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Mausmi Rastogi
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India

Vivek
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India

RK Naresh
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India

Shipra Yadav
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India

Shivangi
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India

M Sharath Chandra
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India

Pradeep Kumar Singh
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India

Corresponding Author:
Mausmi Rastogi
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India

Effect of integrated weed management practices on weed dynamics, productivity and profitability of chickpea (*Cicer arietinum* L.) and associated weeds

Mausmi Rastogi, Vivek, RK Naresh, Shipra Yadav, Shivangi, M Sharath Chandra and Pradeep Kumar Singh

Abstract
A field study was conducted during the *Rabi* season of 2020-21 at Crop Research Center, Sardar Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, to evaluate the performance of post-emergence application of Imazethapyr in combination with pre-emergence application of Oxyfluorfen on chickpea (*Cicer arietinum* L.). The treatments comprised of Control (Weedy check) T_1, Weed free T_2, one hand weeding 25 DAS T_3, two hand weeding 25 and 50 DAS T_4, Oxyfluorfen 100 g a.i./ha Pre emergence T_5, Oxyfluorfen 100 g a.i./ha Pre emergence + one hand weeding 25 DAS T_6, Imazethapyr 50 g a.i./ha Post emergence (25 DAS) T_7, Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS T_8, Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS T_9 and Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS T_{10}. Treatments effects were evaluated in terms of weed dynamics growth, yield and economics of chickpea. The results revealed that the maximum weed control efficiency at 60 and 90 DAS in Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS T_{10} was found at par with Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS T_9 and significantly higher than the rest of treatments. The results also revealed that among the different integrated weed management treatments the highest grain yield (24.8 q ha^{-1}) was obtained under weed free treatment followed by (23.7 q ha^{-1}) with the application of Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS T_{10} which were at par (22.6 q ha^{-1}) with the application of Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS. The results revealed that the highest net monetary return (₹ 103102 ha^{-1}) and B: C ratio (2.67) among all the treatments was obtained with weed free treatment while among herbicides treatments the highest net monetary return (₹ 100102 ha^{-1}) and B:C ratio (2.82) was obtained with Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS which was found at par with Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS. The Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS found better for higher productivity and profitability of chickpea crop due to non availability of laborers.

Keywords: Chickpea, herbicide, weed dynamics, productivity, profitability

Introduction
Pulses are the most easily and cheaply available source of edible protein for the vegetarian population. However their importance has not been understood adequately. This could be attributed to the fact that India has had a large number of malnourished and poor people causing the government to promote cereal centric diet focused on subsidized rice and wheat. This is also evident in the sowing pattern, wherein the area on which pulses are sown are usually of poor soil quality. However, focus now is shifting from addressing just hunger to the larger objective of addressing malnutrition. This has necessitated that more emphasis be laid on pulses which are nutritionally superior. Apart from nutritional benefits, there are other benefits as well. Pulses act as a positive catalyst in sustaining the economy of rainfed farming community, in a number of ways. They improve soil fertility, they fit well in intercropping and mixed farming systems, crop rotation and providing fodder for the cattle. Pulses also have environmental benefits. They enrich the soil through the process of nitrogen fixation, and hence are integral to sustainable agriculture. (Anonymous, 2019) [1].
Globally, the total acreage under pulse cultivation is 85.4 Mha and the production is 87.4 Mt. The yield level stands at 1023 kg/ha. With a total acreage of more than 29 Mha under pulse cultivation, India is the largest pulse producing country in the world.

Noticeably, the productivity of pulses has seen a commendable increase standing at 835 kg/ha during 2019-20, from 662 kg/ha during Eleventh plan and 745 kg/ha during Twelfth plan. Under individual crop category, Gram recorded a highest ever production of 11.08 Mt record productivity level of 1063 kg/ha in an area of 10.56 Mha. If we observe the pattern of sown area in relation to the availability of irrigation we find that 20% of the area under pulse cropping is irrigated while the remaining 80% is rainfed. Amongst the pulses, Gram has the highest area under irrigation standing at 35%, while the remaining pulse crops are under 10%. Major weeds associated with chickpea vary with crops and locations. The Directorate of Weed Research, Jabalpur, has developed a Weed Atlas for major weeds in major crops in 435 districts spread across 19 states of the country and published a handbook on weed identification**.** Its findings revealed that;- Weeds of economic significance in specific crops (Rao *et al*., 2018) [14]. For Chickpea: *Chenopodium album* L., *Avena fatua* L., *Medicago denticulata* Willd., *Chicorium intybus*, *Convolvulus arvensis* L., *Lathyrus aphaca* L. *Lathyrus sativus* L., *Vicia sativa*, *Cyperus rotundus* L., *Orobanche* spp., *Phalaris minor* Rtez., *Avena ludoviciana*, *Euphorbia geniculata* Ortega.

The important reasons responsible for low productivity of chickpea are also attributed to infestation of weeds, insect-pest and diseases, use of local cultivar, inadequate use of fertilizer and lack of knowledge about crop management practices. Among these factors, inadequate weed management often leads to poor yield. Studies conducted under all India co-ordinate pulses improvement project indicate that among various production inputs, weed management was found most important contributing 27.6% to total yield. Weeds are a significant contributor in the yield reduction of chickpea. This can be attributed to the fact that it is traditionally grown on residual soil moisture without any control of weeds in general. The yield losses due to weeds in chickpea range between 25 to 80% (Aslam *et al*., 2007) [2]. Weeds compete with crops for natural and applied resources, thereby causing reduction in quantity and quality of agricultural productivity (Rao and chanuhan, 2015) [13]. Major weeds associated with chickpea vary with crops and locations. The following is a list of weeds of economic significance in specific crops (Rao *et al*., 2018) [14]. For Chickpea: *Chenopodium album* L., *Avena fatua* L., *Medicago denticulate* Willd., *Chicorium intybus*, *Convolvulus arvensis* L., *Lathyrus aphaca* L. *Lathyrus sativus* L., *Vicia sativa*, *Cyperus rotundus* L., *Orobanche* spp., *Phalaris minor* Rtez., *Avena ludoviciana*, *Euphorbia geniculata* Ortega.

Herbicides are the most effective and quickest method of weed control. The judicious use of herbicides reduces yield losses caused by weeds and hence increase yields of chickpea. When properly used, pre-emergence herbicides accomplish effective and economic weed control (Hassan *et al.* 2003). Khan *et al.* (2012) [10] observed the effect of different herbicides on weeds and yield of chickpea. They concluded that Isoproturon 500 EW was very effective in suppressing chickpea-associated weeds by reducing weed density significantly as compared to control.

Integrated weed management approach involves the use of two or more weed control techniques selected from five general categories viz., preventive, cultural, mechanical, biological and chemical in a well-planned sequence. In a recent research, Waqas *et al.* (2016) [22] reported that hand weeding followed by herbicides depicted least density and biomass for weeds. Vaishya *et al.* (1996) [21] found that the integrated weed management was found to be the most economical. Among the chemical weed control treatment, application of pendimethalin @ 0.75 a.i. kg ha^{-1} + 1 hand weeding produced higher yield and gave highest net monetary returns and B:C ratio and found most effective and economical in controlling weeds and increasing the yield of chickpea. Maximum gross monetary returns were observed in weed free treatment because growth of crop was favoured in better partitioning of assimilates and their relative accumulation which finally results into higher yields. While highest net monetary returns and B:C ratios were recorded with the application of Pendimethalin @ 0.75 kg ha^{-1} may be due to higher yield and comparatively lower cost of cultivation as compared to weed free treatment. These results are in conformity with Singh *et al.* (2008) [18].

Materials and Methods

The field experiment was conducted at CRC farm of the Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut located in Indo-Gangetic plains of Western Uttar Pradesh. The soil of experimental site was sandy loam in texture, low in available nitrogen and organic carbon, medium in available phosphorus and potassium and slightly alkaline in reaction. The predominant soil at the experimental site is classified as *Typic Ustochrept* with sandy-loam texture having *p*H 7.4, bulk density 1.49 g/cm^3, low organic carbon content (0.42%), Soil samples for 0–15 cm depth at the site were collected and tested prior to applying treatments and the basic properties were low available nitrogen, low organic carbon, available phosphorus, available potassium medium and alkali in reaction. The gross and net plot size were 4.0 x 3.0 m^2 and 2.0 x 1.8 m^2, respectively. In order to find out the best weed control treatment in gram, field investigation was carried out with four herbicides with and without hand weeding, weed free conditions and control (weedy check). Experiment was laid out randomized block design with three replications. Ten weed management treatments [Weedy check, Weed free, One hand weeding (25 DAS), Two hand weeding (25 and 50 DAS), Oxyfluorfen 100 g a.i./ha Pre emergence, Oxyfluorfen 100 g a.i./ha Pre emergence + one hand weeding 25 DAS, Imazethapyr 50 g a.i./ha Post emergence (25 DAS), Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS, Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS and Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS were used for the experimentation. Plant-to-plant distance was maintained ~ 10 cm in a row spacing of 30 cm. Diammonium phosphate (DAP) was applied 100 kg/ha at the time of seed bed preparation as per recommendation. To ensure proper germination, field was prepared after *pre-sowing* irrigation and subsequent irrigation was given as per requirement. Imazethapyr was applied 25 days after sowing (DAS), whereas Oxyfluorfen in was applied as pre-emergence within 24 hr of sowing. Other practices were followed as per recommendation for this region. An iron square of size 0.25 m^2 (side 0.5 m) was used to take observations on weed population and weed dry weight through random sampling in each plot at 25 (just before application of Imazethapyr), 30, 60 and 90 DAS. The total number of weeds were counted species wise in each plot separately and analyzed. For dry matter, weeds collected from0.25 m^2 areas were dried under the sun and then in an oven at 70 $^{\circ}$C for 72 h, weighed (g/m^2). Economics of treatments was computed on the basis of

prevailing market price of inputs and outputs under each treatment. The total cost of cultivation of crop was calculated on the basis of different operations performed and materials used for raising the crop including the cost of fertilizers and seeds. The cost of labour incurred in performing different operations was also included. Statistical analysis of the data was done as per the standard analysis of variance technique for the experimental designs following SPSS software based programme, and the treatment means were compared at $P<0.05$ level of probability using t-test and calculating CD values.

Results and Discussion

Influence of weedicides on weeds

Density of total weeds was affected significantly by various treatments involving integrated weed management practices. Among weed control treatments, the highest total weed density (12.6, 12.2 and 10.9 m^{-2}) was found under weedy check treatment, at 30, 60 and 90 DAS, respectively (Table 1).

Table 1: Effect of weed management practices on total weeds (m^{-2}) in chickpea at different stages

Treatments	Density of total weed (number per m^2)		
	30 DAS	60 DAS	90 DAS
Control (Weedy check)	12.6 (159.6)	12.2 (147.2)	10.9 (119.1)
Weed free	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
One hand weeding 25 DAS	11.7 (135.2)	9.7 (93.3)	8.8 (77.1)
Two hand weeding 25 and 50 DAS	10.4 (106.8)	8.3 (68.1)	7.3 (52.6)
Oxyfluorfen 100 g a.i./ha Pre emergence	11.9 (142.1)	10.0 (100.1)	9.2 (82.9)
Oxyfluorfen 100 g a.i./ha Pre emergence + one hand weeding 25 DAS	6.8 (45.0)	8.8 (76.4)	7.7 (58.8)
Imazethapyr 50 g a.i./ha Post emergence (25 DAS)	11.4 (128.8)	9.4 (86.6)	8.5 (71.3)
Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS	10.3 (104.6)	7.8 (60.3)	6.9 (46.6)
Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS	11.1 (122.6)	9.1 (81.6)	8.1 (65.3)
Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS	9.8 (94.5)	5.0 (24.5)	4.5 (19.3)
SEm±	0.86	0.72	0.64
CD (P= 0.05)	2.49	2.07	1.85

Among all the treatments except weed free, the lowest total weed density was observed (6.8 m^{-2}) in the treatment of Oxyfluorfen 100 g a.i./ha Pre emergence + one hand weeding 25 DAS, at 30 DAS. At 60 and 90 DAS the lowest total weed density (5.0 m^{-2} & 4.5 m^{-2}) was observed with the application of Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS, which was found statistically at par with Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS (7.8 & 6.9 m^{-2}) at 60 and 90 DAS, respectively.

Total weed dry weight was affected significantly by various treatments involving integrated weed management practices (Table 2). Among weed control treatments, significantly the highest total weed dry weight (8.9, 13.0 & 13.5 g m^{-2}) was found in weedy check while the lowest total dry weight (6.5, 7.8 & 8.1 g m^{-2}) was found in two hand weeding treatment at 30, 60 and 90 DAS. This was due to the fact that at later stage most of the weed growth ceased because of leaf senescence, and thereby resulted in reduction in dry matter accumulation of weeds. Higher infestation of weeds under weedy check were also reported by Singh *et al*. (2017) [20]

Table 2: Effect of integrated weed management practices on dry weight of total weed (g m^{-2}) in chickpea at different stages

Treatments	Dry weight of total weed (g m^{-2})		
	30 DAS	60DAS	90 DAS
Control (Weedy check)	8.9 (78.1)	13.0 (168.2)	13.5 (181.4)
Weed free	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
One hand weeding 25 DAS	6.9 (46.2)	9.4 (87.5)	9.9 (97.1)
Two hand weeding 25 and 50 DAS	6.5 (40.7)	7.8 (59.4)	8.1 (64.6)
Oxyfluorfen 100 g a.i./ha Pre emergence	7.1 (49.6)	9.1 (82.4)	9.5 (89.7)
Oxyfluorfen 100 g a.i./ha Pre emergence + one hand weeding 25 DAS	5.5 (29.7)	8.1 (65.4)	8.9 (77.7)
Imazethapyr 50 g a.i./ha Post emergence (25 DAS)	6.8 (45.5)	8.6 (73.0)	9.2 (83.8)
Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS	6.2 (37.7)	7.7 (58.1)	8.7 (74.2)
Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS	6.5 (40.7)	8.0 (63.2)	8.4 (69.6)
Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS	5.8 (32.9)	6.0 (34.9)	8.1 (64.1)
SEm±	0.54	0.69	0.62
CD (P= 0.05)	1.55	1.98	1.80

Among the herbicides at 30 DAS the total dry weight observed (5.5 g m^{-2}) was lowest with the application of Oxyfluorfen 100 g a.i./ha Pre emergence + one hand weeding 25 DAS than rest of the treatments. At 60 DAS total dry weight observed (6.0 g m^{-2}) was significantly lowest with the application of Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS, which was statistically at par with Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS and Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS (7.7 and 8.0 g m^{-2}). Significantly lower total dry weight at 90 DAS (8.1 g m^{-2}) observed with the application of Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS was found at par with Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS and Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS (8.4 and 8.7 g m^{-2}) and significantly lower than the remaining treatments.

Weed control efficiency (WCE)

Weed control efficiency was affected significantly by various treatments involving integrated weed management practices (Table 3). Among weed control treatments significantly the highest weed control efficiency (100.0 %) was found in weed free at 60, 90 DAS, respectively. Among the herbicides highest weed control efficiency (79.25 %) and (64.66 %) with the application of Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS followed by Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS (62.42 % & 61.63 %) at 60, 90 DAS, respectively. This result is in corroboration with the findings of Kachhadiya *et al.* (2009) [8].

Table 3: Effect of weed management practices on weed control efficiency in chickpea at 60 & 90 DAS

Treatments	Weed control efficiency (%)	
	60 DAS	90 DAS
Control (Weedy check)	0.00	0.00
Weed free	100.0	100.0
One hand weeding 25 DAS	47.97	46.47
Two hand weeding 25 and 50 DAS	64.68	64.38
Oxyfluorfen 100 g a.i./ha Pre emergence	51.01	50.55
Oxyfluorfen 100 g a.i./ha Pre emergence + one hand weeding 25 DAS	61.12	57.16
Imazethapyr 50 g a.i./ha Post emergence (25 DAS)	56.60	53.80
Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS	65.45	59.10
Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS	62.42	61.63
Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS	79.25	64.66
SEm±	2.27	2.12
CD (P= 0.05)	6.57	6.12

Influence on yield parameters of chickpea

Number of pods plant^{-1} was affected significantly by various treatments involving integrated weed management practices. Among weed control treatments, the lowest number of pods plant^{-1} (29.8 pods plant^{-1}) was found in weedy check which was significantly lower than the remaining treatments. The highest number of pods plant^{-1} (35.7 pods plant^{-1}) was found in weed free which was significantly higher than other treatments (Table 4 & Fig.1).

Among the herbicides, the highest number of pods plant^{-1} (35.4 pods plant^{-1}) was recorded with the application of Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS, which was statistically at par with Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS (35.0 pods plant^{-1}), Oxyfluorfen 100 g a.i./ha Pre emergence + one hand weeding 25 DAS (32.9 pods plant^{-1}), Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS (32.8 pods plant^{-1}) and Imazethapyr 50 g a.i./ha Post emergence (25 DAS) (32.7 pods plant^{-1}). Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS recorded (18.79 %) more pods plant^{-1} over weedy check.

Table 4: Effect of weed management treatment on yield attributes at harvest of chickpea

Treatments	Yield attributes		
	Number of pods plant^{-1}	Number of seeds pod^{-1}	Test weight (g)
Control (Weedy check)	29.8	1.28	173.2
Weed free	35.7	1.83	198.7
One hand weeding 25 DAS	31.5	1.36	179.5
Two hand weeding 25 and 50 DAS	33.8	1.68	189.0
Oxyfluorfen 100 g a.i./ha Pre emergence	31.0	1.33	174.4
Oxyfluorfen 100 g a.i./ha Pre emergence + one hand weeding 25 DAS	32.9	1.57	188.4
Imazethapyr 50 g a.i./ha Post emergence (25 DAS)	32.7	1.36	183.0
Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS	35.0	1.73	193.5
Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS	32.8	1.44	186.0
Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS	35.4	1.77	197.0
SEm±	1.27	0.09	6.90
CD (P= 0.05)	3.68	0.26	19.95

Number of pods plant^{-1} was affected significantly by various treatments involving integrated weed management practices. Among weed control treatments, the lowest number of pods plant^{-1} (29.8 pods plant^{-1}) was found in weedy check which was significantly lower than the remaining treatments. The highest number of pods plant^{-1} (35.7 pods plant^{-1}) was found in weed free which was significantly higher than other treatments.

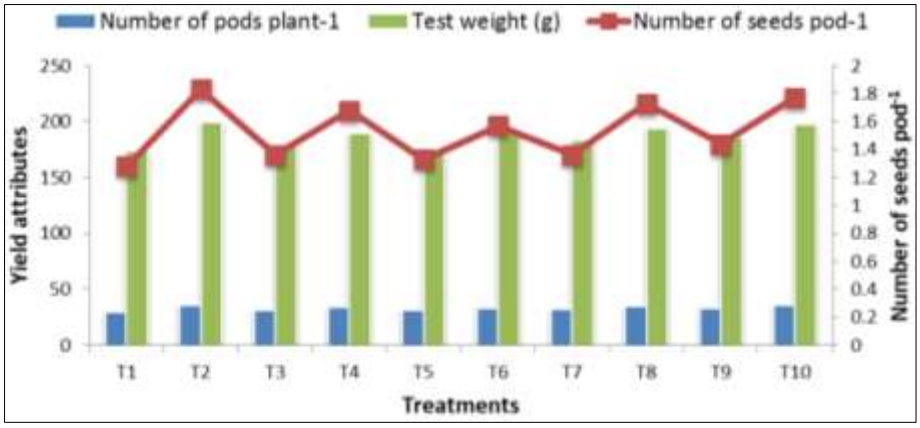

Fig 1: Effect of weed management treatment on yield attributes at harvest of chickpea

Among the herbicides, the highest number of pods plant^{-1} (35.4 pods plant^{-1}) was recorded with the application of Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS, which was statistically at par with Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS (35.0 pods plant^{-1}), Oxyfluorfen 100 g a.i./ha Pre emergence + one hand weeding 25 DAS (32.9 pods plant^{-1}), Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS (32.8 pods plant^{-1}) and Imazethapyr 50 g a.i./ha Post emergence (25 DAS) (32.7 pods plant^{-1}). Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS recorded (18.79 %) more pods plant^{-1} over weedy check.

Number of seeds pod^{-1} was affected significantly by various treatments involving integrated weed management practices. Among weed control treatments, the lowest number of seeds pod^{-1} (1.28 seeds pod^{-1}) was found in weedy check. The highest number of seeds pod^{-1} (1.83 seeds pod^{-1}) was found in weed free.

Among the herbicides, the highest seeds pod^{-1} (1.77 seeds pod^{-1}) was recorded with the application of Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS, which was statistically at par with Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS (1.73 seeds pod^{-1}) and Oxyfluorfen 100 g a.i./ha Pre emergence + one hand weeding 25 DAS (1.57 seeds pod^{-1}). Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS recorded (38.28 %) more seeds pod^{-1} over weedy check.

Test-grains weight was affected significantly by various treatments involving integrated weed management practices. Among weed control treatments, the lowest test-weight (173.2 g) was found in weedy check. The highest test-weight (198.7 g) found in weed free.

Among the herbicides, the highest test-weight (197.0 g) was recorded with the application of Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS, which was statistically at par with Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS (193.5 g), Oxyfluorfen 100 g a.i./ha Pre emergence + one hand weeding 25 DAS (188.4 g) and Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS (186.0 g). Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS recorded (13.74%) higher test-weight over weedy check. Similar results have also been reported by Ratnam and Reddy, (2011) and Pedde *et al*. (2013) [16, 11]. Integrated weed management i.e, herbicides and hand weeding has been reported to be superior over application of herbicide alone by earlier workers as well (Sharma, 2009) [17].

Crop Productivity

Grain yield was affected significantly by various treatments involving integrated weed management practices. Among weed control treatments, the lowest grain yield (12.3 q ha^{-1}) was found in weedy check. The highest grain yield (24.8 q ha^{-1}) was found in weed free (Table 5 & Fig.2).

Among the herbicides the significantly highest grain yield (23.7 q ha^{-1}) was recorded with the application of Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS, which was statistically at par with Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS (22.6 q ha^{-1}). Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS recorded (92.68 %) higher grain yield over weedy check.

Table 5: Effect of integrated weed management treatment on grain, straw and biological yield (q ha^{-1}) and harvest index at harvest of chickpea

Treatments	Yield (q ha^{-1})			Harvest Index
	Grain	Straw	Biological	
Control (Weedy check)	12.3	22.7	35.0	35.1
Weed free	24.8	35.6	60.4	41.1
One hand weeding 25 DAS	15.2	25.6	40.8	37.3
Two hand weeding 25 and 50 DAS	20.1	31.8	51.9	38.7
Oxyfluorfen 100 g a.i./ha Pre emergence	14.6	24.8	39.4	37.1
Oxyfluorfen 100 g a.i./ha Pre emergence + one hand weeding 25 DAS	17.2	27.9	45.1	38.1
Imazethapyr 50 g a.i./ha Post emergence (25 DAS)	16.1	26.5	42.6	37.8
Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS	22.6	34.6	57.2	39.5
Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS	19.1	30.6	49.7	38.4
Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS	23.7	35.3	59.0	40.2
SEm±	0.70	1.10	1.80	1.37
CD (P= 0.05)	2.02	3.17	5.19	NS

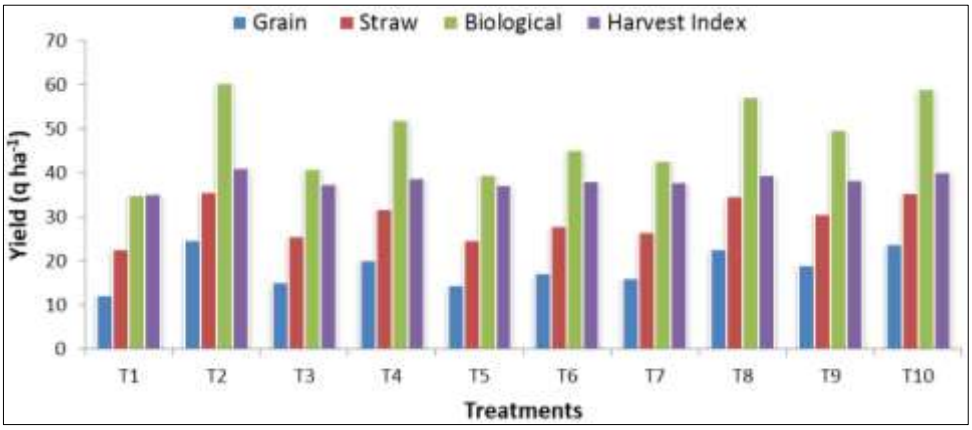

Fig 2: Effect of weed management treatment on grain, straw and biological yield (q ha^{-1}) and harvest index at harvest of chickpea

Biological yield was affected significantly by various treatments involving integrated weed management practices. Among weed control treatments, the lowest biological yield (35.0 q ha^{-1}) found in weedy check. The highest biological yield (60.4 q ha^{-1}) was found in weed free. Similar findings were reported by Deva and kolhe (2018) [3].

Among the herbicides, the highest biological yield (59.0 q ha^{-1}) was recorded with the application of Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS, which was statistically at par with Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS (57.2 q ha^{-1}). Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS (68.57%) higher biological yield over weedy check.

Harvest index was non-significantly affected by various treatments involving integrated weed management practices. Among weed control treatments, the lowest harvest index (35.1%) was found in weedy check while the highest harvest index (41.1%) in weed free. Among the herbicides the highest harvest index (40.2%) recorded with the application of Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS than rest of the treatments. Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS recorded (14.53%) higher harvest index over weedy check. Similar findings were reported by Poonia and pithia (2013) [12]

Economics

Cost of cultivation was affected by various treatments involving integrated weed management practices. Among weed control treatments, the lowest cost of cultivation (Rs. 29638 ha^{-1}) found in weedy check, which was lower than the remaining treatments. The highest cost of cultivation (Rs. 38638 ha^{-1}) was found in weed free treatment, which was higher than other treatments. Among the herbicides, the highest cost of cultivation (Rs. 35543 ha^{-1}) was recorded with the application of Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS, followed by two hand weeding at 25 and 50 DAS (Rs. 34638 ha^{-1}). Hossain (2017) and Kausik *et al.* (2016) [6, 9] also reported similar results.

Gross return was affected significantly by various treatments involving integrated weed management practices. Among weed control treatments, the lowest gross return (Rs. 71055 ha^{-1}) was found in weedy check, which was significantly lower than the remaining treatments (Table 6).

The highest gross return (₹ 141740 ha^{-1}) was found in weed free treatment, which was higher than other treatments. Among the herbicidal treatments, the highest gross return (₹ 135645 ha^{-1}) was recorded with the application of Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS, which was statistically at par with (₹ 129490) Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS. Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS was recorded (90.9%) higher gross return over weedy check.

Net return was affected significantly by various treatments involving integrated weed management practices. Among weed control treatments, the lowest net return (₹ 41417 ha^{-1}) was found in weedy check and significantly lower than the remaining treatments, while the highest net return (₹ 103102 ha^{-1}) was found in weed free treatment and significantly higher than other treatments. Among the herbicides, the highest net return (₹ 100102 ha^{-1}) was recorded with the application of Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS, which was statistically at par with Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS. Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS recorded (141.69%) higher net return over weedy check. These findings are in close agreement with the results of Singh *et al.* (2016) Jain *et al.* (2017), Rathod *et al.* (2017) and Deva and Kolhe (2018) [19, 7, 15, 3].

Table 6: Economics of chickpea as affected by various weed management practices

Treatments	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B: C ratio
Control (Weedy check)	29638	71055	41417	1.40
Weed free	38638	141740	103102	2.67
One hand weeding 25 DAS	32638	87440	54802	1.68
Two hand weeding 25 and 50 DAS	34638	115320	80682	2.33
Oxyfluorfen 100 g a.i./ha Pre emergence	31848	84020	52172	1.64
Oxyfluorfen 100 g a.i./ha Pre emergence + one hand weeding 25 DAS	34348	98785	64437	1.88

Imazethapyr 50 g a.i./ha Post emergence (25 DAS)	30833	92525	61692	2.00
Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS	33332	129490	96158	2.88
Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS	33043	109640	76597	2.32
Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS	35543	135645	100102	2.82
SEm±	-	4012	2829	0.08
CD (P= 0.05)	-	11604	8182	0.24

B: C ratio was affected significantly by various treatments involving integrated weed management practices. Among weed control treatments, the lowest B: C ratio (1.40) was found in weedy check, which was significantly lower than the remaining treatments while the highest B: C ratio (2.67) was recorded in weed free treatment.

Among the herbicides, the highest B: C ratio was recorded with the application of Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS (2.88), which was statistically at par with Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS (2.82). Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS was recorded (105.71%) higher B: C ratio over weedy check**.** Pedde *et al.* (2013) [11] and Gore *et al.* (2015) [4] also reported similar results.

Conclusion

Based on the results of experimentation, it can be concluded that all weed control practices proved effective in controlling the weeds in chickpea and gave significantly higher grain yield over weedy check. Among the different treatments, manual weeding to keep the plot weed free is the most effective weed control measure to control narrow, broad leaved and sedge weeds and resulted into higher value of weed control efficiency followed by Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS and Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS. Highest growth parameters, yield attributes yield of chickpea and nutrient uptake was noticed with weed free, which was found statistically at par with the application of Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS and Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS. Among integrated weed management treatments Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS was found excellent in gross return, net return, and B: C ratio which was at par with Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS. Although maximum net return was obtained in weed free followed by Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS but non-availability of human power may be a constraint therefore chemical weed management practice will be better option. Thus the application of Oxyfluorfen 100 g a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha 25 DAS + one hand weeding 50 DAS seems better for higher productivity and profitability of chickpea crop**.**

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