Utilising the full yield potential of new pulse cultivars in Victoria through improved agronomy

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ABSTRACT

Higher yielding pulse cultivars have been developed in Victoria through breeding for improved adaptation to biotic and abiotic stresses. However, with the rapid release of these new cultivars, there is not enough known of the agronomic requirements of a new cultivar to realise its full yield potential in a range of environments. This paper proposes that agronomic field experiments are vital, if pulses in Victoria are to achieve maximum yields. Genotypes in the pulse breeding programs with potential for release need to be assessed across a wide range of environments and under as many agronomic practices (i.e. time, depth and rate of sowing, tillage practice, nutritional, weed, pest and disease management and harvest timing) as possible prior to release. Information from these agronomic studies will also assist in understanding the physiological attributes and defining future breeding objectives necessary to achieve high yields in Victoria.

KEY WORDS

Pulses, agronomic package, yield potential, plant breeding.

INTRODUCTION

Breeding efforts in pulses throughout the world have resulted in the development of higher yielding cultivars with improved seed quality characteristics. In Australia, yield improvements have been made through the development of cultivars with improved phenology, plant architecture and resistance to diseases. Improved agronomic packages, including optimal sowing time and depth, plant density and the economic chemical control of weeds, pests and diseases, have also contributed to improved yields in a range of environments. However, a current trend in Australia towards the rapid release of superior new cultivars has meant that cultivars are often released without knowledge of the specific agronomic requirements necessary to realise their full yield potential in each local environment.

There is likely to be variation in the response of cultivars to an agronomic package or individual practices (time, depth and rate of sowing, tillage practice, nutritional, weed, pest and disease management and harvest timing), as is found with biotic or abiotic stresses. However, agronomic packages recommended to farmers are generally not cultivar specific. Also, only one agronomic package is generally used in a breeding program (i.e. all sites are sown at the current recommended time for that district, at one depth and density with similar regimes for chemical control of weeds), thus there is inherent selection for cultivars that perform well under those conditions. It is unlikely that one agronomic package will be suitable to maximise the yield of all cultivars within all environments in which they are to be grown. Thus, development of individual agronomic packages is required for each cultivar in each environment in which it is to be grown. For example, a new pea cultivar may flower later and have improved resistance to fungal diseases compared with older cultivars, enabling it to be sown earlier and at a higher density, particularly in environments with high disease pressure.

This paper discusses breeding and agronomic developments in pulses in Victoria, particularly field peas and lentils, presenting evidence of the need to identify the individual agronomic requirements of new cultivars.

BREEDING DEVELOPMENTS

Pulse breeding in Victoria and throughout southern Australia has changed dramatically over the last 10-15 years, with significant improvements in grain yield and quality. Breeding programs have focused on developing cultivars with improved phenology, plant architecture and resistance to major diseases.

Pulse breeders have been developing new cultivars with flowering and maturity times that are suitable for the environments in which they are to be grown. For example, a later flowering line of field pea (PSL4) with rapid pod development has been developed which may enable growers to sow earlier to improve biomass and grain yield across a range of environments. The later flowering reduces the risk of grain yield losses from frosts, particularly in the southern Mallee and Wimmera of Victoria, which often occur during flowering and podding of early cultivars (e.g. Dundale and Snowpeak). The rapid pod development enables the plant to produce adequate yields in short season environments, such as the central and northern Mallee in Victoria. A similar trend has occurred in lentils where the development of medium maturity types (Digger and Nugget) has increased yield and yield stability in the medium rainfall and growing season areas of the southern Mallee and Wimmera, compared to the early maturing cultivar Kye.

Plant architecture also continues to be improved in both lentils and field peas. In both crops the aim has been to produce a more erect cultivar that produces pods that are higher up the canopy compared with older cultivars. For example, older field pea cultivars, such as Dundale and Alma are tall, with a conventional leaf type and a trailing growth habit, which causes the crop to lodge at maturity. This type of plant architecture is conducive to fungal disease development, due to humid conditions within the canopy (E Armstrong, pers. comm.) and the lodging makes the crop difficult to harvest, necessitating the use of specialised pea fronts on harvesters. The harvesting process pulverises the entire plant, thus the soil is exposed to erosion after harvest, especially if the paddock is grazed. To overcome these problems semi-leafless, semi-dwarf cultivars with stiff straw, such as Excell and Snowpeak, have been developed. The stiff straw and intertwining of tendrils, enable the crop to resist lodging, thus allowing harvesting with conventional harvester fronts and reducing harvest losses. As the crop remains standing, conditions within the canopy are likely to be drier and less conducive to disease development compared with cultivars that lodge. In lentils, new cultivars are taller, have improved lodging resistance and set pods higher in the canopy compared to the old cultivars. Improved height has made harvesting easier and reduced seed losses, but further improvements in lodging resistance are required to maximise grain yields and enable lentils to be grown in short season areas where plants generally remain shorter.

In terms of disease resistance, in field peas the focus has been on ascochyta blight (black spot), powdery mildew and downy mildew. Cultivars are now available with resistance to either downy mildew (Snowpeak and Excell), powdery mildew (Glenroy) or both diseases (Mukta). The development of cultivars with resistance to ascochyta blight, which can cause up to 25% yield loss, has been more difficult due to the to the complex nature of the disease and resistance (1). In the breeding program at VIDA, lines with improved resistance to ascochyta blight are being identified, but yield losses can still be expected. In lentils, achieving resistance to ascochyta blight in both the foliage and the seed, and to botrytis grey mould are major objectives. Moderate levels of resistance to foliage infection and good resistance to seed infection by ascochyta blight has been identified in ILL5588 (Northfield). However, further improvements are required to produce cultivars that combine the high yield of cultivars such as Nugget and Digger with good ascochyta blight resistance. Currently, no lentil cultivar has adequate resistance to botrytis grey mould, although lines with high levels of resistance are now being used within the breeding program. Resistances to ascochyta blight and botrytis grey mould are being combined to develop cultivars with high and stable grain yields and quality (Unpublished).

Soil toxicities, such as boron and salinity, also limit yield in lentils and field peas, and are now attracting greater breeding efforts. The grain yield benefits from improving the tolerance of cereal cultivars to high soil boron are between 5 to 50% (9) and similar benefits in field peas and lentils could be expected. Field pea cultivars generally have good tolerance to boron, whilst their tolerance to salinity is being studied. Initial indications are that lentils are sensitive to both toxicities and significant yield losses have been observed in farmers' crops.

In addition to the increased grain yield of new cultivars, significant improvements in grain quality have been achieved, which increases the marketability of the product. New high quality white and blue field peas will enable Australian producers to access high value human consumption markets. New lentil cultivars have specific sizes and shapes to make them attractive in different markets. Northfield lentils have resistance to seed infection by ascochyta blight and have a low risk of seed staining that can reduce marketability (2).

AGRONOMIC DEVELOPMENTS

In Victoria, there have been considerable improvements in agronomic packages relating to pulse crops over the last 10 to 15 years. The general agronomic requirements (e.g. time, depth and rate of sowing, tillage practice, nutritional, weed, pest and disease management and harvest timing) of a particular crop are adequately understood (3,4), but specific information about individual cultivars is limited. In particular, new cultivars are often released without specific information on the agronomic requirements in each environment. Agronomic practices cannot increase the grain yield potential of a cultivar, but a good agronomic package, specific for the cultivar and environment in which it is to be grown, is required to achieve the grain yield potential. A good environment specific agronomic package can also assist in reducing the fluctuations in yield, and thus profitability, of pulses from year to year.

The agronomic requirements of both field peas and lentils have been studied, particularly sowing time and rates (5, 7, 8, 10, 11). However this research has often focussed on only one cultivar across a number of treatments without a comparison among cultivars. Similar to the phenology, plant architecture and biotic and abiotic traits discussed above, there is likely to be genotypic variation for adaptation to different agronomic packages and individual practices. For example, Materne et al. (6) found a significant interaction between sowing time and cultivar for yield and seed infection by ascochyta blight. In another example, new semi-leafless, dwarf pea cultivars have been developed to improve the harvestabilty of the crop compared with the older trailing cultivars. However, to achieve the yield potential of these new cultivars, it is recommended that they are sown at much higher plant densities compared with the older tall, trailing cultivars (65 plants/m^2 cf. 45 plants/m^2). If the new cultivars are sown at plant densities similar to the older trailing types, they become more prone to lodging as plants are further apart and the tendrils do not intertwine as much (see Breeding Developments), thus losing the grain yield benefits associated with improved standability at harvest. Conversely, if the older cultivars are sown at high densities, they do not show any yield improvements and become more prone to diseases.

The development of cultivars with improved disease resistance could significantly change current agronomic packages. For example, if a field pea cultivar was developed with resistance to ascochyta blight, downy mildew and powdery mildew, it could be sown earlier than current cultivars, particularly if it was later flowering. Thus, the yield benefits from the disease resistance are enhanced, as the cultivar will have a longer growing period, developing greater biomass and yield potential. The line, PSL4, with later flowering, rapid pod set, downy mildew resistance and improved ascochyta resistance, combined with excellent lodging and shattering resistance will be released in Victoria within 2 years. PSL4 is likely to be broadly adapted, but will have an advantage over current cultivars in environments where the disease pressure is moderate and frosts are a risk.

Environmental variability can also alter agronomic practices. For example, on a sandy soil in dry areas it may be better to sow field peas and lentils deeper into a moisture layer. This will also minimise effects of post-sowing, pre-emergent chemical damage. Alternatively, if an early rainfall event occurs at the start of the growing season, a farmer may sow shallow to promote rapid crop emergence and to maximise the use of the available water and warmer soil temperatures. On heavier soils, deep sowing may be detrimental to yields, especially in small seeded crops like lentils which can have difficulty emerging due to the force required to push the shoot through the soil. Preliminary results from research on a loamy clay in the southern Mallee of Victoria (Tables 1 and 2) indicate that shallow sowing increases plant emergence, height (not shown) and plant dry weight in lentils, but not in peas when compared with deep sowing. In a trial conducted by the Birchip Cropping Group, shallow sowing increased grain yields in lentils by 15-20%, but only at the lower rates of pre-emergent herbicide (12). Significant interactions between sowing depth and cultivar may be found if cultivars with different levels of herbicide tolerance, maturity or early vigour are used in such studies.

CONCLUSIONS

Improvements in the adaptation provided by more appropriate phenology, plant architecture and resistance to major diseases through breeding, need to be fully exploited through changed agronomic packages. Currently at VIDA we are researching the effects of sowing time, depth and rates across a number of cultivars of peas and lentils at three sites on various factors including water use, emergence, chemical damage, disease, pest and weed control and ultimately grain yield. Information from these agronomic studies will also assist in understanding the physiological attributes and defining future breeding objectives necessary to achieve high yields in Victoria. Individual agronomic requirements of new cultivars need to be determined, so that the grain yield potential can be achieved through a complete agronomic package.

Table 1. The effect of sowing depth on the emergence (plants/m^2) of four lentil and four field pea cultivars at Warne in the Southern Mallee of Victoria.

Cultivar	Depth	
	3 cm	8 cm
Lentils		
Cassab	126	104
Digger	128	99
Northfield	120	96
Nugget	120	96
Field peas		
Dundale	79	76
Excell	64	67
PSL4	85	92
Snowpeak	86	78

LSD (lentils): Cultivar, NS; Depth, 9; Cultivar x Depth, NS.

LSD (field peas): Cultivar, 6; Depth, NS; Cultivar x Depth, NS.

Table 2. The effect of sowing depth on the dry weight (g/m^2) of four lentil cultivars at flowering at Warne in the Southern Mallee of Victoria.

Cultivar	Depth	
	3 cm	8 cm
Lentils		
Cassab	127	97
Digger	121	99
Northfield	173	115
Nugget	123	111

LSD: Cultivar, 22; Depth, 16 Cultivar x Depth, NS.

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