Agronomic research in canola – achievements and challenges

R M Norton
The University of Melbourne, Private Bag 260, Horsham, Victoria, 3401, Australia

ABSTRACT

Canola has been rapidly adopted in Australia, particularly since the release of herbicide tolerant (HT) types. Bioenergetically, in moderate rainfall environments, canola performs similarly to wheat mainly due to the higher energy density in the storage products. Canola now forms a significant part of the farming system and is the third largest winter grain crop grown. This achievement has been driven by improved genetics, largely by developing canola quality types with early flowering and blackleg tolerance. There has been little consideration given to the inclusion of specific traits that could enhance the yield stability and productivity of canola and the objective of this discussion is to develop an alternative ideotype for canola that will enhance its reliability in relatively low or high rainfall areas.

Key Words: Ideotype, herbicide tolerance, salinity tolerance, thermal tolerance, climate change

INTRODUCTION

By area sown, canola is now the third largest winter crop grown in Australia (ABARE 2007). Canola was first grown in Australia in the 1970's, and it was the release of herbicide tolerant (HT) types in 1993 that saw a rapid rise in domestic production, which peaked at about 2.2 Mt from 1.85 Mha in 1999. Since then, a combination of poor seasonal conditions and changing terms of trade has seen canola areas reduce to around 1.0 Mha over the past few years (ABARE 2007). Much of the canola produced is HT, with triazine tolerant (TT) and imidiazolinone tolerant (IT) making up about 60% of the crop grown (Norton 2003).

HT canola has been particularly important to grain growers as there are no herbicides available to control weeds such as wild radish and wild mustard in conventional canola (Norton 2003). These weeds compete with canola crops, can contaminate canola seed and build up and infest subsequent wheat crops. TT canola has been the most popular canola grown, especially in Western Australia, but because of the nature of its herbicide tolerance, it has an inherent yield penalty, estimated at 25% compared to conventional varieties (Robertson et al. 2002). In Canada, HT canola is even more widely adopted; with an estimated 85% of the crop is Roundup Ready®, InVigor® or IT (Canola Council of Canada 2005). Depending on the outcomes of the state moratoria on the growing of GM crops, Australian growers may have access to these technologies, providing them with technology that has been used by our major export competitors for over 10 years.

Also of significance to the adoption of canola in Australia has been the recognition of the "break crop" effect. The rotational benefits of Brassica crops, particularly canola were recognised by farmers and researchers soon after the introduction of the crop, and it is proposed that this positive benefit was one of the major factors contributing to the rapid adoption of canola (Norton et al. 1999). Angus et al. (1989) reported a break crop effect in arid regions in New South Wales, where wheat responses to applied N were more reliable and generally greater for wheat following canola than wheat following other oilseeds.

A recent survey of Australian canola growers (Insightrix 2007) found that the main reasons given for growing canola were reducing the risk of cereal diseases, farming system weed control, rotating herbicide groups, profitability of subsequent crops and diversification of farming operations. These data highlight that canola has been successful because it has significant farming systems benefits, rather than just the straight profitability of the crop. This survey also identified that growers had a flexible approach to planting, with rainfall being the major factor that controls planting areas. Therefore, while yield itself is very important to the adoption of the crop, the reliability of the production system, and the flow on benefits from growing canola should not be underestimated.

RELIABILITY OF CANOLA PRODUCTION

While growers have moved away from canola production since 1999, the evidence is that canola is not as unreliable a crop as growers indicate. If wheat and canola are compared on a bioenergetic basis, a 2.0 t/ha canola crop and a 3.5 t/ha wheat crop both contain a little under 5.0 t/ha of glucose equivalence because of the higher energy density of the oil content in canola. From that, a canola yields would be about 60% of wheat yields for an equivalent efficiency. Figure 1 shows the relative wheat and canola yields on a state by state basis over the past 10 years (ABARE 2007). Across Australia, yields in the past decade canola has generally yielded relatively more than wheat, except in the 2006-07 season where many canola crops completely failed, while a significant number were cut for hay so did not produce a grain yield.

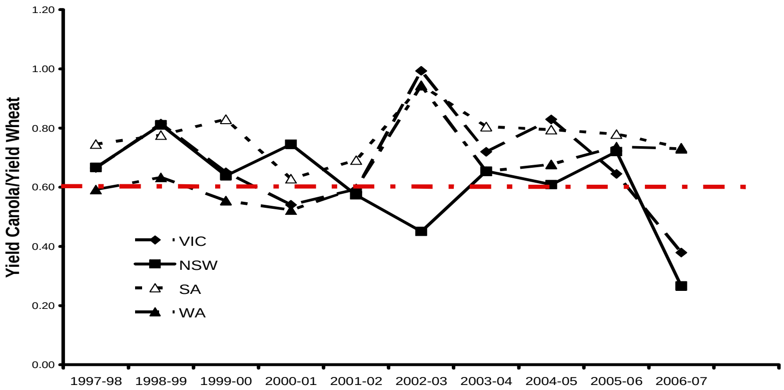

Fig.1 Canola yields relative to wheat yields in Australia, 1997 to 2006.

A similar analysis of the trends in the Victorian Wimmera and Mallee shows that canola averages 54% and 58% of wheat yields respectively. These data also show that at canola yield between 0.5 t/ha and above 2.0 t/ha were higher than the 60% of wheat yields, but beyond 2.0 t/ha canola yields are relatively poorer than wheat. The conclusion from this is that canola performs quite well – *ie* is reliable - at moderate yield potentials, but seems unable to produce very high yields under high potentials. For example, in high rainfall zones where wheat yield is 6 t/ha, canola yields should be near 4 t/ha, but such canola yields are almost unheard of.

The perception of reliability of canola yield is a significant issue for the industry, as this perception has seen canola virtually disappear from lower rainfall regions in southeastern Australia, where it is perceived as high risk and high cost.

Impact of alternative uses for canola

In 2006, significant areas of canola were cut for hay, and from a systems view point, this puts a base in the value of the canola crop even in dry seasons. The alternative uses of canola as either hay or for winter grazing does present growers with ways to increase its value – either actual or salvage – of canola. The current research on developing growing and grazing strategies for canola does allow some of the rotational benefits of this crop to be realised in both high and low rainfall systems. To include grazing canola does require a review of the phenotype required, and maybe winter types with improved cold tolerance (high vigour) and herbicide tolerance are important traits as well as good blackleg resistance in the high rainfall regions.

The Canola Council of Canada (2007) has identified biodiesel as a “Megamarket” trend and this new market sector may have different needs in terms of agronomy and genotypes to edible oil markets. If market fundamentals for biodiesel are established in Australia, a whole new set of production issues will be presented to growers, with oil yield becoming the driver.

TOWARDS LOWER COST CANOLA PRODUCTION SYSTEMS

Given that production systems could be considered as reliable as wheat, and there is likely to be an increasing demand for oilseeds with new markets, a significant issue to address for expanding canola production is to develop low-cost production systems. In reviewing current production costs, the major annual costs are fertilizers (especially N), weed control and windrowing. Collectively these costs constitute around 60% of the total variable costs. There are therefore three developments – on the horizon – to consider:

Improved nitrogen use efficiency (NUE) – Because nitrogen is a significant cost and low efficiency has environmental and economic consequences, there has been considerable interest in identifying the factors that improve the uptake and redistribution of nitrogen in canola. Colleen et al. (2007) demonstrated increased NUE in canola by expressing alanine aminotransferase, a naturally occurring enzyme downstream in the nitrogen assimilation pathway. Field trials over more than seven seasons consistently show NUE canola to yield amounts equivalent to controls, with as much as 50% less nitrogen fertilizer applied. Studies are underway to determine the mode of action of the alanine aminotransferase transgene in NUE canola. The genes for improved NUE are proposed for incorporation into canola genotypes in Canada for 2013-2015 (Canola Council of Canada, 2007).

Improved HT types – TT canola is now largely superseded, and access to alternative HT systems is important. While IT types are useful, the next big step for reducing costs will be introducing GM HT traits for glyphosate or glufosinate ammonium. As has been widely reported, these types are the dominant production traits in canola in Canada. There would appear to be no other HT systems in development and so the critical aspect of adopting Roundup Ready® in particular. is to ensure a rigorous management package comes along with the trait.

Shatter tolerance – The ability to direct head canola would save growers between $15 and $25 per hectare in windrowing costs. While some canola is still likely to be windrowed to even up maturity, the development of non-shattering types would be a great asset to the Australian industry. The Canadians indicate that this trait will be in commercial types in 2011 to 2013 (Canola Council of Canada, 2007).

WHAT ABOUT DROUGHT TOLERANCE

Drought tolerance – long considered the Holy Grail for plant physiologists and agronomists - is itself is a diverse trait, and improved drought tolerance can be developed by a range of strategies. While it would seem best to consider improving transpiration efficiency, the current literature on *Brassica napus* has shown there is some variation in osmotic adjustment or carbon isotope discrimination. The former is very difficult to use as a selection criterion, but default measures (*eg* canopy temperatures) can be used.

From a physiological perspective, there are several aspects that could be considered in improving the performance and reliability of canola production. Much of the breeding effort in canola since commercialisation in Australia has been to ensure canola quality, develop blackleg resistance, incorporate herbicide tolerance (HT) and develop appropriate phenological patterns for canola as the area grew, especially into shorter grower season districts. These breeding aims will continue, especially as both quality and blackleg resistance are moving targets, and the adoption of GM HT types will add additional tools to the weed management options for canola. But there is still a need to consider what canola could look like in the future.

a) Hybrids – hybrid types, both conventional and GM are making a major contribution to increasing yield in Canada. Heterosis provided higher early vigour and this carries with it

b) Big seeds – which have a relatively low seedcoat to embryo ratio. Selection for large seeded canola and developing management practises to raise seed size 10% could be an excellent direction.

c) Uniculm type with no petals - maintaining a favourable light environment during seed growth is fundamental to developing good seed fill. Apetalous characteristics were identified as providing this in the mid-1980's, and the improved light profile achieved by removing some or all of the reflective yellow petals This leads to a couple of potential traits such as thinner pod walls. A useful character to align with this would be the development of an "uniculm" type raceme, where few or no secondary racemes were present. The combined effect of better light penetration and larger pods, should lead to larger seeds, which in turn should provide higher oil content.

d) More determinate flowering – contracting the period of pod growth has potential to concentrate seed fill into more favourable periods although it does present a greater frost risk.

e) Semi-dwarf types – the IRC had several papers on "semi-dwarf" canola, which in fact seems to be short stature canola. This strategy would aim to improve harvest index, which is now usually about 0.33. Uniculm types would help this strategy as well.

f) Storage carbohydrate – the literature is ambivalent about the amount, location and an impact of storage carbohydrate on yield. Having some storage carbohydrates would help improve harvest index and also make to crop somewhat more reliable by "shifting" photosynthate produced early to grain fill.

g) Improved root vigour – especially under minimum tillage, although canola types that allocate more early growth to roots than shoots may provide a greater volume of soil to exploit during reproductive growth. This may largely be an issue of improving cold tolerance in canola, although the caution there is that improved cold tolerance may make the crop more susceptible to heat during grain filling.

h) Specific adaptation to various edaphic stresses such as drought, salinity, boron and subsoil acidity. As the area of canola increases again, better adapted lines will be required to enter situations where these stresses are more common.

It is probably appropriate to revisit the genotype by environment interactions for higher and lower rainfall areas to investigate theoretical patterns of growth and development to exploit these traits.

CLIMATE CHANGE AND CANOLA

At the 12th International Rapeseed Congress, there were around 750 papers presented of which 22% were in the agronomy and farming systems areas. There were many papers on assessing canola adaptation to new growing areas or extension into alternative production areas. However, there were no papers on modelling this adaptation and little effort to integrate the knowledge on growth and development. In Australia, we are fortunate to have significant modelling capacity and this will become more important as the impacts of elevated CO_2 become felt.

At the 12th International Rapeseed congress, there were only two papers that dealt with climate change impacts on canola. One was a modelling exercise on temperature changes opening up new growing regions in China, and the other was about elevated CO_2 responses in *juncea* and *rapa* from India. Given that canola already has some problems moving into warmer and drier regions, there is some additional work to be undertaken on thermotolerance of all three Brassica oilseed species as well as incorporating characteristics of drought tolerance.

Given the financial and ecosystem importance of canola in Australia, and the modelling capacity developed, the next challenge for agronomists is to propose and test future ideotypes for a warmer, more variable, carbon rich environment.

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