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Research Paper

Weed-management strategies in chickpea (*Cicer arietinum*) for higher productivity and profitability in north-western part of India

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ABSTRACT

A field experiment was conducted during 2009–10 and 2010–11 at Ludhiana, Punjab, to investigate the efficacy of different herbicides in chickpea (*Cicer arietinum* L.) for effective management of grass and broad-leaf weeds. The experiment was laid out in randomized complete- block design with 15 treatments replicated thrice. The treatments comprised of pre-emergence (PE) application of oxyfluorfen @ 0.15 kg/ha followed by (*fb*) 1 hand-weeding 45 days after sowing (DAS), oxyfluorfen (PE) @ 0.175, 0.200, 0.225 kg/ha, alachlor (PE) @ 2.0 and 2.5 kg/ha each *fb* 1 hand-weeding at 45 DAS, pendimethalin (PE) @ 0.75 kg *fb* 1 HW at 45 DAS, tank-mix pendimethalin + alachlor (PE) @ 0.50 +1.25 kg/ha, 0.75 + 1.25 kg/ha, pendimethalin + oxyfluorfen (PE) @ 0.75 + 0.15 kg/ha, trifluralin + alachlor (PE) @ 0.50 + 1.25, 0.75 + 1.25 kg/ha, trifluralin + oxyfluorfen (PE) @ 0.75 + 0.15 kg/ha, weed free and unweeded control. The results showed that pendimethalin @ 0.75 kg/ha or oxyfluorfen @ 0.15 kg/ha *fb* 1 hand-weeding at 45 DAS significantly reduced weed density and dry weight, thereby attaining the highest average grain yield of 1.43 and 1.47 t/ha. Benefit: cost ratio was also the highest in pre-emergence application of oxyflourfen @ 0.15 kg/ha *fb* 1 HW at 45 DAS followed by pendimethalin 0.75 kg *fb* 1 HW at 45 DAS.

Key words : Chickpea, Economics, Herbicides, Weed density, Weed dry weight, WCE, Yield

Chickpea is an important protein-rich legume crop grown in India. In Punjab, it was grown on 1.9 thousand ha with a production of 2.4 thousand tonnes during 2013–14 (PAU, 2015). The productivity of chickpea is quite low due to number of reasons but predominantly due to lack of suitable weed-control measures. Average yield of pulse crops in India is low compared to the world average. However, the average yield of pulse crops in the country has increased gradually over the period and it was 690 kg/ha in 2010–11, being 56% higher than the yields during 1950 (Laxmipathi *et al.,* 2013). So there is a great need to increase its area as well as productivity/unit area. Weeds pose a serious problem in this crop due to its short stature and slow initial growth, and weeds also compete severely with the crop for all the growth factors. Significant losses occur if the weeds are not controlled at the right stage. Depending on the intensity of weed flora and duration of weed-infestation, the losses due to weeds may go up to 40–80% (Vaishya *et al.,* 1996). Weeds reduce grain yield of chickpea by 60% (IIPR, 1997) and even higher up to the extent of 75% as reported by Chaudhary *et al.* (2005). Unweeded conditions cause a yield reduction of 40–80% over weed-free check (Patil *et al*., 2002). The initial 60 days period considered to be the critical for crop-weed competition in chickpea (Singh and Singh, 1992). Among various pests, weeds in general reduce yields by 30–54% in chickpea (Mukherjee, 2007). Under Punjab conditions, it is generally grown under irrigated conditions. The area could only be increased under pulses if all the biotic and abiotic stresses can be overcome which will ultimately contribute towards enhancement of yield. Therefore, there is a need to identify effective herbicides and also to integrate various methods of weed control for effective and economical weed management in this crop. Hence a research trial was conducted to find out the effective herbicide for integrated method which can provide good control of weeds in chickpea.

MATERIALS AND METHODS

A field experiment was conducted during the winter (*rabi*) seasons of 2009–10 and 2010–11, to assess the effect of different weed management practices in chickpea at Research Farm, Department of Agronomy, Punjab Ag-

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ricultural University, Ludhiana. It is situated in trans-gangetic agro-climatic zone, representing the Indo-Gangetic alluvial plains at (30° 56' N, 75° 52' E and an altitude of 247 m above mean sea-level). The climate of this region is characterized as sub-tropical semi-arid with hot summer and very cold winters. The soil of the experimental field was loamy sand, normal in reaction (*p*H 7.2) and electrical conductivity (0.14 dS/m), was low in organic carbon (0.37%) and available nitrogen (220.1 kg/ha) while medium in available phosphorus (18.0 kg/ha) and potassium (209 kg/ha). The experiment was laid out in randomized complete-block design with 15 treatments replicated three times. The treatments were: T_1, Pre-emergence (PE) application of oxyfluorfen (23.5 EC) @ 0.15 kg/ha followed by (*fb*) 1 hand-weeding (HW) at 45 days after sowing (DAS); T_2, oxyfluorfen @ 0.175; T_3, oxyfluorfen @ 0.200; T_4, oxyfluorfen @ 0.225 kg/ha; T_5, alachlor (PE) @ 2.0 *fb* 1 HW at 45 DAS; T_6, alachlor (PE) @ 2.5 kg/ha *fb* 1 HW at 45 DAS; T_7, pendimethalin (PE) 30 EC @ 0.75 kg *fb* 1 HW at 45 DAS; T_8, tank-mix pendimethalin + alachlor (PE) @ 0.50 + 1.25; T_9, tank-mix pendimethalin + alachlor (PE) @ 0.75 + 1.25 kg/ha; T_{10}, pendimethalin + oxyfluorfen (PE) @ 0.75 + 0.15 kg/ha; T_{11}, trifluralin + alachlor (PE) @ 0.50 + 1.25; T_{12}, trifluralin + alachlor (PE) @ 0.75 + 1.25 kg/ha; T_{13}, trifluralin + oxyfluorfen (PE) @ 0.75 + 0.15 kg/ha; T_{14}, weed-free; and T_{15}, unweeded control. All herbicides as per the treatment were applied with knap-sack sprayer fitted with flood jet nozzle with discharge rate of 500 litres water/ha. Sowing of chickpea variety 'GPF 2' and 'PBG 5' was done manually on 3 November 2009 and 4 November 2010 respectively, in rows spaced 30 cm apart with *pora* method. A seed rate of 40 kg/ha was used during both the years. The seed was treated with chlorpyriphos @ 10 ml/kg followed by fungicide Captan @ 3 g/kg. Crop was raised by applying 15 kg N (32.5 kg urea) and 20 kg P_2O_5/ha (125 kg single super phosphate). All the fertilizers were applied at the time of sowing.

The crop was harvested manually. The data on yield attributes and seed yield were recorded and analyzed statistically using online analysis of data (http://stat.iasri.res.in/sscnarsportal). In each plot, 2 spots were randomly selected for recording the data on weed density and dry-matter accumulation at 60 DAS, using a quadrat measuring 0.50 m × 0.50 m. The weeds were counted and removed for recording their biomass. Weed samples were initially sun-dried and then dried in an oven at a temperature of 60°± 2ºC until constant weight was attained. The data on weeds were subjected to square-root transformation before statistical analysis. The weed-control efficiency (WCE) was calculated as:

$$WCE\ (\%) = (DMC–DMT)/DMC \times 100$$

where DMC is the weed dry matter (g) in unweeded control and DMT is weed dry matter (g) in a particular treatment.

Weed index is defined as the magnitude of yield reduction due to presence of weeds in comparison with weed free. Weed index was calculated by using following formulae:

$$Weed\ Index\ (\%) = X–Y/X \times 100$$

where, X = crop yield from the weed free check; Y = crop yield from the treatment.

The benefit: cost ratio (B:C) was calculated by dividing gross returns with cost of cultivation.

RESULTS AND DISCUSSION

Effect on weeds

The crop was naturally infested with both grass and broad-leaf weeds and the major weed flora observed in the experimental field were: *Phalaris minor, Chenopodium album, Medicago denticulata, Coronopus didymus, Rumex dentatus, Anagallis arvensis* etc. On an average, weed density of 172 plants/m^2 was recorded in the unweeded control. The efficacy of different herbicides including pendimethalin, oxyfluorfen, trifluralin, alachlor on weeds and seed yield of chickpea was studied. The results (Table 1) revealed that density of weeds was significantly influenced by the different weed-control treatments. The density of grass weeds was observed the minimum in oxyfluorfen @ 0.150 kg/ha *fb* 1 HW at 45 DAS which was statistically at par with pendimethalin @ 0.75kg/ha *fb* 1 HW at 45 DAS, alachlor 2.0 and 2.5 kg/ha each *fb* 1 HW at 45 DAS, pendimethalin + alachlor 0.75 + 1.25 kg/ha, trifluralin + alachlor 0.5 + 1.25 kg/ha and 0.75 + 1.25 kg/ha and significantly less than all other treatments. Tank-mix application of pendimethalin + oxyfluorfen (0.750 + 0.150 kg/ha) or trifluralin + oxyfluorfen (0.750 + 0.150 kg/ha) proved more effective and also recorded significantly lesser numbers of grass weeds than that of oxyfluorfen alone when applied at 0.200 or 0.225 kg/ha alone.

Similarly, the density of broad-leaf weeds was significantly less in oxyfluorfen-treated plots, irrespective of its doses as compared to other herbicides and was statistically at par with trifluralin + oxyfluorfen @ 0.75 + 0.150 kg/ha. Further, higher doses of oxyfluorfen (0.200 and 0.225 kg/ha) proved more effective in controlling grass and broad-leaf weeds both in terms of density and dry weight. Pendimethalin controlled the weeds effectively up to 30–35 days and later on weeds started emerging which were effectively controlled by 1 hand-weeding 45 DAS hence showed much better results.

Dry weight of grass weeds was significantly affected by weed-control treatments. Significant reduction in dry

weight of grass weeds was recorded in pendimethalin @ 0.75 kg/ha *fb* 1 HW at 45 DAS which was equally effective as tank-mix application of trifluralin + alachlor (0.50 + 1.25 kg/ha and 0.75 + 1.25 kg/ha), pendimethalin + oxyfluorfen 0.75 + 0.150 kg/ha, pendimethalin + alachlor 0.75 + 1.25 kg/ha but showed superiority to rest of the treatments. Like-wise dry-matter of broad-leaf weeds was significantly less in pendimethalin 0.75 kg/ha *fb* 1 hand-weeding (45 DAS) and at par with oxyflourfen 0.150 kg/ha *fb* 1 hand-weeding (45 DAS). However, significantly higher weed dry-matter was obtained in tank-mix application of alachlor with pendimethalin and trifluralin at both the respective doses. Similar trends were noticed in dry-matter accumulation of total weed. Pendimethalin @ 0.75 kg or oxyfluorfen @ 0.15 kg/ha each integrated with 1 hand-weeding at 45 DAS decreased the dry-matter accumulation of weeds to the tune of 67.7 and 67.9% compared to unweeded control. Integration of hand-weeding with pre-emergence application of pendimethalin @ 0.75 kg/ha or oxyfluorfen @ 0.15 kg/ha resulted in significant reduction in dry-matter accumulation of weeds as compared to oxyfluorfen alone irrespective of its different doses (0.175, 0.200 and 0.225 kg/ha). Singh and Sahu (1996) and Siag (2000) also reported lower weed dry-matter accumulation by integration of herbicide with hand-weeding. The highest weed-control efficiency (WCE) was recorded in weed-free as the plots were free from weeds. It was followed by oxyfluorfen @ 0.15 kg/ha or pendimethalin @ 0.75 kg/ha, each integrated with 1 hand-weeding at 45 DAS owing to better control of weeds. Ratnam *et al*. (2011) also reported that integrated treatments were found to be superior (83–89% WCE) to sole application of herbicides in chickpea. The lowest weed index (WI) was recorded in oxyfluorfen followed by pendimethalin both *fb* hand-weeding treatments. Higher weed index (WI) was recorded in the unweeded control, indicating greater loss due to weeds.

Effect on crop

Plant height recorded at maturity was comparable under different weed-control treatments; however, suppressed drastically in unweeded control due to heavy infestation of grass and broad-leaf weeds. The plant height of chickpea was 74.9 cm in weed-free treatment which was 41% higher than that of unweeded control.

The average number of pods/plant, 100-seed weight and branches/plant recorded at the time of harvesting were significantly more under different herbicidal and herbicide *fb* hand-weeding treatments as compared to unweeded control (Table 2). This might be owing to effective control of weeds which in turn recorded significantly higher number of pods, 100-seed weight and branches/plant. Mishra *et al*. (2005) also reported 56.8% reduction in number of pods and 23.1% reduction in grains/pod and hence reduction in grain yield (68.3%) in weedy check. There was no significant difference between number of seeds/pod among the treatments.

Weed-free plot recorded the highest number of pods/

Table 1. Effect of weed-control treatments on weed density and dry weight (60 days after sowing) of chickpea (pooled data of 2 years)

Treatments	Dose (kg/ha)	Weed density (No./m^2)		Weed dry weight (g/m^2)			WCE (%)	WI (%)
		Grasses	BLW	Grasses	BLW	Total	Total	
Oxyfluorfen *fb* 1 HW(45 DAS)	0.150	3.2 (9.3)	3.9 (14.2)	4.8 (22.4)	7.1 (48.7)	8.5 (71.1)	67.9	0.27
Oxyfluorfen	0.175	4.2 (16.9)	3.6 (11.9)	5.8 (32.1)	7.9 (62.0)	9.8 (94.1)	57.5	21.0
Oxyfluorfen	0.200	4.1 (15.9)	3.4 (10.9)	5.4 (28.6)	7.7 (58.5)	9.4 (87.0)	60.7	25.2
Oxyfluorfen	0.225	3.5 (11.0)	3.5 (11.0)	5.7 (31.4)	7.4 (53.7)	9.3 (85.1)	61.6	27.9
Alachlor *fb* 1 HW (45 DAS)	2.00	3.1 (8.6)	4.6 (20.6)	5.7 (31.5)	7.7 (57.8)	9.5 (89.3)	59.7	13.7
Alachlor *fb* 1 HW (45 DAS)	2.50	3.2 (9.5)	5.0 (23.6)	5.6 (30.3)	7.5 (55.0)	9.3 (85.3)	61.5	23.9
Pendimethalin *fb* 1 HW (45 DAS)	0.75	3.3 (9.7)	4.5 (19.5)	4.8 (22.4)	7.1 (49.1)	8.5 (71.5)	67.7	3.0
Pendimethalin + alachlor	0.50+1.25	3.5 (11.4)	5.3 (26.8)	5.3 (27.0)	8.2 (65.0)	9.6 (91.9)	58.5	27.7
Pendimethalin + alachlor	0.75+1.25	3.2 (9.5)	4.8 (22.5)	4.9 (22.7)	8.2 (66.4)	9.5 (89.1)	59.8	21.5
Trifluralin + alachlor	0.50+1.25	3.2 (9.2)	5.1 (24.5)	4.8 (22.5)	8.3 (67.9)	9.6 (90.4)	59.2	17.3
Trifluralin + alachlor	0.75+1.25	3.2 (9.0)	5.1 (25.2)	4.9 (23.5)	8.1 (64.9)	9.5 (88.4)	60.1	19.4
Pendimethalin + oxyfluorfen	0.75+0.150	3.4 (10.6)	4.1 (15.9)	5.0 (23.8)	7.7 (58.0)	9.1 (81.8)	63.1	20.5
Trifluralin + oxyfluorfen	0.75+0.150	3.1 (8.8)	3.9 (13.8)	5.1 (25.5)	7.5 (55.4)	9.1 (80.9)	63.5	23.6
Weed-free	–	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	100	–
Unweeded control	–	5.0 (23.8)	12.2 (148)	9.8 (95.4)	11.3 (126.2)	14.9 (221.6)	–	63.3
SEm±	–	0.09	0.12	0.10	0.08	0.09	–	–
CD (P=0.05)	–	0.27	0.34	0.29	0.25	0.27	–	–

*Figures in parentheses are subjected to square-root transformation; BLW, broad leaf weed; DAS, days after sowing; *fb*-followed by; HW, hand-weeding; WCE, weed control efficiency; WI, weed-index

plant, 100-seed weight and branches/plant over all the other weed-control treatments. This might be owing to lesser crop competition with weeds in terms of soil moisture and nutrients. The higher values of these attributes were owing to positive effect of better plant growth in weed-free treatment during the critical stages of crop growth. The treatments involving mixture of different herbicides did not show any significant increase in number of pods/plant and number of branches/plant over herbicide *fb* hand-weeding treatments. Oxyfluorfen at higher dose of 0.200 and 0.225 kg/ha showed phytotoxicity hence failed to get good number of pods and branches/plant. Burning of leaf tips were the prominent symptoms of the herbicidal phytotoxicity.

The seed yield was significantly high in weed free as compared to all other treatments during both the years and comparable with pre-emergence application of pendimethalin @ 0.75 kg/ha or oxyfluorfen @ 0.150 kg/ha each *fb* 1 hand-weeding at 45 DAS and were significantly higher than all other herbicide treatments during both the years. On an average of 2 years, 63.3% reduction in seed yield was recorded due to weeds. Weed-free treatment recorded the highest values of pods/plant, 100-seed weight and branches/plant which contributed towards the highest average yield (1.47 t/ha). Oxyfluorfen in combination with pendimethalin recorded seed yield at par with its combination with trifluralin but significantly lesser than oxyfluorfen @ 0.15 kg/ha or pendimethalin @ 0.75kg/ha *fb* 1 HW at 45 DAS. Trifluralin used in combination with alachlor @ 0.50 + 1.25 and 0.75 + 1.25 kg/ha and pendimethalin + alachlor @ 0.75 + 1.25 kg/ha were at par with respect to seed yield.

Different weed-control treatments registered significant increase in seed yield of chickpea compared with unweeded control. Among the treatments, unweeded control registered the lowest average seed yield, whereas pre-emergence application of pendimethalin @ 0.75 kg/ha or oxyfluorfen @ 0.150 kg/ha each *fb* 1 HW at 45 DAS proved as effective as weed-free treatment and recorded significantly higher seed yield over rest of the treatments. Chaudhary *et al.* (2005) also reported 75% reduction in chickpea yield reduction due to weeds. The lowest values of yield among all the weed-control treatments were recorded under oxyfluorfen, especially at higher dose, viz. 0.200 and 0.225 kg/ha. This was due to phytotoxicity of this herbicide on the crop, resulting in mortality of some plants. Ratnam *et al.* (2011) also reported that pre-emergence application of lower dose of oxyfluorfen 0.10 kg/ha along with 1 HW at 30 DAS recorded the maximum yield (2.27 t/ha) which was comparable with 2 hand-weedings at 15 and 30 DAS.

Table 2. Effect of weed-control treatments on growth, yield attributes and seed yield of chickpea (pooled data of 2 years)

Treatments	Dose (kg/ha)	Plant height (cm)	Branches/ plant	Pods/ plant	Seeds/ pod	100-seed weight (g)	Seed yield (t/ha)	Straw yield (t/ha)	Harvest index (%)	Net returns (₹/ha)	Benefit: cost ratio
Oxyfluorfen *fb* 1 HW (45 DAS)	0.150	72.1	7.5	45.7	1.33	13.22	1.47	4.45	24.83	9,856	1.16
Oxyfluorfen	0.175	71.7	6.7	39.1	1.30	13.36	1.16	3.10	27.23	359	1.01
Oxyfluorfen	0.200	72.0	5.3	35.6	1.32	11.75	1.10	3.03	26.63	–524	0.94
Oxyfluorfen	0.225	71.0	5.5	34.1	1.36	11.09	1.06	2.86	27.04	–927	0.90
Alachlor *fb* 1 HW (45 DAS)	2.00	74.1	7.0	40.6	1.32	12.72	1.27	3.94	24.38	–447	0.96
Alachlor *fb* 1 HW (45 DAS)	2.50	70.7	5.4	31.4	1.35	11.91	1.12	3.06	26.79	–712	0.83
Pendimethalin *fb* 1 HW (45 DAS)	0.75	73.5	7.8	47.3	1.34	13.22	1.43	4.33	24.84	7,051	1.11
Pendimethalin + alachlor	0.50+1.25	72.5	6.1	35.4	1.38	11.05	1.06	2.84	27.18	–259	0.87
Pendimethalin + alachlor	0.75+1.25	72.1	6.5	37.1	1.36	11.97	1.16	3.13	27.04	–202	0.98
Trifluralin + alachlor	0.50+1.25	72.1	6.4	40.7	1.35	12.50	1.22	3.65	25.05	2,981	1.05
Trifluralin + alachlor	0.75+1.25	71.1	6.8	38.5	1.33	12.22	1.19	3.13	27.55	1,062	1.02
Pendimethalin + oxyfluorfen	0.75+0.15	71.0	7.5	43.7	1.32	12.02	1.17	3.10	27.40	9,582	1.07
Trifluralin + oxyfluorfen	0.75+0.15	70.1	6.4	34.1	1.30	11.88	1.13	3.04	27.10	–321	0.96
Weed-free	–	74.9	7.9	50.6	1.40	13.28	1.47	4.44	24.87	1,612	1.02
Unweeded control	–	53.1	4.2	9.9	1.31	10.95	0.54	2.06	20.77	–4,129	0.50
SEm±	–	0.8	0.1	1.6	0.001	0.02	0.038	0.35	–	–	–
CD (P=0.05)	–	2.2	0.4	2.6	NS	0.06	0.11	1.02	–	–	–

Relationship between weed-dry weight and seed yield

Correlation and regression analysis indicated that there was significant negative linear relationship between seed yield and weed dry weight at 60 DAS. In regression analysis, the equation Y = –4.5844 x + 1588.8 (Fig. 1) was found to be fit for the chickpea seed yield and dry matter of weeds which was obtained from pooled data, where Y is seed yield and x is weed dry matter. The results indicated that as the weed biomass increased, the seed yield of chickpea was decreased as significant correlation (R^2 = 0.7629) between seed yield and weed biomass was observed at 60 DAS (Fig.1).

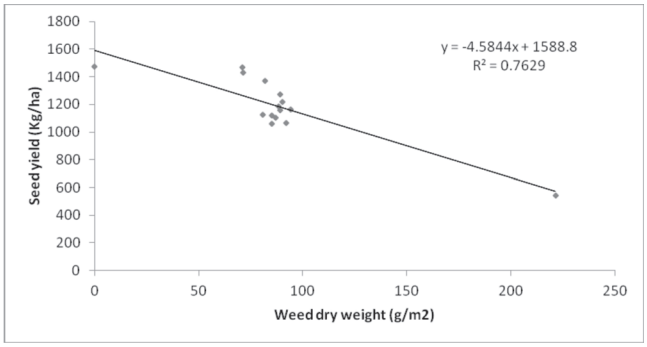

Fig. 1. Relationship between weed dry weight and seed yield of chickpea

Economics

Based on an average, the benefit: cost ratio was markedly higher with the application of oxyfluorfen 0.15 kg/ha *fb* 1 HW at 45 DAS (1.16), followed by pendimethalin @ 0.75 kg/ha along with 1 hand-weeding (1.11) over rest of the weed-control treatments (Table 2). This might be owing to good seed yield obtained under these treatments because of better management of weeds. But the benefit: cost ratio was the lowest in the unweeded control due to more weed density and lesser yield. Though weed-free treatment resulted in the highest seed yield (1.47 t/ha) owing to 100% WCE, but could not found as profitable as herbicidal treatments due to higher expenditure incurred on engaging labourers. Similar results were reported in most of the crops where weeds were solely control by hand-weedings (Kumar *et al*., 2014). Buttar *et al.* (2008) also recorded the maximum benefit: cost ratio (1.43) in pendimethalin @ 0.75 kg/ha followed by pendimethalin @ 1.0 kg/ha.

Integrated treatments of pre-emergence application of either pendimethalin 0.75 kg/ha or oxyfluorfen 0.15 kg/ha each *fb* 1 hand-weeding (HW) 45 days after sowing (DAS) produced the best results in reducing the weed density and dry weight in chickpea. Further, it can be concluded that pre-emergence application of oxyfluorfen 0.15 kg/ha or pendimethalin 0.75 kg/ha each *fb* 1 HW at 45 DAS was found to be more effective in getting higher yield and economic returns of chickpea in north-western part of India.

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