EFFECT OF PRECISION GUIDED CULTIVATION ON WEED CONTROL IN WIDE ROW CROPPING SYSTEMS

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ABSTRACT

Wide row cropping has been traditionally followed in summer crops but it is also becoming popular in winter crops such as chickpeas and lupins. High precision guidance systems with 2 cm accuracy offer unique opportunities to cultivate closer to the row and increase weed control efficiency in wide row cropping systems. Two field experiments were conducted in chickpeas with a Real Time Kinematic Differential Global Positioning System (RTK-DGPS) controlled mechanical cultivation. Cultivation treatments were 2 cm, 5 cm and 15 cm from the row at six weeks after emergence (6WAE) in the first experiment, and 7.5 cm and 15 cm from the row at 5WAE in the second experiment. Percentage of weeds removed, crop damage, crop and weed biomass at flowering, and crop yield were measured. For experiment 1, weed removal rates were 59%, 55% and 49% for 2 cm, 5 cm and 15 cm treatments, respectively. Random errors in the accuracy of GPS caused about 20% crop damage for 2 cm treatment. Thus, crop yield of 5 cm treatment tended to be highest and similar to the weed-free treatment. Significant yield differences were most likely precluded by large spatial variability of weed density among treatments. Much higher weed removal rates were observed in experiment 2 (77% and 54% for 7.5 cm and 15 cm treatments, respectively), primarily due to lower weed density and earlier cultivation. This resulted in a trend to higher crop biomass at flowering for 7.5 cm treatment (4.6 t/ha compared to 4.0 t/ha for 15 cm). The same trend was found for crop yield. Precision mechanical weed control 5 to 7.5 cm from the row was effective and would help farmers control herbicide escapes, and slow development of herbicide-tolerant species.

Keywords: Precision guidance, mechanical weed control, wide-row cropping

INTRODUCTION

Weeds are a major economic threat to Australian agriculture. They compete with crops, have allelopathic chemical and poisonous properties, as well as cause harvest difficulties and contaminate seed and act as carriers of harmful pests and diseases (Singh et al., 2005). The annual cost of weed control is estimated to be around $1.4 billion in Australia (Sinden et al., 2004).

Since the introduction of herbicides and farming systems such as zero tillage, the use of mechanical weed control has reduced (Bishop and Collins, 2004). However, there has been renewed interest in mechanical weed control due to increasing impact of herbicide resistance, environmental and safety concerns, and adoption of wide row cropping systems.

Wide row cropping systems have been traditionally used for summer crops such as sorghum, maize and cotton. However, winter crops such as chickpeas and lupins are also now being planted in wide rows. Whish et al. (2002) found that crops such as chickpeas (*Cier arietinum* L.) can be grown in rows 50-75 cm without reducing yield. Similar results were obtained by Felton et al. (2004) who found that doubling the row spacing from 32 to 64 cm did not reduce the yield of chickpea under weed-free conditions. French (2004) also did not find any significant reduction in yield of lupins (*Lupinus angustifolius* L.) grown in 50 cm or 74 cm row spacing compared to traditional 25 cm row spacing. A recent review by Peltzer et al. (2009) concluded that wide row cropping has been widely adopted to conserve water, to control pests and diseases, and to minimize problems associated with stubble management encountered under the traditional narrow row spacing during sowing.

Wide row cropping systems offer unique opportunities for use of new and emerging technologies for weed control such as precision guided mechanical weed control. The most obvious example of precision weed control is where a human eye and hand identifies the weed and precisely positions a hoe to destroy it. Where the crop is planted and managed with great precision, spatial selectivity (i.e. identification of weeds as plants outside the row) can achieve a similar result. With the availability of high precision guidance systems (~ 2 cm accuracy), the width of the crop strip within which weeds may survive becomes smaller resulting in greater control of weeds competing with crop.

High-precision field guidance has developed to the point where the performance limitations of traditional inter-row cultivation no longer apply (Wilson, 2000). Skilled operators can steer equipment reliably to within perhaps ± 5 cm for relatively short periods at limited speed. The precision guidance systems being purchased by farmers can operate to within ± 2 cm indefinitely at normal field speeds (~8 km/h).

The main aim of this study was to assess the effectiveness of precision-guided mechanical weed control in a chickpea crop (*Cier arietinum* L.) grown in a wide row system. Weed removal, crop damage, weed and crop biomass at flowering, and crop yield were ascertained to compare various cultivation treatments.

METHODOLOGY

Two field experiments were conducted at the University of Queensland Gatton Farm by growing chickpeas in wide rows. The first experiment was carried out in 2006 with five treatments:

T1 = no weed control
T2 = control of weeds 15 cm from the row with precision guided cultivator
T3 = control of weeds 5 cm from the row with precision guided cultivator
T4 = control of weeds 2 cm from the row with precision guided cultivator
T5 = entirely weed free

Treatments were carried out in a randomized complete block design with four replications. Each plot was 3 m wide and 20 m long with 4 rows on 0.75 m spacing. A 4-row planter attached to John Deere 4040 tractor with a Real Time Kinematic Differential Global Positioning System (± 2 cm accuracy) was used to plant chickpea seed (desi variety, cultivar Jimbour) at a depth of 5 cm on 8 May 2006. Fig. 1 shows the general layout of the experiment. The trial was completely surrounded by four guard rows to minimize edge effects, and was fenced to prevent hares consuming young chickpea plants.

Fig. 1. General layout of field trial at Gatton farm.

Cultivation within the inter-row occurred at 6 weeks after emergence (WAE) using a rear mounted cultivator with beet knives. Again, the John Deere 4040 tractor with RTK-GPS was used to carry out three cultivation treatments (T2, T3 and T4). The gravimetric soil moisture was 14.2% at cultivation. Weeds in the weed free treatment (T5) were removed at 3, 5, 7 and 9 WAE by using chip hoes between the rows and manual pulling of weeds within the crop rows. The following measurements were taken from the intra-row and inter-row zones of the two middle rows of each treatment:

- dominant weed species
- crop density at 3 WAE
- crop density at maturity
- weed density before and after cultivation
- crop damage by cultivation
- crop and weed biomass at full flowering stage
- crop yield

Intra-row zone is defined as the area where majority of plants grow (Fig. 2). The inter-row zone is defined as the area between crop rows where no plants grow; with the exception of outlying crop plants. As the width of cultivation increases, the inter-row zone increases and the intra-row zone decreases.

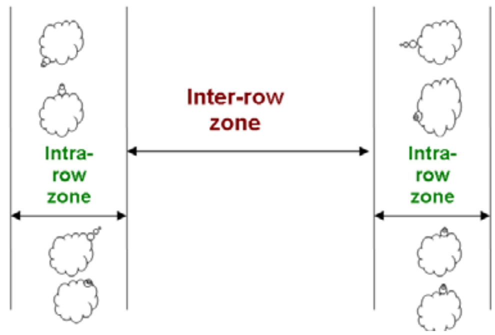

Fig. 2. Inter-row and intra-row zones of the crop.

Weed species present in the trial area were identified using weed identification manuals (Lamp and Collet, 1989; Wilson et al., 1995; Dight et al., 2003). Crop density was determined by counting chickpea plants within one meter at two random locations in the two middle rows of each plot. Weed density was determined by counting the number of weeds in five quadrats placed at different locations in the two middle rows. The following equation was used to determine the efficiency of weed removal under each cultivation treatment:

$$\textit{Weeds removed}\ (\%) = \frac{WD_{bc} - WD_{ac}}{WD_{bc}} \times 100$$

WD_{bc} = Weed density before cultivation (weeds/m^2)
WD_{ac} = Weed density after cultivation (weeds/m^2)

The amount of crop damage by cultivation was determined by measuring the length of row with dead plants in the middle rows of each plot (2 rows × 20 m row) a week after the cultivation:

$$\textit{Crop damage}\ (\%) = \frac{\textit{Row length of dead plants (m)}}{\textit{40 m}} \times \textit{100}$$

At full flowering stage, the crop and weed biomass were measured by cutting plants at ground level from two quadrats placed on the intra-row and inter-row zones of each plot. The chickpea plants and each separate weed species were put in separate bags and labelled. The material was then dried in fan forced ovens for five days at 60°C to determine the dry biomass of the crop and weeds from each treatment. The crop yield was determined by harvesting each plot manually. The cut plants were dried in fan forced ovens at 60ºC for one day before threshing. The samples were cleaned by using screens/indent cylinder and the clean seed for each plot was weighed to determine yield.

The second experiment was carried out in 2007 with the following four treatments:

T1 = no weed control
T2 = post-sowing pre-emergent (PSPE) application of simazine over whole plot
T3 = control of weeds 15 cm from the row with precision guided cultivator
T4 = control of weeds 7.5 cm from the row with precision guided cultivator

The chickpea crop was planted on 5 June 2007. Cultivation treatments were carried out at 5WAE. The gravimetric soil moisture was 14.1% at cultivation. Preliminary trials with 5 cm from the row showed that most plants were covered by the soil dispersed by the cultivating tool. Field measurements were taken using the techniques similar to first experiment.

Data from both experiments were analyzed by using a Minitab statistical package (version 14, Minitab Inc., State College, PA, USA) and treatment means were compared using Tukey's Simultaneous Tests.

RESULTS AND DISCUSSION

Experiment 1

Weed Species

The chickpea trial area was infested with a wide variety of weeds - 4 monocotyledons and 11 dicotyledon weed species (Table 1). Out of these 15 species, the predominant weeds were marsh mallow, fat hen, turnip weed, liverseed grass and burr medic.

Table 1. Weed species found in the chickpea trial in experiment 1.

Common name	Scientific name
Monocotyledons (Grasses)	
Awnless Barnyard grass	*Echinochloa colona*
Liverseed grass	*Urochloa panicoides*
Oats	*Avena sativa*
Prairie grass	*Bromus catharticus*
Dicotyledons (Broadleaf weeds)	
Apple of Peru	*Nicandra physalodes*
Bell vine	*Ipomoea plebian*
Blackberry nightshade	*Solanum nigrum*
Burr medic	*Medicago polymorpha*
Dead nettle	*Lamium amplexicaule*
Fat hen	*Chenopodium album*
Lesser swinecress	*Coronopus didymus*
Marsh mallow	*Malva parviflora*
Milk Thistle	*Sonchus oleraceus*
Powell amaranth	*Amaranthus powellii*
Turnip weed	*Rapistrum rugosum*

Crop density

The crop density was fairly uniform throughout the treatments at 3 weeks after emergence (WAE). The average crop density was between 18.6 and 20.5 plants/m^2. At crop maturity each treatment declined in density; however the decline was greatest with T4 where cultivation was carried out at 2 cm from the row (Table 2). T4 was significantly different ($P<0.05$) from T2 and T5.

Table 2. Density of chickpea plants in experiment 1.

Treatment	Crop density at 3WAE (plants/m^2)	Crop density at maturity (plants/m^2)
No weed control (T1)	18.6	17.1
Cultivation 15 cm from the row (T2)	19.1	17.4
Cultivation 5 cm from the row (T3)	18.9	15.5
Cultivation 2 cm from the row (T4)	19.6	9.9
Weed free (T5)	20.5	19.6

Overall weed control

The average percentage of weeds removed by each cultivation treatment is shown in Fig. 3. As expected the general trend was for the percentage of weeds removed to increase as cultivation occurred closer to the row. There was a significant ($P<0.10$) difference between T4 (59% removed) and T2 (49% removed); T3 had 55% of weeds removed.

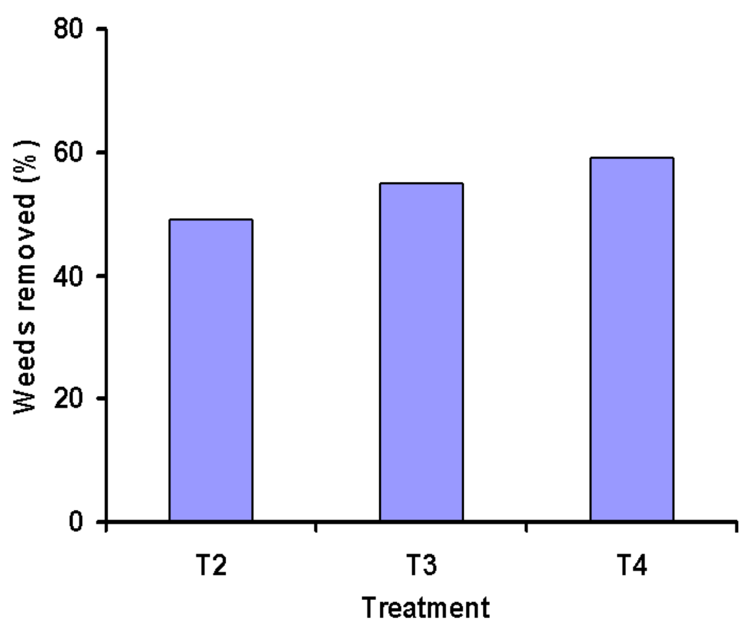

Fig. 3. Weeds removed by precision guided cultivation in experiment 1.

Crop damage from cultivation

Visual damage to the crop caused by cultivation was very minor in T2 and T3 and appeared to be mainly from tines blocking up with weeds and resulting in a bulldozing effect (Table 3). T4 was significantly different ($P<0.05$) to all other treatments; on average 20.6% of plants were killed from cultivation damaging root systems causing death to plants (Fig. 4). Damage to the crop was caused by the cultivator when the guidance system deviated off course. This is evidenced from the fact that no crop damage occurred in one of the replications for T2 treatment (R2). This may be due to trees obstructing the signal and would not be an issue in large paddocks in open areas.

Table 3. Crop damage caused by cultivation during experiment 1.

Treatment	Crop damage (%)
No weed control (T1)	N.A.
Cultivation 15 cm from the row (T2)	0.1
Cultivation 5 cm from the row (T3)	0.2
Cultivation 2 cm from the row (T4)	20.6
Weed free (T5)	N.A.

Fig. 4. Five days after cultivation at 2 cm from the row in experiment 1.

Crop biomass

Crop biomass at full flowering stage (13 WAE) is shown in Fig. 5. Dry matter was not significantly different for treatments ($P<0.05$) but the weed free treatment T5 tended to produce the largest amount of dry matter (8.9 t/ha) while T4 (cultivation 2 cm from the row) produced the least amount (7.4 t/ha) due to cultivation damage. T2 and T3 (8.5 t/ha) produced equal amounts of dry matter, which was more than T1 and T4.

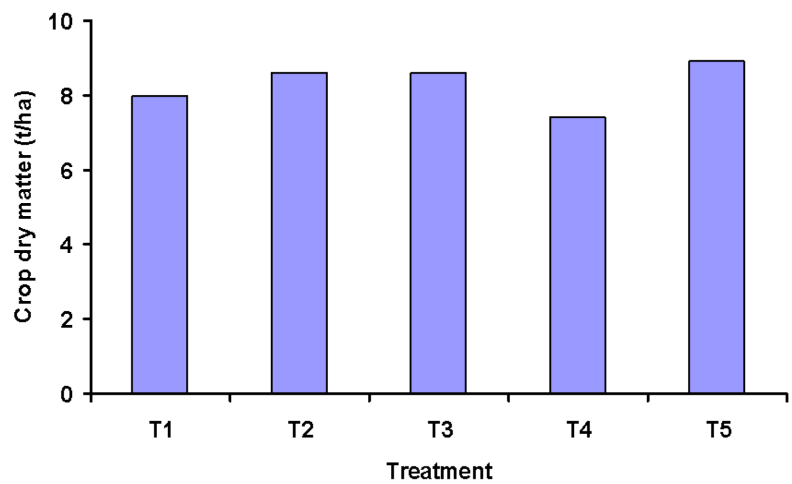

Fig. 5. Crop biomass at full flowering for experiment 1.

Weed biomass

Fig. 6 shows the dry matter of weeds at full flowering stage. Weed biomass in the inter-row was significantly different ($P<0.05$) between treatments. As expected T1 had a weed dry matter weight considerably higher than all other treatments. T3 tended to have the highest amount of biomass of the cultivated treatments, followed by T4 and T2 respectively. This was surprising considering the higher removal of weeds by T3. The biomass of weeds within the intra-row at full flowering was highest for T3 (Fig. 6). T3 was significantly ($P<0.05$) higher than T4 and T5, but not significantly different to T1 and T2. This was also surprising because it would be expected that T3 at 5 cm would reduce the weed population more than cultivation at 15 cm. These anomalous results for T3 may reflect the spatial variability of weeds in this trial; in this case, a bias against T3. This could be overcome in future work by sowing another crop as a weed to achieve uniform coverage and then planting chickpea into it.

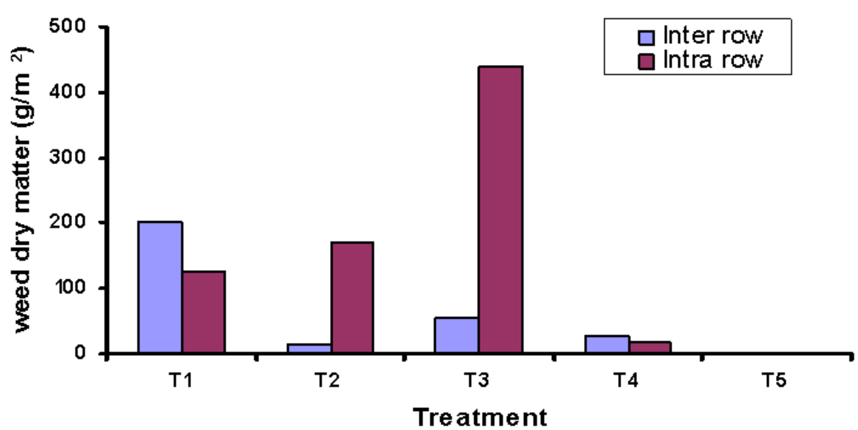

Fig. 6. Weed biomass at full flowering for experiment 1.

Crop yield

There was no significant difference (P<0.05) in crop yield between the treatments (Fig. 7). T1 (control treatment) tended to have the lowest yield (0.83 t/ha), with T2 and T3 increasing to 0.95 t/ha and 1.35 t/ha respectively. T4 tended to be lower in yield (1.05 t/ha), but not less than T2. The weed free treatment had a high yield of 1.31 t/ha similar to T3.

Plants with the most biomass (excluding T5), were severely lodged from rainfall and strong westerly winds prior to harvesting. These lodged plants had wet and moldy seeds many of which shattered. Treatments with a large biomass were also much greener during harvesting and thus the moisture of the seed and pods was higher causing threshing difficulties. A great amount of yield loss was caused by *Heliothis armigera* and *H. punctigera* as larvae were present in large numbers (>50 larvae/m). Thus, the yield data does not reflect the crop biomass present at full flowering stage.

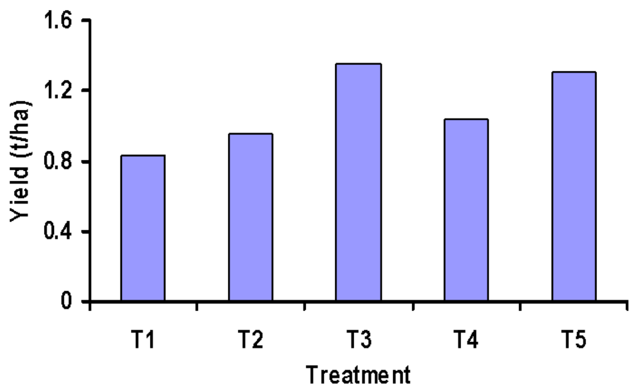

Fig. 7. Crop yield for various weed control treatments for experiment 1.

Experiment 2

Weed Species

Weeds in Experiment 2 were similar to those in the first experiment with liverseed grass being predominant followed by turnip weed and fat hen.

Table 4. Weed species found in the chickpea trial in experiment 2.

Common name	Scientific name
Monocotyledons (Grasses)	
Awnless Barnyard grass	*Echinochloa colona*
Liverseed grass	*Urochloa panicoides*
Dicotyledons (Broadleaf weeds)	
Burr medic	*Medicago polymorpha*
Fat hen	*Chenopodium album*
London rocket	*Sisymbrium irio*
Marsh mallow	*Malva parviflora*
Turnip weed	*Rapistrum rugosum*

Crop density

The crop density was quite uniform for all the treatments at 3 weeks after emergence (Table 5). The average crop density was between 19.3 and 20.1 plants/m^2.

Table 5. Density of chickpea plants at 3 WAE for experiment 2.

Treatment	Crop density at 3WAE (plants/m^2)
No weed control (T1)	20.1
PSPE Simazine (T2)	19.3
Cultivation 15 cm from the row (T3)	20.0
Cultivation 7.5 cm from the row (T4)	19.6

Overall weed control and crop damage

Both cultivation treatments were very effective in removal of weeds without damage to the crop (Table 6). Closer cultivation to the row (7.5 cm) resulted in significantly more weed removal (77%) than further away (54%). With a stable GPS system, it is feasible to remove weeds close to the row without damaging the crop.

Table 6. Overall weed control and crop damage during experiment 2.

Treatment	Weed removal (%)	Crop damage
Cultivation 15 cm from the row	54	Nil
Cultivation 7.5 cm from the row	77	Nil

Crop biomass

Crop biomass showed no significant differences but the trend was for increased crop biomass with cultivation treatments (Table 7). Close cultivation tended to show higher biomass than cultivation at 15 cm which was similar to the Simazine treatment. Larger biomass for closer cultivation would be expected with greater weed removal which results in less competition for the crop.

Table 7. Crop biomass at full flowering for experiment 2.

Treatment	Crop biomass (t/ha)
No weed control (T1)	3.8
PSPE Simazine (T2)	4.1
Cultivation 15 cm from the row (T3)	4.0
Cultivation 7.5 cm from the row (T4)	4.6

Weed biomass

Weed biomass at flowering was significantly different among cultivation treatments – 72 g/m^2 for 7.5 cm, and 247 g/m^2 for 15 cm cultivation treatment. Weed biomass for PSPE simazine treatment (77 g/m^2) was close to being significantly lower (P=0.062) than the non-weeded treatment (306 g/m^2) (Fig. 8). Compared to the non-weeded control (T1), inter-row cultivation 7.5 cm from the row (T4) resulted in 76% reduction in weed biomass. Reduced weed biomass for close cultivation was most likely due to effective removal of weeds 5WAE. The larger value for 15 cm treatment (T3) was unexpected and may reflect variability in weed density.

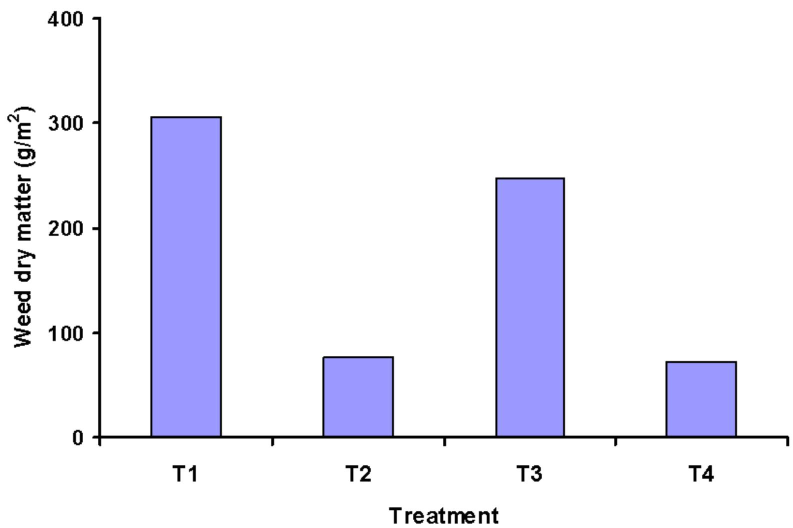

Fig. 8. Weed biomass at full flowering for experiment 2.

Crop yield

Crop yields were relatively low and may reflect the poor growing conditions during the trial (Table 8). Crop yields were not significantly different but cultivation treatments tended to be higher yielding than the control. However, there appeared to be little difference between the 7.5 cm and 15 cm treatments. This was surprising considering the apparent difference in crop biomass at flowering. Crop yield for Simazine was unexpectedly low and difficult to explain when one considers the reduction in weed biomass and crop biomass at flowering for this treatment.

Table 8. Crop yield for various treatments for experiment 2.

Treatment	Crop yield (t/ha)
No weed control (T1)	0.69
PSPE Simazine (T2)	0.60
Cultivation 15 cm from the row (T3)	0.74
Cultivation 7.5 cm from the row (T4)	0.77

CONCLUSIONS

No crop damage occurred with inter-row cultivation up to 5 cm from the row in Experiment 1 and 7.5 cm from the row in Experiment 2 using Real Time Kinematic Differential Global Positioning System. This is much improved over cultivations using operator guidance where 10 to 15 cm from the row is the norm. Inter-row cultivation 2 cm from the row is possible but random GPS guidance inaccuracy can cause crop damage up to 20%. If there are no accuracy problems as is likely where the signal is unobstructed, then damage may not occur and it would be possible to cultivate effectively as close as 2 cm from the row. Compared to the non-weeded control, inter-row cultivation 7.5 cm from the row resulted in 76% reduction in weed biomass in Experiment 2. Crop yield for 5 cm cultivation from the row approached the weed free treatment in Experiment 1. High–precision field guidance is now an option on all broadacre tractors sold in Australia. This increasingly common system, with the appropriate cultivating tools, has the basis of a mechanical weed control option. Intermittent use of a non-herbicide weed management option might be extremely valuable to help farmers cope with herbicide escapes, and slow the development of herbicide-tolerant species.

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REFERENCES

Bishop, A.C., and M. Collins. 2004. Physical weed control working group – a case study of a weed information network. p. 620-622. *In* B.M. Sindel and S.B. Johnson (eds.) Proc. 14th Australian Weeds Conference, 6-9 September 2004, The Charles Sturt University, Wagga Wagga, NSW, Australia.

Dight, G.A., J.A. Huggins, M.J. Lucy, and G.R. Zerner. 2003. Weeds of Southern Queensland. Dept. of Primary and Fisheries Industries, Brisbane, Australia.

Felton, W.L., B.M. Haigh, and S. Harden. 2004. Comparing weed competition in chickpea, fababean, canola and wheat. p. 304-307. *In* B.M. Sindel and S.B. Johnson (eds.) Proc. 14th Australian Weeds Conference, 6-9 September 2004, The Charles Sturt University, Wagga Wagga, NSW, Australia.

French, B. 2004. Effect of environment to lupin yield response to row spacing. *In* Crop Updates, Technical Information for Agribusiness. p. 31-32. Dept. of Agriculture, Perth, WA, Australia.

Lamp, C., and F. Collet. 1989. Field guide to weeds in Australia. Inkata Press, Melbourne, Australia.

Peltzer, S.C., A. Hashem, V.A. Osten, M.L. Gupta, A.J. Diggle, G.P. Riethmuller, A. Douglas, J.M. Moore, and E.A. Koetz. 2009. Weed management in wide

row cropping systems: A review of current practices and risks for Australian farming systems. Crop and Pasture Science, 60:395-406.
Sinden, J., R. Jones, S. Hester, D. Odom, C. Kalisch, R. James, and O. Cacho. 2004. The Economic Impact of Weeds in Australia. CRC for Australian Weed Management, Technical Series No. 8, Adelaide, Australia.
Singh, H.P., D.R. Batish, and R.K. Kohli (eds.). 2005. Handbook of Sustainable Weed Management. Haworth Press, Inc. New York.
Whish, J., B. Sindel, R. Jessop, and W. Felton. 2002. The effect of row spacing and weed density on yield loss of chickpea. Australian Journal of Agricultural Research, 53:1335-1340.
Wilson, B.J., D. Hawton, and A.A. Duff. 1995. Crop weeds of northern Australia: identification at seedling and mature stages. Dept. of Primary Industries, Brisbane, Australia,
Wilson, J.N. 2000. Guidance of agricultural vehicles – a historical perspective. Computers and Electronics in Agriculture, 25:3-9.