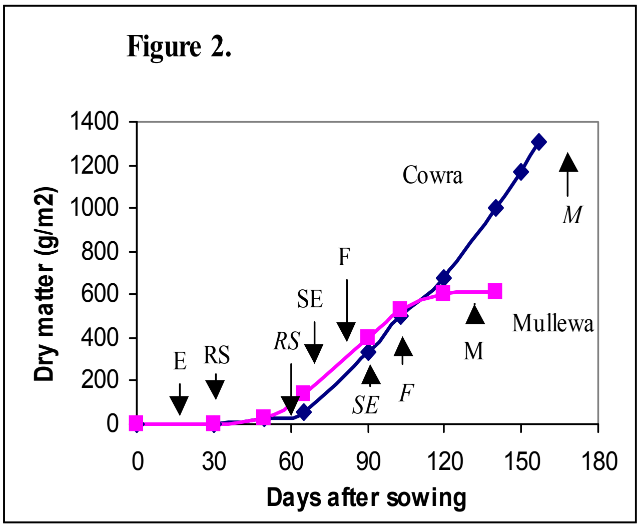

Figure 2. Dry matter accumulation of a canola crop grown at Mullewa, Western Australia, and at Cowra, New South Wales
E = seedling emergence; RS = rosette stage; SE = stem elongation commenced; F = flowering commenced; M = physiological maturity (Cowra site in *italics.*)

DRY MATTER PRODUCTION

Dry matter accumulation in shoots of canola is initially slow (Figure 2), but once canopy closure is reached a period of rapid growth ensues reaching a maximum before slowing as leaves senesce during pod filling. In the absence of major stress from drought or disease, the crop accumulates about 1.2 grams of dry matter in the shoots for each megajoule of solar radiation intercepted by the canopy. At flowering approximately 60% of the shoot dry matter is in the leaves and 40% in stems. During pod filling significant amounts of dry matter may be mobilised from the leaves (before being shed), stem and pod walls and used to fill grain. The green pod walls and stems will photosynthesise actively, although not as efficiently as leaves, as stomatal density is not as high.

Harvest index (the ratio of grain dry weight to above-ground dry weight at harvest maturity) of Australian canola crops typically varies between 0.25 and 0.35. In stressful situations the harvest index may be substantially lower, due to poor pod set. Harvest indices of canola are similar to other grain crops, when account is made for the higher energy content of canola grain (oil containing about 2.5 times as much energy as carbohydrate, as in cereals). At maturity, about 60% of the combined pod and seed weight is in the seed. Seed size varies between 2.5 and 5 mg per seed. While grain yield under dryland conditions generally varies between 0.5 and 3 t/ha, yields in excess of 5 t/ha have been recorded in favourable situations with a long, cool growing season and adequate moisture.

Root growth continues until reaching a maximum late in the flowering phase when water and nutrients may be extracted from as deep as 1-1.5 metres. In the absence of significant soil constraints the leading roots will penetrate downwards through the soil at about 1 cm per day. Typically about two-thirds of the total root system length is found in the top 30 cm of the profile.

OIL ACCUMULATION

Seed oil concentration in Australian crops increases through seed development following an 'S' curve pattern commencing 20 days after anthesis, with a plateau occurring around 60 days after anthesis, the time when seed dry weight is about 70% of its final value (Figures 3a and 3b). Final seed oil concentrations usually vary between 30 and 50% (as received). In general, high temperatures during grain filling, terminal water stress, and high nitrogen supply depress final seed oil concentration. There is a significant impact of variety, with triazine tolerant varieties typically having lower oil concentrations, due to their less efficient photosynthetic system.

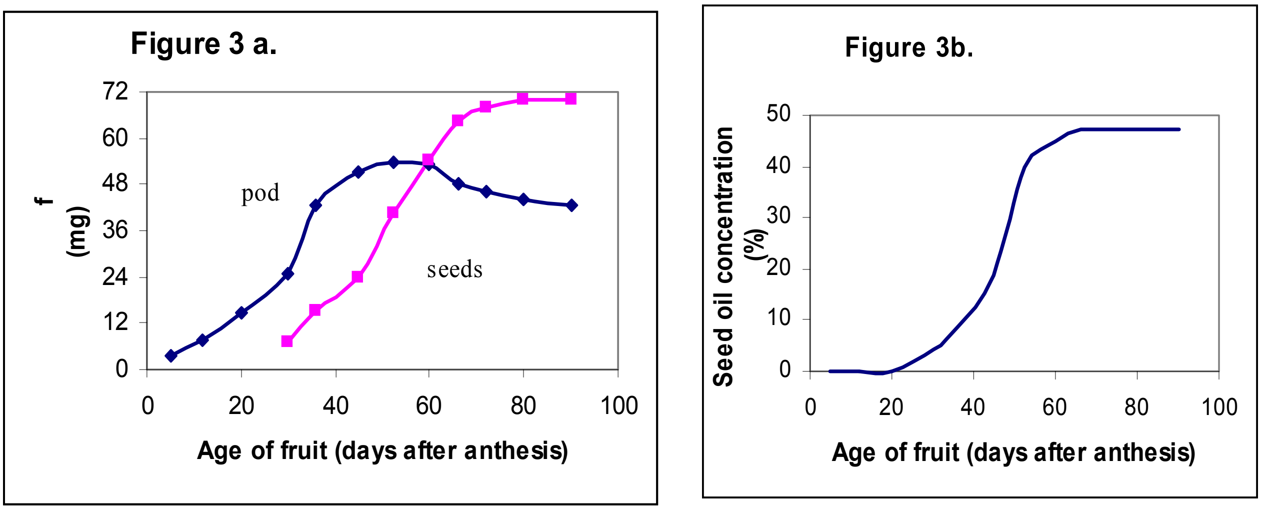

Figure 3. (a) Patterns of growth of pod walls and seeds of fruits of canola; (b) Pattern of oil concentration in seeds (From Hocking and Mason, 1993.)

CROP WATER USE

Canola is generally regarded as less tolerant to water deficit than other grain crops such as wheat. Seasonal water use will depend on starting soil water, the distribution and amount of in-crop rainfall and irrigation, and the plant available water holding capacity of the soil type. The water use of a canola crop from sowing to harvest can vary from as little as 160-180 mm (in low rainfall) to 400-500 mm in a favourable situation. The water use efficiency for potential seed yield is accepted as being 10-12 kg/ha/mm. While this is lower than for cereals, if the greater energy content of the oilseed is taken into account, it is probably close to the potential under Australian conditions.

AGRONOMY

Rain-fed crops are sown with the onset of significant rain (in April or May) to provide soil moisture for germination and to sustain growth. Except for irrigated crops, the duration of crop growth (from 5 to 7 months) is determined by sowing date and the duration of the rainfall. Time is allowed before seeding for seedbed preparation, including mechanical cultivation of hard-setting soils and weed control prior to planting. With the development of herbicide resistant varieties of canola and minimum tillage systems of sowing, the period needed for seedbed preparation has been reduced, a significant factor in short season environments. These low rainfall environments are where average annual rainfall is less than 325 mm in Western Australia (due to the greater winter incidence of rainfall in Western Australia), and less than 375 mm in the other canola growing states. In these areas with low rainfall, canola is often sown dry at a set date (early to mid May) rather than waiting for the germinating rains, to optimise yield and oil content. This has proved relatively successful provided that good seed to soil contact is made. If the break to the season has not occurred by late May in low rainfall areas, many farmers will consider changing to another crop as there is less chance of obtaining acceptable seed yields due to the shortened growing season. In long growing season environments (ie annual rainfall more than 500 mm), sowing can be delayed until May and can continue until July to avoid the crop flowering in the months with predominant frosts. Frost during early pod fill can kill newly formed seeds in the pods but the lengthy flowering period usually provides adequate compensation for losses. Occurrence of frost when the crop has finished flowering and the seed is at approximately 60% moisture can cause major yield loss. A small area of canola is spring sown (August or September) in South Australia and Victoria where waterlogging may preclude normal sowings. These areas are near the coast and receive annual rainfall above 600 mm, ensuring conditions in spring for rapid crop growth.

SOIL FACTORS AFFECTING THE PRODUCTIVITY OF CANOLA

Soil moisture deficits after anthesis may reduce yields by 50% as this is when seeds are most likely to abort and pod numbers per plant are reduced. Such a deficit is common in Australia due to the highly variable climate, hence the emphasis on genotypic and agronomic adaptation. Crops are sown to have flowering occur at a time when severe moisture stress is not expected. Canola is also a relatively sensitive crop to waterlogging and a waterlogged site may achieve only 50% of the yield of a well-drained site through the restriction of root development. For this reason fields prone to waterlogging are avoided. Canola is most sensitive during the seedling stage and at flowering. In southern Australia, transient waterlogging occurs frequently on duplex soil in winter.

Canola has some tolerance to soil salinity and is sown into relatively saline soils in Australia. Yield is affected when electrical conductivity of the saturation extract is more than 400 milliSiemens per metre. The minimum pH_{CaCl} for canola is thought to be 4.5 (pH_{water} = 5.5), below which the crop is likely to be stunted and not reach its yield potential. Application of lime is frequently used to raise the soil pH. Canola is grown on calcareous soils, up to pH_{CaCl} of 8.0 (pH_{water} = 8.5).

Compacted traffic pans or plough pans on sandplain soils slow root elongation in canola and can influence the onset of moisture stress at the end of the growing season. Mechanical deep ripping of the compacted layer increases canola yield by 12-15%. Canola has had the reputation of having a strong tap root that can grow down through hard soil, however in practice, the tap root of canola is often bent by even a small compaction layer. Canola seedlings are susceptible to sand blasting during the first four to six weeks. Soils with loose, coarse-grained texture are susceptible and on these soils canola should be sown into standing cereal stubble covering more than 30% of the soil surface.

SEED RATE

The canola yield response to seed rate reaches a plateau at a low rate of 2 to 3 kg/ha. The ideal plant population is from 50-70 plants per square metre, achieved using 3-4 kg seed/ha. The average sowing rate of canola in Australia tends to be between 4 and 6 kg/ha, with hybrid seed sown at 3 kg/ha. A higher seeding rate of 5-6 kg/ha is sown when the seedbed condition is not ideal, when sowing late or into stubble residues, when dry sowing or when using air seeders. A canola crop that has had the plant population reduced to as low as 20 plants per square metre is normally worth leaving rather than resowing because of the plants great ability to compensate with higher branch numbers. High densities of 80-100 plants per square metre improve the uniformity of crop maturation and assist in the timing of swathing. Uniformity of plant population to minimise interplant competition is more important than having an ideal population.

SOWING DEPTH

Availability of surface moisture and soil temperature influences sowing depth. When soil moisture is adequate for germination, canola sown at 2–4 cm depth gives rapid emergence. While some Australian crops are sown by dropping seed onto the soil surface and lightly harrowing to incorporate seed, most crops are now drilled below the soil surface down to about 2 cm. For dry sowing or sowing early when soil temperatures are high and the seedbed dries out rapidly, canola can be sown deeper into the firm, moist base of soil, but no deeper than 5-6 cm.

IRRIGATED CROPS

Commercial irrigation of canola crops in Australia has expanded as strong-stemmed, high yielding varieties become available. The land for flood irrigation must be laser-levelled to a uniform grade to allow efficient watering. Raised beds are the preferred irrigation method because it reduces soil crusting and improves the plant's anchorage. Irrigation is particularly suited to self-mulching grey clay soils that have a high fertility and good water absorption.

Paddocks for irrigation are watered-up before sowing for rapid emergence. Sowing normally occurs at the normal time with irrigation used to achieve higher grain yields. Irrigation of the crop is timed for the peak water use, from stem elongation until the end of seed filling. The first irrigation is timed for the flowering period. Water stress at this time can reduce yield by 50%. A minimum of two to three irrigations are needed to finish the crop.

HARVEST

The canola crop is harvested in summer, under warm, dry conditions which produces seed of low moisture with good storage characteristics. These conditions also favour high quality seed low in chlorophyll and free fatty acids. The majority of the Australian crop is swathed to avoid seed losses through pod shatter. Swathing is commenced when 40-60% of seed in pods in the middle of the crop canopy have turned black or brown. This indicates a seed moisture of 30-40% and physiological maturity. Pick-up and threshing of the windrow commences when the seed moisture has fallen to less than 8.5%, about 7 to 10 days after swathing.

Direct heading of crops with open front harvester is more prominent in the low rainfall regions where crops are shorter and have lower yield potential. Crops are ready for direct harvesting when nearly all the pods are dry and rattle when shaken. The seed moisture needs to be less than 8.5% in Western Australia and 8% in other states.

There has been interest shown recently in the prospect for aerating canola stored in silos on farm to lower the moisture content of early harvested crops.

FUTURE DIRECTIONS

Parameters describing the phenological responses of Australian varieties are being incorporated into a simulation model of development, growth and yield by Robertson. This model will be used by researchers to examine the consequences of different varietal phenologies for growth, yield and quality across different environmental conditions.

FURTHER READING

Hocking P.J. and Mason L. (1993) Accumulation, distribution and redistribution of dry matter and mineral nutrients in fruits of canola (oilseed rape) and the effects of nitrogen fertilizer and windrowing. *Australian Journal of Agricultural Research* **44**, 1377-88.

Mendham N.J. and Salisbury P.A. (1995) Physiology: Crop development, growth and yield. Ch.2, in "*Brassica Oilseeds: production and utilization*". Kimber D. and McGregor D.I. (Eds). CAB International, Wallingford, UK, pp. 11-64.