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The effect of row spacing and weed density on yield loss of chickpea

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Abstract. The adoption of no-till farming and the desire to maintain stubble cover when sowing legumes in northern New South Wales and southern Queensland have resulted in an increase in commercial row spacing for chickpea (*Cicer arietinum* L.). This paper examines the effects of increasing crop row widths on weed competition in chickpea crops. Weed densities of 0, 2, 4, 8, 16, and 32 plants/m² of wild oats (*Avena sterilis* ssp. *ludoviciana*) and turnip weed (*Rapistrum rugosum*) were established with chickpea crops planted with either 32 or 64 cm row configurations in northern New South Wales during 1996 and 1997. A rectangular hyperbolic model adequately represented the loss in chickpea yield with increasing density of either weed. Even low densities of <10 plants/m² caused large (approx. 50%) reductions in yield, particularly with turnip weed. In these experiments, weed-free yields were higher when chickpea was sown in 32 cm rows compared with 64 cm rows, but weeds caused no greater loss in crop yield with the wider row spacing. The results of this work show that the use of wide rows has minimal impact on weed competition in northern chickpea crops.

Additional keywords: weed competition, crop agronomy.

Introduction

Chickpea (*Cicer arietinum* L.) is increasingly being grown as a rotation crop in the northern cropping region of eastern Australia to enhance soil nitrogen and break graminaceous disease cycles. However, it develops slowly and has an open canopy architecture and low structure (Amor and Francisco 1987; Knights 1991) that reduce its competitive ability against weeds. The adoption of no-till farming and the desire to maintain stubble cover when sowing legumes in the northern grain region have resulted in an increase in row spacing for chickpea.

In most situations, weed competition is reduced following crop canopy closure (Swanton and Weise 1991; Malik *et al.* 1993) so earlier canopy closure minimises the effect that weeds have on yield. Narrow row spacing has improved crop yields in both weed-free (Felton 1976; Koscelny *et al.* 1990; Silim *et al.* 1990) and weedy situations (Holland and McNamara 1982; Koscelny *et al.* 1990; Hosmani and Meti 1993; Malik *et al.* 1993).

On the other hand, chickpea grown in the northern grain region of eastern Australia is susceptible to several fungal diseases and its slow initial growth, open canopy architecture, and production based on stored soil moisture make wide rows the spatial arrangement of choice (Felton *et al.* 1996). Where weeds have been well controlled in wide-row systems, chickpea yields have declined only

marginally compared with narrower row spacings (Felton *et al.* 1996). It is not known how row spacing affects chickpea yield in weedy situations.

During 1996 and 1997, experiments were conducted at 2 sites in northern New South Wales to examine the effect of weed density on chickpea production in both wide and narrow rows. The dominant broad-leaved weed in the region, *Rapistrum rugosum* (turnip weed), and the dominant grass weed, *Avena sterilis* ssp. *ludoviciana* (wild oats), were used in the study.

Materials and methods

The row spacing experiments in chickpea were completed during 1996 and 1997 at 2 sites: the University of New England's Douglas McMaster Research Farm, 36 km north-west of Warialda, at latitude (29° 18' 19" S, 150° 36' 01" E), and the Tamworth Centre for Crop Improvement (31° 08' 55" S, 150° 59' 05" E). The soil at Warialda is a self-mulching black Vertosol (Isbell 1996), and at Tamworth a grey clay, calcareous phaeozem (Uf6.42; Northcote 1971). Both sites had been sown to wheat in the previous year.

In the northern grains region of eastern Australia the predominant type of wild oats is *Avena sterilis* ssp. *ludoviciana*. Wild oats seed was collected from Warialda Seed Cleaners and graded to produce a sample that contained 99% *Avena sterilis* ssp. *ludoviciana*. It had a glasshouse emergence of 66% in 1996 and 75% in 1997.

Turnip weed occurs throughout New South Wales, but displays considerable phenotypic differences and germination behaviour in seed collected from different areas (Cousens *et al.* 1994). Turnip weed seed for the 1996 experiments was collected from a single roadside patch

found outside the Tamworth Centre for Crop Improvement. Seed for the 1997 experiments was collected from plants found at each site in 1996. Turnip weed produces 2 types of seed. Distal seeds, contained in the turnip weed pod, are difficult to liberate and are often dormant, whereas proximal seeds are more easily liberated and are less dormant than the distal seeds (Cousens *et al.* 1994). Proximal seeds were used in all these experiments. The turnip weed seed had a glasshouse emergence of 40% in both years.

Treatments

In 1996, the chickpea variety Amethyst was sown at Warialda on 29 May and at Tamworth on 4 June at 140 kg/ha in 32 cm rows with a no-till planter, the aim being to achieve establishment of 70 plants/m². The weed seed was mixed with dry sand and spread across the plots on 5 June at Warialda and 18 June at Tamworth. Weed seed was not incorporated, because rain occurred at both sites within 24 h of spreading. The desired densities of both the wild oats and turnip weed were 0, 2, 4, 16, and 32 plants/m².

To achieve the desired chickpea density of 35 plants/m² for the 32 and 64 cm row spacing treatments, the experimental plots were sown thickly and thinned. Thinning took place on 4 July at Warialda and on 12 July at Tamworth, and involved the removal of every second row in the wide row plots and about every second plant in the narrow row plots. Plants were removed by spraying glyphosate at 675 g a.i./ha (as Roundup CT) through a knapsack sprayer fitted with a 10-cm-diam. spray shield and small cone nozzle.

Plant density counts on randomly selected 1 m sections of row from each plot on 19 July at Warialda and on 1 August at Tamworth showed an average crop density of 31 plants/m² in the narrow rows and 33 plants/m² in the wide rows, at both sites.

In 1997, the chickpea variety Amethyst was sown at Warialda on 4 June and at Tamworth on 12 June. Instead of thinning, alternating runs of wide and narrow rows were sown using the same seeder as in 1996. Wide rows were on 64 cm centres and narrow rows were on 32 cm centres. Both were sown to achieve a chickpea density of 35 plants/m².

In 1997, weed seeds were mixed in dry sand and spread by hand prior to the chickpea sowing, so that the weed seed would be incorporated by the sowing process. Only low densities of turnip weed were sown in 1997 to better reflect weed densities observed in commercial chickpea crops, and wild oats were not included in the 1997 experiments. The turnip weed densities were 0, 4, and 8 plants/m².

Both the Tamworth and Warialda sites experienced dry weather following sowing and were infected by a seed-borne root fungus (*Botrytis*) that reduced the chickpea plant population at Warialda to 15–20 plants/m² and at Tamworth to 20–25 plants/m². The weed populations were also below the desired levels (0, 2, and 4 plants/m²).

Experimental design

In 1996, the experiment was a factorially arranged randomised complete block design, with 4 replicates of 2 crop row spacings, 2 weed species, and 5 weed densities. The plots were 3.5 m wide by 3 m long and contained either 5 wide-crop rows or 11 narrow-crop rows.

A split-plot design with 5 replicates was used in 1997, with 2 row spacings as the main plots and the 3 turnip weed densities as the subplots. The plots were 3.5 m wide by 8 m long and contained 5 wide-crop rows (crop rows 64 cm apart) or 11 narrow-crop rows (crop rows 32 cm apart).

Maintenance

During 1996, the unusually wet season meant that the removal of naturally occurring weeds was a priority. Broad-leaved weeds were removed by hand-chipping in all plots; wild oats emerging mid-season were controlled with a broadcast application of fluazifop-p at 106 g a.i./ha (as Fusilade) at Warialda on 15 August and with the same

herbicide at Tamworth on 22 August with a hand-held 3-m boom spray, operating at 172 kPa and a water volume of 85 L/ha. Only the turnip weed and weed-free plots were sprayed. The wild oats plots were thinned to achieve densities approximately equal to the desired range by hand-pulling of random plants.

Very few broad-leaved weeds occurred in the plots during 1997. Grass weeds were a problem, especially at Tamworth where *Phalaris paradoxa* (Paradoxa grass) occurred. Grass weeds were controlled with fluazifop-p at 106 g a.i./ha (as Fusilade), which was applied at Warialda on 27 August, and Tamworth on 13 August and 15 October with a hand-held 3-m boom spray, operating at 172 kPa and a water volume of 85 L/ha.

Measurements

The chickpeas were harvested by hand in December 1996 by cutting two 1-m² quadrats from each plot. Weeds growing in the quadrat area were collected and counted. Following harvest, the weed and crop samples were dried at 80°C for 48 h before being weighed. Chickpea grain yield was recorded after the samples had passed through a stationary thresher. Seeds were randomly selected from each sample and weighed to obtain a 100-seed weight.

In December 1997, weeds were hand-harvested from the crop inter-row space and the crop rows, and then the chickpea crop was harvested using a small plot harvester. The harvested section removed 3 wide rows or 5 narrow rows from the centre of the 8-m-long plot. Harvested weeds were counted and dried. Following drying and weighing, turnip weed seed weight was recorded after the samples were passed through a stationary thresher. The machine-harvested chickpea grain was also weighed, and its 100-seed weight determined.

Statistical analysis

Both experiments were additive in design allowing regression analysis to describe the crop and weed relationships (Cousens 1985a, 1985b). A rectangular hyperbolic model was used:

$$Y_L = Id/[1 + (Id/A)] \quad (1)$$

where Y_L is percentage of yield lost because of weed competition, d is weed density, A is percentage yield loss as $d \rightarrow \infty$, and I is percentage yield loss per unit weed density as $d \rightarrow 0$.

Data from both years were analysed using the maximum likelihood function of the statistical software package Splus-4 (Mathsoft 1997). In 1997 the low range of densities meant that estimates of the A parameter contained a high degree of error so the A parameter was constrained to 100% and only the I parameter was estimated. Despite the hyperbolae being poorly defined, it was felt that this approach was more appropriate than fitting a linear curve to the data. Comparisons between the curves were made using Hotelling's T^2 test (Anderson 1958).

Results

Chickpea grain yield was highly correlated with chickpea dry matter for crops grown in the presence of both turnip weed and wild oats at Tamworth and Warialda, with R^2 values between 0.93 and 0.97. Chickpea row spacing and weed density had no significant effect on the 100-seed weights of chickpea (data not shown).

Weed density

The weed densities achieved in both 1996 and 1997 were approximate to the desired densities described in the

methods; this gave a range of densities from the lowest to the highest across all treatments and replicates.

Weeds caused a significant reduction in chickpea yield. The rectangular hyperbolic model (Eqn 1) accounted for much of the variation in the data with increasing weed density. In 1996, wide and narrow row curves differed for turnip weed and for wild oats at Warialda, but no significant differences were observed between wide and narrow rows at Tamworth (Fig. 1). The *I* parameter (percentage yield loss per unit weed density as $d \rightarrow 0$) differed between wide and narrow rows at Warialda and between sites (Table 1) for both weed types. The significantly larger *I* value for the narrow row turnip weed treatments at Warialda (P chi-square <5%) indicates that at low turnip weed densities, wide crop rows maintained yield better than narrow crop rows (Table 1).

Low densities of turnip weed caused large yield losses (Fig. 1a, c); 5 plants/m² depressed chickpea yield by at least

40%. A similar, but less dramatic, response was seen with wild oat (5 plants/m² depressed chickpea yield by about 25%), which was generally less competitive than turnip weed (Fig. 1b, d).

When these experiments were repeated in 1997 with low turnip weed densities, yield losses did not differ between sites (Fig. 2). The parameters estimated by the rectangular hyperbolic model (Eqn 1, Table 2) of the wide and narrow crop row treatments in 1997 were not significantly different using Hotelling's T^2 test.

The *A* parameter estimates (percentage yield loss as $d \rightarrow \infty$) for the wild oats treatments in 1996 and the turnip weed experiments in 1997 exceeded 100%. In 1997 the *A* parameter was constrained to 100%, but for consistency between sites this was not done in 1996. To estimate the effects of high weed densities, high densities are needed in the experiment regardless of the agronomic relevance

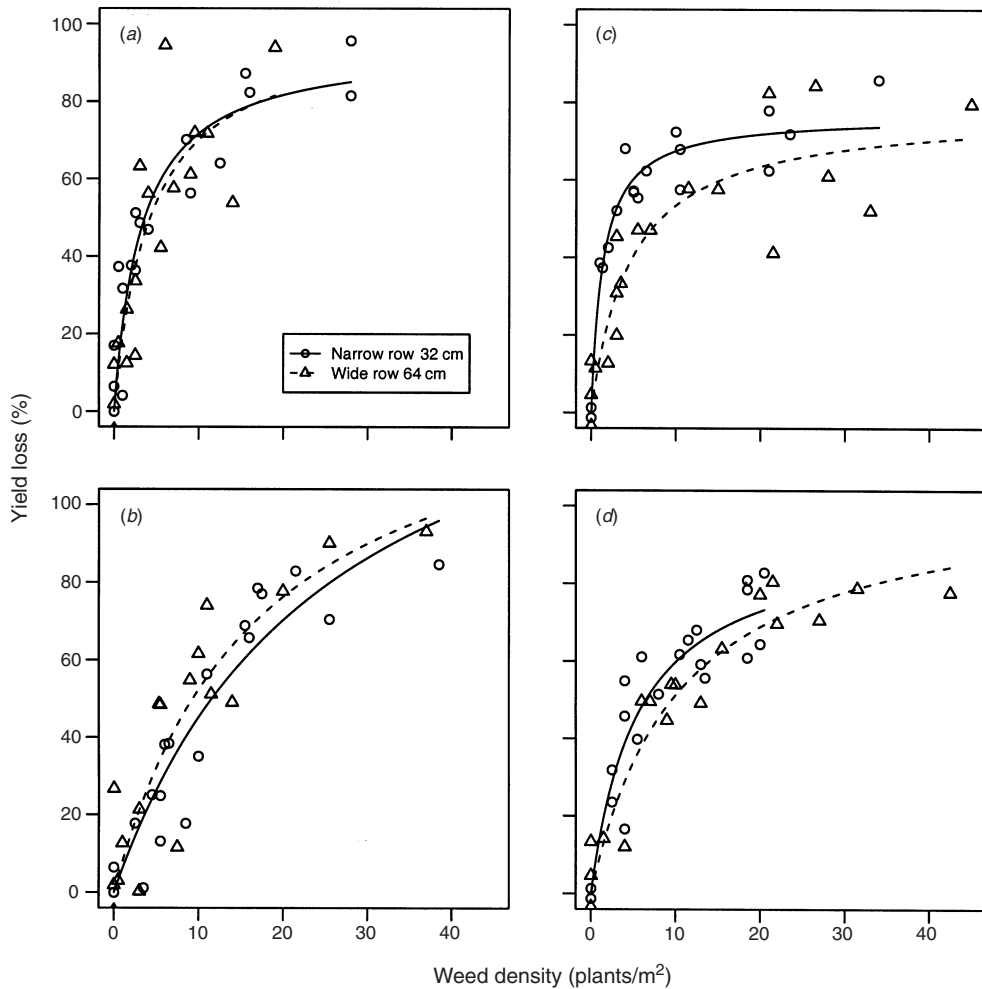


Fig. 1. Hyperbolic curves of chickpea grain yield loss fitted to the weed density and row spacing data for 1996. Letters denote treatments: (a) wide and narrow rowed turnip weed at Tamworth; (b) wide and narrow rowed wild oat at Tamworth; (c) wide and narrow rowed turnip weed at Warialda; and (d) wide and narrow rowed wild oat at Tamworth.

(Cousens 1991). For this reason only the *I* parameter was used to compare curves.

The weed-free chickpea yields (mean *wfY*) consistently showed higher yields in the narrow rows compared with the wide rows; however, apart from the turnip weed treatments at Warialda in 1996, no difference was observed between the

yield loss curves from wide or narrow spaced chickpea rows (parameters *I* and *A* in 1996; Table 1).

Discussion

Chickpea yields from crops grown in narrow rows were consistently higher than yields with wide row spacing under weed-free conditions. However, when growing in competition with weeds, there was no significant difference in yield loss between the 2 row widths. Narrower row spacings have improved the competitive ability of many crops as a result of earlier canopy closure and earlier competition with weeds (Holland and McNamara 1982; Koscielny *et al.* 1990; Hosmani and Meti 1993; Malik *et al.* 1993). In our experiments, no measurable advantage was obtained by planting chickpeas on narrow row spacing.

Much of the work showing that narrow rows improve the competitive ability of crops has been undertaken with cereals

Table 1. Mean weed-free yields and estimated values of the parameters for the hyperbolic curves fitted to the 1996 data in Fig. 1

Standard errors are given in parentheses. Mean *wfY*, mean yield from the weed-free plots (g/m^2); *A*, percentage yield loss as $d \rightarrow \infty$; *I*, percentage yield loss per unit weed density as $d \rightarrow 0$

Treatment	Mean <i>wfY</i>	<i>A</i>	<i>I</i>
Tamworth narrow row turnip weed	315.5 (52.8)	94.8 (9.3)	29.5 (7.4)
Tamworth wide row turnip weed	273.9 (38.7)	99.5 (19.1)	23.8 (7.9)
Tamworth narrow row wild oats	315.5 (52.8)	158.7 (41.1)	6.3 (1.2)
Tamworth wide row wild oats	273.9 (38.7)	140.6 (36.3)	8.31 (2.1)
Warialda narrow row turnip weed	381.2 (9.7)	76.8 (3.1)	56.15 (9.65)
Warialda wide row turnip weed	334.2 (38.9)	78.3 (8.1)	16.77 (4.7)
Warialda narrow row wild oats	381.2 (9.7)	93.4 (10.1)	16.6 (3.5)
Warialda wide row wild oats	334.2 (38.9)	105.2 (12.9)	10 (2.0)

Table 2. Weed-free yields and estimated values of the parameters for the hyperbolic curves fitted to the 1997 turnip weed data in Fig. 2

Standard errors are given in parentheses. Mean *wfY*, mean yield from the weed-free plots (g/m^2); *A*, percentage yield loss as $d \rightarrow \infty$; *I*, percentage yield loss per unit weed density as $d \rightarrow 0$

Treatment	Mean <i>wfY</i>	<i>A</i>	<i>I</i>
Tamworth narrow row	244.7 (12.5)	100	30.24 (6.7)
Tamworth wide row	186.4 (34.8)	100	28.5 (7.4)
Warialda narrow row	326.3 (26.2)	100	23.9 (3.2)
Warialda wide row	289.2 (23.2)	100	30 (3.5)

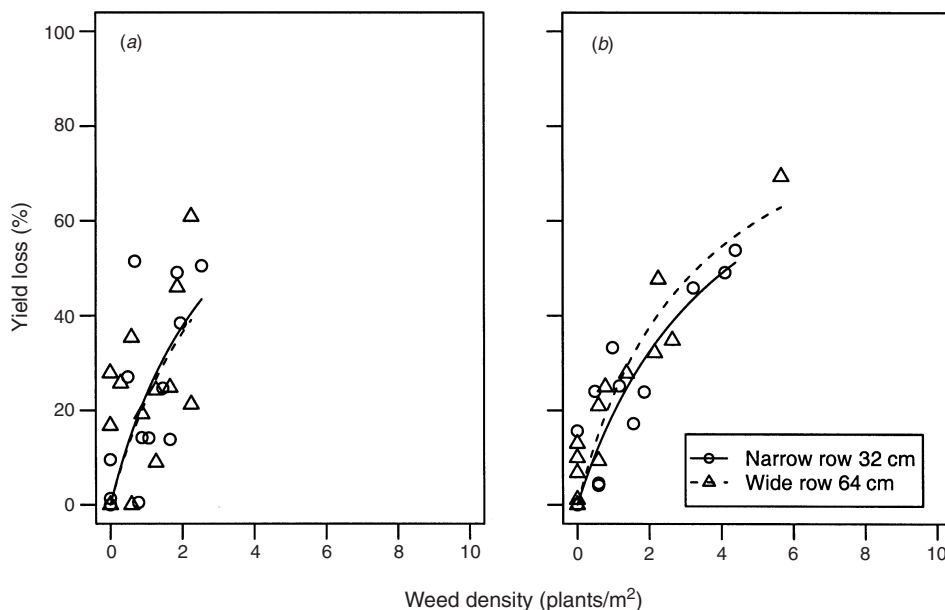


Fig. 2. Hyperbolic curves of chickpea grain yield loss fitted to the turnip weed density data for 1997. Letters denote treatments: (a) wide and narrow rowed turnip weed at Tamworth; and (b) wide and narrow rowed turnip weed at Warialda.

(Holland and McNamara 1982; Medd *et al.* 1985; Koscelny *et al.* 1990) or large-leaved legumes (Felton 1976; Malik *et al.* 1993). Cereals and large-leaved legumes will reduce the light available to late-emerging weeds when sown in a dense stand with early canopy closure. Winter cereal crops show fast initial growth compared with many weeds (Cousens *et al.* 1991), and where this leads to rapid canopy closure, it is only the weeds that germinate around the same time as the crop that are likely to be reasonably competitive. Chickpeas, however, have slow initial growth (Amor and Francisco 1987; Knights 1991) and a fine open canopy that results in incomplete capture of light, allowing weeds to emerge and establish with few competitive effects (Mwanamwenge *et al.* 1997; Thomson and Siddique 1997). Following establishment, the filtered light passing through the fine canopy of the chickpeas is likely to be sufficient to enable weeds such as turnip weed to elongate and emerge above the chickpea canopy.

The aim in integrated weed management is to find complementary strategies. The use of wide rows had no negative effect on the competitive ability of chickpea and may enable a greater diversity of management practices to be employed such as in-row spraying, inter-row spraying, or cultivation. Wide rows can also improve the health of the crop by improving air-flow and reducing disease (Felton 1976). Nevertheless, if weeds are present at high densities, wide rows will reduce yield losses only when coupled with some other form of weed management.

Increasing weed density significantly reduced chickpea grain yield, with wild oats and turnip weed. However, the response curves show that turnip weed had a greater effect on chickpea yields at lower weed densities than did wild oats (Fig. 1). This effect may have been a result of late-season turnip weed growth shading the chickpea during flowering. The steep slope of the turnip weed and wild oats curves at low densities shows that chickpeas have a low tolerance to competition. A comparison of yield loss curves generated for other crops gives some indication of how competitive chickpeas are. In an experiment conducted by Lutman *et al.* (1994) for low oat (*Avena sativa*) densities, the percentage yield losses per plant/m² (*I*) were between -0.29 and -0.48% for barley, -0.06 and -2.29% for oil-seed rape, -0.37 and -1.33% for faba beans, and -0.34 and -7.18 for field peas. Martin *et al.* (1987) described yield loss responses of wheat to wild oat (*ssp. ludoviciana*) at 7 sites over 3 years in northern NSW; their percentage yield losses per plant/m² (*I*) were between -0.65 and -2.24%. In this experiment, the *I* values for chickpea in competition with wild oat were between -6.3 and -16.6 (Table 1). This comparison helps demonstrate the degree to which chickpeas can tolerate competition with weeds and shows how a few weeds can significantly reduce chickpea yields. However, this work has not considered the influence of climatic variables that may influence the competitive ability of the weeds with respect to

the chickpea crop and cause significant seasonal changes to the *A* and *I* parameters.

Although the experiments described in this paper were not designed to determine the resources for which the chickpea and weeds were competing, shading may have been a key competitive mechanism. It was particularly wet in 1996 and nutrients were applied to be non-limiting; this suggests that the crop and weeds may have been competing principally for light. Future work using simulation modelling is planned to identify the influence of climate on the *A* and *I* parameters and this work will help identify the importance of resources for which chickpeas and weeds compete.

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