INTRODUCTION

Continuous cropping of grain cereals has been common practice in northern New South Wales (NSW) (Hallsworth et al. 1954, Holland et al. 1987, Martin et al. 1988). This form of cropping has resulted in the depletion of soil organic carbon and nitrogen levels, and decreased crop yields, grain protein contents and financial returns to producers (Holland et al. 1987, Horn et al. 1996). Pulse crops have often been incorporated into a rotation to benefit following cereal crops and slow soil nitrogen losses while providing a disease and pest break (Doughton et al. 1981, Marcellos et al. 1998).

Chickpea is grown on a wide range of soil types in northern NSW, but is best suited to the medium to heavy clays (Knights 1991). The use of chickpea in rotations has been widely promoted after it was shown that their inclusion could improve subsequent wheat yields, (Marcellos 1984, Felton et al. 1998). However, there are a number of difficulties associated with growing chickpea in the grains region of north-eastern Australia. Traditionally, lucerne has been grown in the region, however, many of the pathogens and pests which are associated with lucerne production have also been found to affect chickpea (Knights 1991).
attention to the major findings from this work with respect to these objectives, and discuss directions for potential new research.

CHICKPEA/WEED COMPETITION

The relative growth rates of chickpea, turnip weed (*Rapistrum rugosum*) and wild oat (*Avena sterilis subsp. ludoviciana*) were examined at two sites, Tamworth and Warialda, to investigate their competitive interactions. The results from this single year experiment showed that chickpea, turnip weed and wild oat had similar growth curves. Active growth of all plants commenced around 450 degree-days after sowing and produced a classical growth curve (Fig 1).

![Figure 1. Relative growth rates of chickpea (▲), turnip weed (●) and wild oats (■) at Tamworth in 1997. Degree-days were calculated from sowing assuming a base temperature of 5°C](image)

When chickpea was grown in the presence of turnip weed or wild oat, dry matter peaked at a lower level. The point where the values predicted by the curves (weedy and weed-free) diverged and differed significantly was defined as the point of observed competition and, in the case of turnip weed, this separation occurred at around 1100 degree-days after sowing (Fig 2).

![Figure 2. Chickpea dry matter accumulation as a result of increasing degree-days under weed-free (▲) conditions and in the presence of turnip weed (■) at Tamworth in 1997. Broken lines show the 95% confidence interval for each fitted curve. Degree-days were calculated from sowing assuming a base temperature of 5°C.](image)

From these data control options for different regions and sowing times can be calculated. This approach would be improved by the combination of degree-days and photoperiod such as in the crop development modelling tool “DEVEL” (Holzworth and Hammer 1992).

Different densities of weeds were shown to affect the yield of chickpea in a predictable manner. A rectangular hyperbolic curve described the effect of increasing weed density on chickpea yield loss. Relatively low densities of turnip weed (8 plants m⁻²) or wild oat (10 plants m⁻²) growing throughout the life of the crop could reduce chickpea grain yield by 50% (Fig 3). This information would help predict potential yield losses early in the season and enable more informed decisions to be made on weed control.

![Figure 3. Hyperbolic curve fitted to the turnip weed density data for 1996 and 1997. Broken lines show the 95% confidence interval](image)

The location of the weeds within the crop, i.e. growing in the crop row, between the crop rows or randomly dispersed through the crop did not affect yield loss; however, poor emergence reduced the weed density in this trial. The results may have been different had higher weed densities been achieved. Smaller, high-density weed patches within the chickpea crop did not
reduce chickpea yield to the same extent as distributing the same number of weeds more uniformly throughout the crop area. These two results have implications for management practices that rely on predictive models, because the weed distribution within the crop, if not considered, can significantly bias results, and overestimate the need for weed control.

To assist in the management of weeds in chickpea, predictive models based on relative leaf area were investigated to help estimate the effect of specific weed infestations on chickpea yield early in the season. Relative leaf area was selected as a modelling parameter because it could be measured non-destructively, and its potential for incorporation into a practical mechanised system for routine use. The 1-parameter leaf area model (Kropp and Spitters 1991) offered the most robust predictions from the data collected. Weed density was not used to predict yield loss due to unfavourable reports within the literature, relating to the problem of assigning equal damage coefficients to very small and large weeds (Kropp and Spitters 1991). However, examination of the chickpea and weed (wild oat and turnip weed) growth curves suggested that density may be suitable for yield loss prediction, because the late season flush of weed growth may cause early- and late-emerging weeds to elongate together, and compete similarly with the crop.

**TIMING OF WEED CONTROL**

The relative crop growth curves with and without weeds (Fig. 2) highlight suitable times, based on accumulated degree-days, to control weeds in chickpea. The optimum time at around 500 degree-days after sowing was the same at both the experimental sites, and was determined by maximising chickpea yields as well as minimising weed seed returns to the seed bank. This timing was considerably later than expected but resulted from slow initial growth rates of the weeds (turnip weed and wild oat) and chickpea (Fig. 1).

**CULTURAL MANAGEMENT AND BREEDING**

Decreasing the distance between crop rows is often seen as a way to improve crop competitive ability because narrow row spacing reduces the time to full canopy closure. Conversely, producing chickpea on wide rows has some benefits. The wider rows increase airflow between the plants, reducing disease, and allow cereal stubble to remain undisturbed, which helps prevent erosion. On the other hand, increasing row widths may promote weed growth by delaying crop canopy closure. This research showed that increasing the row spacing from 32 to 64 cm had no detrimental effect on the yield of chickpea when grown in the presence of either wild oats or turnip weed at weed densities between 2 and 32 plants m\(^{-2}\). The weed density response curves in the narrow and wide rows showed a positive effect on yield by the use of wide rows in one case, but for the remainder there was no significant difference between results from the two row spacings. The positive effect of wide rows may have resulted from better disease control. The use of wide rows also would allow additional weed control to be applied to the between-row space during crop development.

A number of different chickpea varieties and breeding lines are available in Australia. Some of these were shown to differ in their competitive ability, but were all considerably lower than wheat or canola. This is unlikely to dramatically improve with breeding in the foreseeable future. Current breeding objectives of improving plant height and vigour are leading to small improvements in the competitive ability of new chickpea varieties. If a variety of chickpea could be developed with radically different plant architecture, e.g. greater height and denser canopy, this would help with the competitive ability of the crop. For added benefits, such a variety would also require a growth curve with a shorter lag phase in the early stages, thus enabling it to reach its mature height faster and shade the weeds earlier in the season.

**FUTURE RESEARCH DIRECTIONS**

The main areas arising from this program that would benefit from further investigation are the effects of time of weed removal, the examination of different weed species, and the effect of location, and therefore climate and photoperiod, on chickpea and weed growth.

The date of optimal weed removal obtained in this work showed particular promise and potential for improving chickpea weed management. Only data from two sites in one season were used to create the growth so to improve reliability repeated experiments under different environmental conditions, and using a range of weed species, are needed.

The effect of weed density is an important criterion in understanding crop/weed interactions. This study focused on turnip weed and wild oat as the two principal weeds of the northern grains region of Australia, but other problem weeds in northern chickpea crops include common sowthistle (*Sonchus oleraceus*), bindweed (*Convolvulus elatius*), paradoxa grass (*Phalaris paradoxa*) and deadnettle (*Lamium amplexicaule*). Little is known of the competitive
effect of these weeds on chickpea, or how combinations interact to reduce crop yield. An understanding of the relative damage imposed by these secondary weeds would help grain growers give priorities to weed management and decide on control strategies. The removal of specific weeds may be more important than creating a weed-free crop, potentially reducing herbicide use and production costs. Economic modelling, simulation modelling, decision support systems and precision weed management systems all require a good understanding of weed/crop interactions, and their effectiveness in any integrated weed management system is dependent on the quality and diversity of these interaction data.

Environmental effects

The relationship between the environment, the crop and the weed community are vital in understanding how a cropping system works. While this research was conducted at two sites, future experiments, as outlined above, should involve the collection of detailed climatic information to enable comprehensive simulation models to be developed. Simulation models require considerable input, but their use in predicting outcomes (yield loss, economic returns, relative growth rates of weeds and crops, weed seed production) and identifying gaps in current knowledge are invaluable.

Other research areas such as precision weed management and economic modelling are worthy of investigation, but without a thorough understanding of the competitive effects of different weeds on chickpea, and the effects of the timing of weed control, these other areas of research are likely to be less effective.

CONCLUSION

This paper identifies a number of factors that can be combined to help improve chickpea weed management. As part of an integrated weed management package this work provides information on crop/weed interactions and strategic times to apply weed control that may reduce the need for repeated herbicide application.

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REFERENCES


