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Evaluation of effective weed management strategy for enhancing productivity and profitability of chickpea (*Cicer arietinum* L.) under sub-tropical climate of western U.P.

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Abstract
A field study was conducted during the *Rabi* season of 2018–19 at Sardar Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, to assess the performance of post-emergence application of Imazethapyr in combination with pre-emergence application of pendimethalin on chickpea (*Cicer arietinum* L.). The treatments comprised of Control (Weedy check) T_1, Weed free T_2, manual weeding 20 DAS T_3, two manual weeding 20 and 40 DAS T_4,Pendimethalin @1 kg a.i./ha PE T_5,Pendimethalin @1 kg a.i./ha PE fb manual weeding 20 DAS T_6,Imazethapyr @50 g a.i./ha Post emergence (20 DAS) T_7,Imazethapyr @50 g a.i./ha 20 DAS fb manual weeding 40 DAS T_8,Pendimethalin @1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha 20 DAS T_9 and Pendimethalin 1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha 20 DAS fb manual weeding 40 DAS T_{10}. The results revealed that the maximum weed control efficiency at 60 and 90 DAS and minimum total dry weight of weedsinPendimethalin@1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS) fb manual weeding (40 DAS) T_{10} were found at par with Pendimethalin@1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS) T_9.Significantly highest pods plant^{-1},seeds pod^{-1}andtest weight (g)were found with the application of Pendimethalin@1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS) fb manual weeding (40 DAS)treatment. However, the highest grain yield (27.0 q ha^{-1}) and straw yield(35.6 q ha^{-1}) were obtained under weed free treatment T_2 followed by (25.2 q ha^{-1})and (33.5 q ha^{-1}) with the application of Pendimethalin @1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS) fb manual weeding (40 DAS) T_1.Similarly, higher net returns and benefit:cost ratio was recorded in Pendimethalin@1 kg a.i./ha PE fbImazethapyr@ 50 g a.i./ha (20 DAS) fb manual weeding (40 DAS).Therefore,Pendimethalin@1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS) found better for higher productivity and profitability of chickpea cropunder Sub-tropical climate of western Uttar Pradesh.

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

Introduction
Gram (*Cicer arietinum* L.) is an important pulse crop of the world occupying third position amongst pulses. Among a dozen of different grain legumes under cultivation in India, gram is the leading crop and is grown in rabi season. Indian subcontinent accounts for 67 per cent of production of gram in the world. This crop occupies an area of 9.93 mha and 9.53 m tonnes during 2014-15 and productivity 920 kh/ha which is deplorably lower as compared to 6120 kg/ha in Israel.Today, 80% of total pulses production, in India, is realized in six states namely, Madhya Pradesh, Maharashtra, Rajasthan, Andhra Pradesh, Karnataka and Uttar Pradesh. Indian farmers pay reasonable attention to cultivation, especially in respect of seed bed preparation, manuring and irrigation. Crop yield losses due to weeds have been estimated to range from 30 to 50 per cent (Aslam *et al*., 2007; Rao *et al*., 2015a) [1, 13].

The poor productivity of chickpea is mainly due to competition from diverse weed population (Kumar, 2010). Most weed species can grow faster and taller than the chickpea and inhibits the plant growth by curtailing sunlight, nutrients and moisture; and reduces the grain yield up to 75% (Balyanand Bhan, 1984) [2]. So far, pendimethalin was identified as a suitable pre-emergence (PE) herbicide effective against emerging broad-leaf weeds (especially *Chenopodium album*). However, it is not found effective against many other weeds including *Cyperus rotundus* (Kumar and Hazra, 2012) [7].

Therefore, pendimethalin along with a manual weeding at 35–40 days after sowing was recommended (Chaudhary *et al*., 2011) [3]. Although weed-management practices through manual weeding are effective in weed control, it is uneconomical due to higher costs (Kumar *et al*., 2010). Use of post-emergence herbicides in combination with pre-emergence may be one of the tool for broad-spectrum weed control.

However, sufficient attention has not been paid to weed control aspect which remains one of the constraints in boosting up the gram production. The predominant method of weed control by mechanical hoeing and manual weeding over extensive scale is found to decline because of shift of agricultural labourers to industries for better and assured wages. The current trend and future development of intensive agriculture is likely to seek the use of chemicals as an effective weed control measures and replace the conventional method of weed control. Waqas *et al*. (2016) [21] also found that hand weeding followed by commercial herbicides depicted least density and biomass for weeds. Mahoney (1981) [9] found that net returns were relatively higher with chemical weed control and resulted in seed yields of 1.87 t ha^{-1} compared with 1.34 t ha^{-1} without weed control. Singhte *et al*. (1984) [19] reported that the application of weedicides help in controlling weeds population, increase in grain yields and net return. Therefore, the present study was proposed to assess the field efficacy of Imazethapy in combination with pendimethalin in chickpea.

Materials and Methods

A field experiment was laid out during *rabi* 2018-19 at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (29^0 04''Nlatitude and 77^0 42' 'E longitude a height of 237 m above mean sea level), Uttar Pradesh Province, India. The region has a semi-arid sub-tropical climate with an average annual temperature of 16.8^0C. The highest mean monthly temperature (38.9^0C) is recorded in May, and the lowest mean monthly temperature (4.5^0C) is recorded in January. The average annual rainfall is about 665 to 726 mm (constituting 44% of pan evaporation) of which about 80% is received during the monsoon period. The experimental field had an even topography with a gentle slope and good drainage. The predominant soil at the experimental site is classified as *Topic Ustochrept* with sandy-loam texture having *p*H 7.8, bulk density 1.44 g/cm^3, low organic carbon content (3.1 g/kg), 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 6.0 x 3.6 m^2 and 5.0 x 2.7 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). The experiment comprising of ten weed management treatments viz., T_1-Control (Weedy check), T_2-weed free, T_3- manual weeding 20 DAS, T_4- two manual weeding 20 and 40 DAS, T_5-Pendimethalin@1 kg a.i./ha PE, T_6- Pendimethalin@1 kg a.i./ha PE fb manual weeding 20 DAS, T_7- Imazethapyr@50 g a.i./ha Post emergence (20 DAS), T_8- Imazethapyr@50 g a.i./ha 20 DAS fb manual weeding 40 DAS, T_9-Pendimethalin@1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha 20 DAS and T_{10}- Pendimethalin@1 kg a.i./ha PE fbImazethapyr @ 50 g a.i./ha 20 DAS fb manual weeding 40 DAS. The experiment was laid out in randomized block design (RBD) with 3 replications. 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. Imazethapy was applied 20 days after sowing (DAS), whereas pendimethal 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 90DAS. The total number of weeds were counted species wise in each plot separately and analysed. 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:

All the weed control treatments significantly reduced the total weeds density over weedy check at all stages of observation (Table 1). All the integrated treatments were significantly superior to alone application of herbicides in reducing weed dry weight. Among the treatments, Pendimethalin@1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS) fb manual weeding (40 DAS) which was found statistically at par with Pendimethalin@1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS). This resulted in less crop-weed competition. Furthermore, increased infestation of weeds showed negative influence on the crop growth as reflected in terms of lower plant biomass due to poor resource utilization (like nutrients uptake) at the critical period of crop-weed competition period *i.e*. 15-60 DAS.The results are corroborating with those reported by Ratnam and Reddy (2011); Taran *et al.* (2013) [16, 20].

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
Weedy check	12.5 (155.4)	12.0 (143.0)	10.7 (114.9)
Weed free	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
Manual weeding (20 DAS)	7.9 (62.3)	9.2 (83.4)	8.7 (74.3)
Two manual weeding (20 and 40 DAS)	7.9 (62.1)	7.7 (58.8)	7.5 (54.6)

Pendimethalin@1 kg a.i./ha PE	9.6 (90.5)	9.1 (82.5)	8.3 (68.1)
Pendimethalin@1 kg a.i./ha PE fb manual weeding (20 DAS)	9.0 (79.6)	8.6 (72.8)	7.2 (50.3)
Imazethapyr@50 g a.i./ha Post emergence (20 DAS)	9.5 (88.4)	8.8 (76.6)	8.0 (63.3)
Imazethapyr@50 g a.i./ha (20 DAS) fb manual weeding (40 DAS)	8.7 (75.2)	7.8 (60.4)	7.3 (52.8)
Pendimethalin@1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS)	8.3 (67.3)	7.0 (48.0)	6.7 (43.7)
Pendimethalin:@1 kg a.i./ha PEImazethapyr@50 g a.i./ha (20 DAS)fb manual weeding (40 DAS)	7.7 (59.0)	6.6 (43.7)	5.8 (32.6)
CD (P= 0.05)	2.4	1.9	1.7

Total weed dry weight was affected significantly by various treatments involving weed management practices. Among weed control treatments, significantly the highest total weed dry weight (7.7, 12.5 & 13.4 g m^{-2}) was found in weedy check while the lowest total dry weight (6.5, 4.2 & 7.9 g m^{-2}) was found in two hand weeding treatment at 30, 60 and 90 DAS (Table 2). Among the herbicides at 30 DAS the total dry weight observed (5.7 g m^{-2}) was lowest with the application of Pendimethalin@1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS) fb manual weeding (40 DAS) than rest of the treatments. At 60 DAS total dry weight observed (7.2g m^{-2}) was significantly lowest with the application of Pendimethalin@1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS) fb manual weeding (40 DAS)was statistically at par with Pendimethalin@1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS) and Imazethapyr@50 g a.i./ha (20 DAS) fb manual weeding (40 DAS) (7.6 and 7..8 g m^{-2}). Significantly lower total dry weight at 90 DAS (7.9 g m^{-2}) observed with the application of Pendimethalin@1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS) fb manual weeding (40 DAS)was found at par with Pendimethalin@1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS) and Imazethapyr50 g a.i./ha (20 DAS) fb manual weeding (40 DAS) (8.2 and 8.5 g m^{-2}) and significantly lower than the remaining treatments.Similar finding were reported by Deva and kolhe, (2015); Poonia and pithia (2013) [4, 12].

Table 2: Effect of 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
Weedy check	7.7 (85.0)	12.5 (169.9)	13.4 (179.8)
Weed free	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
Manual weeding (20 DAS)	6.5 (41.8)	9.3 (85.7)	9.8 (95.9)
Two manual weeding (20 and 40 DAS)	6.5 (41.6)	4.2 (52.3)	7.9 (63.4)
Pendimethalin@1 kg a.i./ha PE	6.8 (46.0)	8.8 (77.2)	9.4 (88.2)
Pendimethalin@1 kg a.i./ha PE fb manual weeding (20 DAS)	6.4 (41.4)	8.1 (65.3)	8.7 (76.5)
Imazethapyr@50 g a.i./ha Post emergence (20 DAS)	6.6 (43.3)	8.4 (70.9)	9.1 (82.4)
Imazethapyr@50 g a.i./ha (20 DAS) fb manual weeding (40 DAS)	6.2 (38.4)	7.8 (60.8)	8.5 (72.6)
Pendimethalin@1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS)	6.0 (35.5)	7.6 (57.5)	8.2 (68.0)
Pendimethalin@1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS) fb manual weeding (40 DAS)	5.7 (32.9)	7.2 (51.7)	7.9 (62.7)
CD (P= 0.05)	1.5	2.2	2.5

Weed control efficiency (WCE) and weed index (%)

Among weed control treatments significantly the highest weed control efficiency (100.0%) was found in weed free at 60, 90 DAS, respectively (Table 3). Among the herbicides highest weed control efficiency (69.5%) and (71.4%) with the application of Pendimethalin @1 kg a.i./ha PE fb Imazethapyr @50 g a.i./ha (20 DAS) fb manual weeding (40 DAS), which was statistically at par with Pendimethalin @1 kg a.i./ha PE fb Imazethapyr @50 g a.i./ha (20 DAS) (62.2 and 68.1%) and followed by Imazethapyr @50 g a.i./ha (20 DAS) fb manual weeding (40 DAS)(64.2 and 65.7%) at 60, 90 DAS, respectively. Weed index was affected significantly by various treatments involving weed management practices (Table 3). Among weed control treatments significantly the highest weed index (50.7%) was found in weedy check at harvest. Among the herbicides highest weed index (40.3%) with the application of Imazethapyr @50 g a.i./ha (20 DAS), which was statistically at par with Pendimethalin @1 kg a.i./ha PE (36.6%). The lowest weed index (6.7%) found with the application of Pendimethalin @1 kg a.i./ha PE fb Imazethapyr @50 g a.i./ha (20 DAS) fb manual weeding (40 DAS), respectively. This result is in corroboration with the findings of Kachhadiya *et al.* (2009) [5].

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

Treatments	Weed control efficiency (%)		Weed Index (%)
	60 DAS	90 DAS	At harvest
Weedy check	0.0	0.0	50.7
Weed free	100.0	100.0	0.0
Manual weeding (20 DAS)	49.5	48.6	47.7
Two Manual weeding (20 and 40 DAS)	69.2	70.7	41.0
Pendimethalin @1 kg a.i./ha PE	54.5	55.6	36.6
Pendimethalin @1 kg a.i./ha PE fb manual weeding (20 DAS)	61.5	63.3	19.4
Imazethapyr @50 g a.i./ha Post emergence (20 DAS)	58.3	59.5	40.3
Imazethapyr @50 g a.i./ha (20 DAS) fb manual weeding (40 DAS)	64.2	65.7	23.1
Pendimethalin @1 kg a.i./ha PE fb Imazethapyr @50 g a.i./ha (20 DAS)	66.2	68.1	13.4
Pendimethalin @1 kg a.i./ha PE fb Imazethapyr @50 g a.i./ha (20 DAS) fb manual weeding (40 DAS)	69.5	71.4	6.7
CD (P= 0.05)	5.7	6.1	3.8

Influence on yield parameters of chickpea

The perusal of data in Table 4 indicated that all weed control treatments were significantly superior to weedy check in influencing number of pods per plant. Maximum number of pods (35.1 plant^{-1}) was recorded with the application of Pendimethalin@1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS) fb manual weeding (40 DAS) which was statistically at par with Pendimethalin@1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS) (34.7 pods plant^{-1}) and Pendimethalin@1 kg a.i./ha PE fb manual weeding (20 DAS) (33.5 podsplant^{-1}). Pendimethalin@1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS) fb manualweeding (40 DAS) recorded (18.9%) more pods plant^{-1} over weedy check.

Therefore the number of seeds pod^{-1} was affected significantly by various treatments involving weed management practices. Among weed control treatments, the lowest number of seeds pod^{-1} (1.2) was found in weedy check. The highest number of seeds pod^{-1} (1.7) was found in weed frees (Table 3). Among the herbicides, the highest seeds pod^{-1} (1.7) was recorded with the application of Pendimethalin@1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS) fb manual weeding (40 DAS) which was statistically at par with Pendimethalin 1 kg a.i./ha PE fbImazethapyr 50 g a.i./ha (20 DAS) (1.6 seeds pod^{-1}) and Imazethapyr@50 g a.i./ha (20 DAS) fb manual weeding (40 DAS) (1.6 seeds pod^{-1}). Pendimethalin@1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS) fb manual weeding (40 DAS) recorded (41.66%) more seeds pod^{-1} over weedy check. Similarly, Test-grains weight was affected significantly by various treatments involving weed management practices. Among weed control treatments, the lowest test-weight (172.2 g) was found in weedy check. The highest test-weight (198.0 g) found in weed free. The highest test-weight (196.0 g) was recorded with the application of Pendimethalin@1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS) fb manual weeding (40 DAS) which was statistically at par with Imazethapyr@50 g a.i./ha (20 DAS) fb manual weeding (40 DAS) (192.5 g), Pendimethalin@1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS)(188.0 g) and Pendimethalin 1 kg a.i./ha PE fb manual weeding (20 DAS) (187.4 g). Pendimethalin@1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS) fb manual weeding (40 DAS) recorded (13.82%) higher test-weight over weedy check.Similar results have also been reported by Ratnam and Reddy, (2011) [16] and Pedde *et al*. (2013) [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; Singh and Singh 2000) [17, 18].

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)
Weedy check	29.5	1.2	172.2
Weed free	35.4	1.7	198.0
Manual weeding (20 DAS)	30.7	1.3	173.4
Two manual weeding (20 and 40 DAS)	31.2	1.3	182.0
Pendimethalin @1 kg a.i./ha PE	32.4	1.4	178.5
Pendimethalin @1 kg a.i./ha PE fb manual weeding (20 DAS)	33.5	1.5	187.4
Imazethapyr @50 g a.i./ha Post emergence (20 DAS)	32.6	1.3	185.0
Imazethapyr @50 g a.i./ha (20 DAS) fb manual weeding (40 DAS)	32.5	1.6	192.5
Pendimethalin @1 kg a.i./ha PE fb Imazethapyr @50 g a.i./ha (20 DAS)	34.7	1.6	188.0
Pendimethalin @1 kg a.i./ha PE fb Imazethapyr @50 g a.i./ha (20 DAS) fb manual weeding (40 DAS)	35.1	1.7	196.0
CD (P= 0.05)	3.4	0.2	19.1

Crop Productivity

Seed yield is an important parameter which decides the efficiency and superiority of a particular treatment over other treatments. The highest grain yield of chickpea was recorded under Pendimethalin@1 kg a.i./ha Pre emergence fb Imazethapyr 50 g a.i./ha (20 DAS) fbmanual weeding (40 DAS) which was at par with Pendimethalin@1 kg a.i./ha PEfb Imazethapyr@ 50 g a.i./ha (20 DAS) and Pendimethalin@1 kg a.i./ha PE fb Imazethapyr @ 50 g a.i./ha (20 DAS) fb manual weeding (Table 5). The higher grain yield under Pendimethalin @1 kg a.i./ha PE fb Imazethapyr @50 g a.i./ha (20 DAS) fb manual weeding (40 DAS) was mainly owing to proper growth and development of chickpea under poor crop-weed competition, i.e. less weed population and weed biomass. These treatments were significantly out seed yielded over other weed management treatments. The high seed yield in these treatments could be attributed to more number of branches and number of pods per plants and bold seed size due to lesser competition offered by weeds for light, water and nutrients etc., which resulted in more uptake of nutrients, water and produced more photo synthates. Application of herbicides followed by hand weeding provided better environment to crop growth and development which ultimately yielded higher than either one chemical or manual weed management practice. These results are confirming with earlier work of Kumar *et al*. (2015) [8] and Mudalagiriyappa *et al* (2013) [10].

Among weed control treatments, the lowest straw yield (22.6 q ha^{-1}) was found in weedy check. The highest straw yield (36.7 q ha^{-1}) was found in weed free. However, the highest straw yield (35.6 q ha^{-1}) was recorded with the application Pendimethalin @1 kg a.i./ha PE fb Imazethapyr @50 g a.i./ha (20 DAS) fb manual weeding (40 DAS) which was statistically at par with Pendimethalin @1 kg a.i./ha PE fb Imazethapyr @ 50 g a.i./ha (20 DAS) (33.5 q ha^{-1}). Pendimethalin @ 1 kg a.i./ha PE fb Imazethapyr @50 g a.i./ha (20 DAS) fb manual weeding (40 DAS) recorded (57.52%) more straw yield over weedy check. Higher straw yield was due to more accumulation of dry matter (g plant^{-1}) along with the highest plant height and number of nodules plant^{-1}. Similar findings were reported by Kumar *et al.* (2014) [6].

Table 5: Effect of 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	
Weedy check	13.4	22.6	36.0	37.2
Weed free	27.0	36.7	63.7	42.4
Manual weeding (20 DAS)	14.2	22.8	37.0	38.4
Two manual weeding (20 and 40 DAS)	16.0	24.6	40.6	39.4
Pendimethalin @1 kg a.i./ha PE	17.2	26.4	43.6	39.4
Pendimethalin @1 kg a.i./ha PE fb manual weeding (20 DAS)	21.8	31.7	53.5	40.8
Imazethapyr @50 g a.i./ha Post emergence (20 DAS)	16.2	25.4	41.6	38.9
Imazethapyr @50 g a.i./ha (20 DAS) fb manual weeding (40 DAS)	20.8	31.0	51.8	40.1
Pendimethalin @1 kg a.i./ha PE fb Imazethapyr @50 g a.i./ha (20 DAS)	23.4	33.5	56.9	41.1
Pendimethalin @1 kg a.i./ha PE fb Imazethapyr @50 g a.i./ha (20 DAS) fb manual weeding (40 DAS)	25.2	35.6	60.8	41.4
CD (P= 0.05)	2.1	3.0	5.1	NS

Economics

The economic analysis revealed that application of weedicides seems to be economical in all treatments over hand-weeding and more especially over control in enhancing yield level and accumulating net return over control (Table 6). The highest gross return (Rs. 138540 ha^{-1}) was found in weed free treatment than other treatments. Among the herbicidal treatments, the highest gross return (Rs. 130600 ha^{-1}) was recorded with the application of Pendimethalin @1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS) fb manual weeding (40 DAS) which was statistically at par with (Rs. 121660) Pendimethalin @1 kg a.i./ha PE fbImazethapyr@50 g a.i./ha (20 DAS) and (Rs. 113780) Pendimethalin@1 kg a.i./ha PE fb manual weeding (20 DAS) [Table 6]. The lowest gross returns (Rs.72760 ha^{-1}) was recorded with weedy check, which was mainly owing to less seed yield obtained due to uncontrolled weeds throughout the crop growth. Whereas, highest net return (Rs106796 ha^{-1}) was recorded in weed free followed by pendimethalin @ 1.0kg a.i ha^{-1}PE fb Imazethapyr @50 g a.i./ha (20 DAS) fb manual weeding (40 DAS) (Rs.100579 ha^{-1}) and Pendimethalin@1 kg a.i.ha^{-1} PE fbImazethapyr@50 g a.i.ha^{-1} (20 DAS) (Rs.93459ha^{-1}). However, maximum B: C ratio (4.35) was recorded in pendimethalin @ 1.0kg a.i ha^{-1}PE fb Imazethapyr @50 g a.i./ha (20 DAS) fb manual weeding (40 DAS) followed by Pendimethalin @1 kg a.i.ha^{-1} PE fb Imazethapyr @50 g a.i.ha^{-1} (20 DAS) (4.31) which was significantly superior over rest treatments. Because, this was resulted to get higher net return along with higher yield with lesser cost of cultivation. Minimum B: C ratio (2.87) was recorded in weedy check. The net return and B: C ratios were low in weed free treatment due to high cost of cultivation. These results are conformed from finding of Ratnam *et al*. (2011) [16]; Pedde *et al*. (2013) [11] and Rathod *et al.* (2017) [14]. Zafar (1985) [22] concluded that by spending one rupee on weeding and hand-weeding, one can get Rs.3.60, 3.24, 2.96 and 2.65 respectively, as a return.

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

Treatments	Cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B:C ratio
Weedy check	25374	72760	47386	2.87
Weed free	31744	138540	106796	4.36
Manual weeding (20 DAS)	27194	76000	48806	2.79
Two hand weeding (20 and 40 DAS)	29014	84640	55626	2.92
Pendimethalin @1 kg a.i./ha PE	27157	91000	63843	3.35
Pendimethalin @1 kg a.i./ha PE fb manual weeding (20 DAS)	28977	113780	84803	3.93
Imazethapyr @50 g a.i./ha (20 DAS)	26418	86200	59782	3.26
Imazethapyr @50 g a.i./ha (20 DAS) fb manual weeding (40 DAS)	28238	109280	81042	3.87
Pendimethalin @1 kg a.i./ha PE fb Imazethapyr @50 g a.i./ha (20 DAS)	28201	121660	93459	4.31
Pendimethalin @1 kg a.i./ha PE fb Imazethapyr @50 g a.i./ha (20 DAS) fb manual weeding (40DAS)	30021	130600	100579	4.35
CD (P= 0.05)	-	10856	7994	0.63

Conclusion

Based on the findings, 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 higher value of weed control efficiency was at par with the application of Pendimethalin @1 kg a.i.ha^{-1} PE fb Imazethapyr 50 g a.i.ha^{-1} (20 DAS) fb manual weeding (40 DAS) and Pendimethalin @1 kg a.i.ha^{-1} PE fb Imazethapyr @50 g a.i./ha (20 DAS). However, higher yield attributes and yield of chickpeawas noticed with weed free, which was found statistically at par with the application of Pendimethalin@1 kg a.i.ha^{-1} PEfbImazethapyr@50 g a.i.ha^{-1} (20 DAS) fb manual weeding (40 DAS) andPendimethalin@1 kg a.i.ha^{-1} PE fbImazethapyr@50 g a.i.ha^{-1} (20 DAS). Among weed management treatments, weed free was found excellent in gross return, net return, and B: C ratio, which was found statistically at par with the Pendimethalin@1 kg a.i.ha^{-1} PE fb Imazethapyr @50 g a.i.ha^{-1} (20 DAS) fb manual weeding (40 DAS) and Pendimethalin @1kg a.i.ha^{-1} PE fb Imazethapyr @50 g a.i.ha^{-1} (20 DAS). Although maximum net return was obtained in weed free followed by Pendimethalin @1 kg a.i.ha^{-1} PE fbImazethapyr @50 g a.i.ha^{-1} (20 DAS) fb manual weeding (40 DAS) but non-availability of human power may be a constraint therefore chemical weed management practice will be better option. Thus the application of Pendimethalin@1 kg a.i.ha^{-1} PE fb Imazethapyr @50 g a.i.ha^{-1} (20 DAS) as pre and post-emergence herbicide may be feasible and taken for further research and found better for higher productivity and profitability of chickpea crop.

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