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Studies on the Effect of Chemical Weed Management on Growth Indices, Yield and Quality of Irrigated Chickpea (*Cicer arietinum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Chickpea, characterized by its short stature and slow initial growth, is highly susceptible to a wide range of weed species. The field experiment was designed during the Rabi season of 2021-22 at Agronomy Research Farm, Chaudhary Charan Singh Haryana Agricultural University, Hisar to evaluate the chemical weed management in irrigated chickpea. The experiment was laid out in a Randomised Block Design (RBD) with thirteen treatments replicated thrice. The treatments combinations areT1 (Pendimethalin 30EC @ 1000g a.i ha-1 as PPI), T2 (Imazethapyr 10EC @ 75g

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a.i ha-1 as PPI), T3 (Imazethapyr 10EC @ 100g a.i ha-1 as PPI), T4 (Pendimethalin 30EC + imazethapyr 2EC (RM) @ 1000g a.i ha-1 as PPI), T5 (Pendimethalin 30EC @ 1000g a.i ha-1 as PRE), T6 (Imazethapyr 10EC @ 75g a.i ha-1 as PRE), T7 (Imazethapyr 10EC @ 100g a.i ha-1 as PRE), T8 (Pendimethalin 30EC + Imazethapyr 2EC (RM) @ 1000g a.i ha-1 as PRE), T9 (Imazethapyr 10EC @ 75g a.i ha-1 as POE), T10 (Imazethapyr 10EC @ 100g a.i ha-1 as POE), T11 (Two hand hoeing at 30 & 50 DAS), T12 (weed free) and T13 (weedy check). The results of this study showed that PPI and PRE application of any herbicide did not cause any phytotoxic effect on chickpea. The Ready mix (RM) herbicide applied as PPI and PRE performed better than sole PPI, PRE, and POE herbicides. Among herbicidal treatments, PPI and PRE application of pendimethalin + imazethapyr (RM) @ 1000 g a.i ha-1 gave excellent control of complex weed flora and increased the yield of chickpea significantly over the weedy check. Different weed control treatments could not bring significant variation in plant population in the initial stage but the plant population declined at maturity. The maximum plant growth attributes were observed with the application of pendimethalin + imazethapyr (RM) @ 1000 g a.i ha-1 as PRE. The POE application of imazethapyr irrespective of the dose recorded the lowest dry matter accumulation throughout the growing season of chickpea. The unchecked growth of weeds in the weedy check caused a 55.2% reduction in seed yield as compared to weed-free treatment. The maximum seed yield (1968 kg ha-1) and yield attributes of chickpea were recorded with weed-free treatment and among herbicidal treatments, maximum seed yield (1827 kg ha-1) was recorded with application of pendimethalin + imazethapyr (RM) @ 1000 g ha-1 PRE.

Keywords: Weed; chickpea; imazethapyr; pendimethalin; growth attributes; yield.

1. INTRODUCTION

Legumes have been an integral part of the human diet since time immemorial. They are also one of the most extensively consumed food crops in the world. Legumes readily adapt to a vast range of soil and environmental conditions and therefore play a crucial role in mitigating the adverse effects of climate change [1]. They are immensely nutritious and are often considered "poor man's meat" on account of their high protein content [2]. The major pulses of India are chickpea, dry bean (mung bean, urd bean, moth bean and red kidney bean), pigeon pea, lentils, dry peas, etc. Chickpea (*Cicer arietinum*L.) is a self-pollinated legume crop that belongs to the family Leguminosae. The average chickpea yield in India stands at around 11.9 million tons, grown over 8.8 million hectares with a national productivity rate of 1.11 tons per hectare [3]. It is the leading producer and consumer of chickpea in the entire world. The leading pulse-producing states in decreasing order are Madhya Pradesh, Maharashtra, Uttar Pradesh, Rajasthan and Andhra Pradesh. The carbohydrate and protein in chickpea account for approximately 80 percent of total dry seed mass. Chickpea's agronomical importance for human and animal diets is based on their high protein concentration (19.3-25.4%), carbohydrates (52-70%), fat (4-10%), minerals (calcium, phosphorous and iron), vitamin (niacin) and trace elements [4,5]. The protein quality of chickpea is superior to other pulses. Chickpea is highly regarded for its nutritional value in vegetarian diets, serving as a crucial source of proteins and minerals [6]. The germinated chickpea seeds are also believed to cure scurvy disease. Chickpea contains more carotenoids than genetically modified golden rice [7]. It is also used as fodder and green manure crop [8]. Chickpea can fix up to 141 kg of nitrogen ha^{-1} $year^{-1}$ under congenial management conditions and can meet 80 percent of their nitrogen requirement through their symbiotic relationship with *rhizobium* [9].

Chickpea is a short-stature crop with slow initial growth and limited leaf area development due to which it is heavily infested with a wide spectrum of weeds. The menace of weeds has increased to such an extent that an effective weed management schedule has become a necessity. The presence of weeds throughout the crop season reduced the seed yield of chickpeas by up to 68 per cent [10]. The major weeds in chickpea at Hisar, Haryana were *Chenopodium album*, *Fumaria parviflora* and *Phalaris minor* and other minor weed species were *Convolvulus arvensis*, *Anagallis arvensis*, *Melilotus alba*, *Coronopusdidymus* and *Spergula arvensis* [11]. The yield loss in chickpea due to weeds ranged between 40 to 90 percent [12]. Pendimethalin belongs to the class of dinitroaniline and is used as pre-emergence (PRE) and post-emergence (POE) to control a wide variety of weeds. The imidazolinone class of herbicides provides a broad spectrum of weed control activity [13]. Application of pendimethalin as PRE @ 1.0 kg ha^{-1} provided effective control of annual broad-leaved and grassy weeds in chickpea fields at early stages [14]. The later flushes of weeds can only be controlled by the application of imazethapyr as POE [15]. Efficient management of weeds can lead to optimal utilization of the available resources which can in turn ensure a good yield of chickpea. Keeping the above points in view a study was planned to understand the effect of chemical weed management practices on growth indices, yield and quality of chickpea.

2. MATERIALS AND METHODS

2.1 Experimental Site

The field experiment was carried out during the *Rabi* season of 2021-22 at the Crop physiology laboratory area, Agronomy Research Farm, Chaudhary Charan Singh Haryana Agricultural University (CCSHAU), Hisar, Haryana, India. The mean weekly meteorological data during the *Rabi* season of 2021-22 was recorded at the meteorological observatory located at the Research Farm of CCSHAU.

2.2 Climatic Conditions

The field experiment is situated at 29º 10´ N latitude and 75º 46´ E longitude with an elevation of 215.2 m above mean sea level in the Haryana State of India. Hisar has a typical semi-arid and sub-tropical climate with hot, dry and desiccating winds during the summer season and severe cold during the winter season. The maximum temperature touches around 48°C during the hot summer months of May and June, while during the winter months of December and January, the minimum temperature may even reach subzero. The average annual rainfall of the area is around 450 mm out of which, 70-80 percent is received during the monsoon period *i.e.,* July to September and the rest is received in showers of cyclic rains during the remaining months of the year.

2.3 Soil Characteristics

The texture of the soil on which the experiment was conducted was sandy loam with organic carbon 0.5%, available nitrogen 113kg/ha, available P 11.7 kg/ha, available K 252 kg/ha and pH 8.1.

2.4 Experimental Details

The experiment was conducted in randomized block design with three replications and 13 treatments. Thirteen treatments were allotted randomly in the field with the help of a random number list. The variety of chickpea was HC-6 and plot size 5 m long and 4.5 m wide. The details of 13 treatments are as follows in the list 1.

2.5 Agronomical Practices Adopted

The experimental area was prepared properly in the last week of October 2021. To crush the clods, the field was ploughed twice with a tractor drawn cultivator. Previous crop residues were removed from the field. The field was again ploughed by cross harrowing, followed by cultivator twice and at last, planking to bring the soil to a fine tilth before sowing. A standardized basal dose of fertilizers, 20 kg ha^{-1} nitrogen and 40 kg ha^{-1} phosphorous were applied

List 1. List of treatments use in the study

Sl. No.	Treatments
T1	Pendimethalin 30EC @ 1000 g a.i ha^{-1} as PPI-Pre Plant Incorporation
T2	Imazethapyr 10EC @ 75 g a.i ha^{-1} as PPI
T3	Imazethapyr 10EC @ 100 g a.i ha^{-1} as PPI
T4	Pendimethalin 30EC + imazethapyr 2% EC (Ready mix RM) @ 1000 g a.i ha^{-1} as PPI
T5	Pendimethalin 30EC @ 1000 g a.i ha^{-1} as PRE-Pre emergence
T6	Imazethapyr 10EC @ 75 g a.i ha^{-1} as PRE
T7	Imazethapyr 10EC @ 100 g a.i ha^{-1} as PRE
T8	Pendimethalin 30EC + Imazethapyr 2EC (RM) @ 1000 g a.i ha^{-1} as PRE
T9	Imazethapyr 10EC @ 75 g a.i ha^{-1} as POE-Post emergence
T10	Imazethapyr 10EC @ 100 g a.i ha^{-1} as POE
T11	Two hand hoeing at 30 & 50 DAS
T12	Weed free
T13	Weedy check

through DAP at the time of preparation of the field. After the planned layout and marking of the field, the sowing of the crop was done by *pora* method on the well-prepared field. The sowing of chickpea crop was done on 30 October 2021. Herbicides application was done with the help of a knapsack sprayer and sufficient moisture was maintained in the soil at the time of application. One light irrigation was applied nearly 55 days after the sowing of the chickpea crop on 25th December 2021. The treatment plot (T_{12}) was maintained weed free throughout the growing season of the crop by carrying out hand weeding. Two hoeing were performed at 30 and 50 DAS in the treatment plot (T_{11}) with the help of a hand hoe. Hoeing and weeding were done as per schedule to maintain recommended spacing and a proper weed-free environment. No severe incidence of insect, pest and other diseases was observed in the experimental area and the plant stand was at a satisfactory level. Therefore, there was no requirement for other plant protection measures. At the full physiological maturity stage, chickpea crop was harvested with the help of a sickle by cutting close to the ground from each plot separately. The harvested produce was kept as such in the respective plot for sun drying until a constant weight was obtained. After the completion of drying, plot-wise bundles of produce were formed and separately, the weight of the produce was recorded. After that, the crop was threshed by hand. The weight of the seed of each plot was taken in kg plot^{-1} and later computed to kg ha^{-1}.

2.6 Statistical Analysis

The distribution of various treatments within the experimental plot followed the prescribed design. Subsequently, the data acquired on various growth parameters, yield characteristics, and seed yield during the research were analyzed using suitable statistical methods based on a Factorial Complete Randomized Design as detailed by Gomez and Gomez [16]. This analysis aimed to determine any significant disparities among the treatment averages. To assess these differences, the Least Significant Difference (LSD) test was employed at a significance level of 5%.

3. RESULTS AND DISCUSSION

3.1 Plant Population

Chickpea is a non-tillering leguminous plant therefore plant population plays an important role in the chickpea production. Data presented in Table 1 showed no significant effect on plant stand at 15 DAS but plant stand decreased at maturity especially in case of POE application of imazethapyr @ 75 and 100 g ha^{-1} respectively. Similar plant population in all the PPI and PRE treatments may be due to assured germination, proper soil moisture, no phytotoxicity and proper irrigation facilities throughout the crop growth period. Decreased plant stand at maturity could be attributed to significant phytotoxic effect of imazethapyr applied as POE on chickpea emergence [17].

3.2 Plant Height

Plant height is a crucial parameter related to growth and development of the crop. It indicates the vigour, strength and adaptability of the plant to the existing environmental conditions. Weed free recorded maximum plant height (Table 1) at all the stages which was statistically par with two hand hoeing performed at 30 and 50 DAS. The chickpea plants were taller in weed free treatment compared to the weedy check and this was observed throughout the crop growth period which might be due to lesser crop weed competition for space, light, moisture and other resources thus giving ample scope to weed free treatment plants to reach their full potential without any adverse effect of weeds. On comparing the sole applied herbicides, the plant height of chickpea was more in pendimethalin applied at 1000 g ha^{-1} irrespective of the time of application which may be due to the better weed control and lower weed dry weight in this treatment as compared to application of imazethapyr. Among herbicidal treatments, PRE pendimethalin + imazethapyr (RM) at 1000 g ha^{-1} was the most effective treatment in relation to plant height of the crop. Effective weed control might have developed favourable environment in chickpea crop for absorption of more water and nutrient which in turn enabled the availability of nutrients, water, light and space to the crop which ultimately resulted in increased plant height. All the treatments significantly enhanced the plant height of chickpea, at all the stages over weedy check plot except POE application of imazethapyr at 75 and 100 g ha^{-1}, respectively which recorded 15.74 and 15.20 cm at 30 DAS, 19.7 and 20.6 cm at 60 DAS, 31.33 and 32.17 cm at 90 DAS, 36.18 and 35.90 cm at 120 DAS and 45.90 and 46.87 cm at maturity, respectively. Imazethapyr applied as POE at 75 and 100 g ha^{-1}respectively reduced the plant height numerically than its application as PPI and PRE under the same doses. This could be due to the more phytotoxic effect of herbicide when applied as POE, which resulted in stunted growth [18].

Table 1. Effect of weed management on plant population and height of chickpea

Treatments	Plant population (no. per metre row length)		Plant height (cm)			
	15 DAS	**30 DAS**	**30 DAS**	**60 DAS**	**90 DAS**	**120 DAS**
T_1	11.67	18.68	18.68	32.77	52.47	71.00
T_2	11.50	16.63	16.63	30.78	49.72	65.30
T_3	11.77	17.47	17.47	32.41	50.93	67.70
T_4	11.23	19.97	19.97	35.07	55.37	74.47
T_5	11.60	18.74	18.74	33.03	52.24	71.40
T_6	11.50	16.77	16.77	30.91	49.07	65.97
T_7	11.23	17.23	17.23	32.07	51.43	66.87
T_8	11.87	20.60	20.60	35.37	55.33	74.60
T_9	11.17	15.74	15.74	19.70	31.33	36.18
T_{10}	11.67	15.20	15.20	20.60	32.17	35.90
T_{11}	11.50	21.46	21.46	35.03	54.43	75.83
T_{12}	11.50	22.69	22.69	36.57	55.20	76.00
T_{13}	11.67	15.07	15.07	20.03	33.63	38.10
SEm±	**0.42**	**0.37**	**0.37**	**0.89**	**0.90**	**0.88**
CD (p=0.05)	**NS**	**1.09**	**1.09**	**2.62**	**2.65**	**2.58**

3.3 Dry Matter Accumulation:

The plant growth is a product of its genetic constitution and its environment. The genetic constitution of any particular variety regulates its full growth potential under an environment that is suitable for its development. The dry matter accumulation per plant is quite an important parameter of the plant growth and is a product of its height, leaves, roots and number of branches per plant. Dry matter production (Table 2) in crop was maximum in weed free plots because of complete absence of crop weed competition for growth resources (Table 2) while it was minimum in case of weedy check as no measures were taken towards weed management which reduced the photosynthesis, leaf area and thereby reduced the dry matter production of chickpea. POE application of imazethapyr at 75 and 100 g ha^{-1}, respectively recorded lowest dry matter because it caused phytotoxic effect resulting into complete mortality of plant. The leftover plants recorded the lowest dry matter even lower than weedy treatment. PRE application of pendimethalin + imazethapyr (RM) at 1000 g ha^{-1} provided better results among herbicidal treatments. Dry matter accumulation per plant increased with the advancement of age of crop and maximum dry matter per plant was recorded at maturity. Weed free, two hand hoeing, RM applied at 1000 g ha^{-1} as PRE and PPI respectively, increased dry matter accumulation per plant over weedy by a margin of 147, 142, 137 and 136 per cent, respectively at maturity. The increase in dry matter might be due to cumulative effect of increased plant height, number of branches per plant, better development of plants and reduced dry weight of weeds.

3.4 Leaf Area Index

The highest leaf area index (Table 2) was recorded in weed free followed by two hand hoeing. This might be because of the absence of crop weed competition as evident from the higher weed control efficiency in these. RM applied at 1000 g ha^{-1} as PRE produced significantly higher leaf area index than imazethapyr and pendimethalin treated plots which may be due to the better development of the crop plants as evident from plant height and the dry matter production of the crop. The application of imazethapyr produced lower leaf area index as compared to pendimethalin treated plots because the former was phytotoxic to the chickpea plants and the phytotoxicity ranges from 50 to 60 per cent in this herbicide which later on vanished.

3.5 Crop Growth Rate

The maximum crop growth rate (Table 2) was recorded between 90-120 days due to increased plant height, leaf area, dry matter and congenial temperature for growth during this period and later on it showed declining trend due to the maturity period of crop. At maturity weed free and two hand hoeing recorded the highest crop growth rate. Among herbicides, imazethapyr as POE recorded lower crop growth rate due to stunting of plant growth. Weed free provided an

Table 2. Effect of weed management practices on dry matter accumulation, CGR, LAI and chlorophyll content of chickpea

Treatments	Dry matter accumulation (g $plant^{-1}$)					CGR (g $plant^{-1}$ day^{-1})					LAI at flowering	Chlorophyll content (%)
	30 DAS	**60 DAS**	**90 DAS**	**120 DAS**	**Maturity**	**0-30 DAS**	**30-60 DAS**	**60-90 DAS**	**90-120 DAS**	**120-Maturity**	1.13	3.12
T_1	0.45	1.35	5.05	18.42	29.30	0.015	0.030	0.123	0.446	0.272	1.13	3.13
T_2	0.30	1.05	4.38	18.26	25.74	0.010	0.025	0.111	0.463	0.187	1.15	3.13
T_3	0.30	1.12	4.73	18.97	26.90	0.010	0.028	0.120	0.474	0.198	1.14	3.11
T_4	0.52	1.64	5.50	22.66	32.19	0.017	0.037	0.128	0.572	0.238	1.12	3.13
T_5	0.31	1.36	5.07	19.82	29.22	0.010	0.035	0.124	0.492	0.235	1.14	3.14
T_6	0.26	1.03	4.31	18.73	25.81	0.009	0.025	0.109	0.481	0.177	1.14	3.16
T_7	0.29	1.15	4.78	19.43	27.17	0.010	0.029	0.121	0.488	0.193	1.16	3.16
T_8	0.52	1.63	5.55	22.46	32.28	0.017	0.037	0.131	0.564	0.245	0.77	1.06
T_9	0.23	0.85	1.99	10.11	13.83	0.008	0.021	0.038	0.271	0.093	0.80	1.03
T_{10}	0.22	0.86	1.89	10.28	13.63	0.007	0.022	0.034	0.280	0.084	1.17	3.16
T_{11}	0.54	1.65	5.61	23.12	33.05	0.018	0.037	0.132	0.584	0.248	1.19	3.15
T_{12}	0.54	1.68	5.85	23.39	33.62	0.018	0.038	0.139	0.584	0.256	1.05	3.07
T_{13}	0.20	0.74	1.68	10.07	13.63	0.007	0.018	0.031	0.279	0.089	0.05	0.01
SEm±	**0.03**	**0.03**	**0.14**	**0.68**	**0.51**	**0.001**	**0.002**	**0.005**	**0.024**	**0.022**	**0.14**	**0.04**
CD(p=0.05)	**0.09**	**0.09**	**0.42**	**2.00**	**1.50**	**0.003**	**0.004**	**0.014**	**0.069**	**0.066**	**1.13**	**3.12**

Note: The chlorophyll content was measured at flowering by using CCM-200 plus chlorophyll meter at full bloom stage by randomly selecting three plants in each is plot

Table 3. Effect of weed management practices on yield and economics of chickpea

Treatment	Seed yield (kg ha^{-1})	Cost of cultivation (INRha^{-1})	Gross returns (INR ha^{-1})	Net returns INR ha^{-1})	B:C
T_1	1702	33346	86812	53466	2.6
T_2	1309	32823	66773	33949	2.0
T_3	1385	32841	70633	37792	2.2
T_4	1811	33411	92381	58970	2.8
T_5	1784	33346	91001	57655	2.7
T_6	1323	32823	66475	33652	2.0
T_7	1475	32841	75227	42386	2.3
T_8	1827	33411	93168	59757	2.8
T_9	767	32823	39110	6287	1.2
T_{10}	755	32841	38510	5669	1.2
T_{11}	1940	34563	98952	64389	2.9
T_{12}	1968	50771	100390	49619	2.0
T_{13}	880	32771	44874	12103	1.4
SEm±	**37**	**-**	**-**	**-**	**-**
CD(p=0.05)	**110**	**-**	**-**	**-**	**-**

environment which saved several growth inputs like moisture, nutrients, light and space and provided better edaphic and nutritional environment in root zone, resulting in higher photosynthesis and translocation of photosynthates which enhanced the growth parameters of chickpea [19,20]. The improvement in the growth attributes of chickpea due to different treatments seems to be on account of their direct impact on reducing the weed density and weed dry matter, as a result of which manifold reduction in crop-weed competition occurred.

3.6 Seed Yield

The seed yield (Table 3) was found highest in weed free followed by two hand hoeing. Weedy produced 55 per cent lower seed yield as compared to weed free which was attributed to the 38, and 39 per cent fewer number of pods per plant and seeds per pod over weed free. The higher yields under hand weeding might be due to the early removal of weeds from the crop, minimized crop weed competition creating a weed-free environment [18]. Moreover, better development of crop plants and higher weed control efficiency in weed free treatment also contributed to the increase in seed yield as compared to weedy, which was having the highest weed intensity and dry weight of weeds. All the herbicide irrespective of the time and dose of application produced significantly lower seed yield as compared to weed free. Similar results were reported by Mishra et al. [19]. Imazethapyr applied at 100 g ha^{-1} as PPI and PRE produced 83 and 95 per cent higher grain yield as compared to its application as POE which might be due to the higher number of pods per plant (64% and 68%). Imazethpyr applied at 75 or 100 g ha^{-1} as POE resulted in lower grain yield as compared to pendimethalin or RM treatments. This might be due to the phytotoxic effect of imazethapyr on chickpea crop plant which reduced the overall growth and the development of chickpea as clearly evident from lower values of LAI, dry matter accumulation and the various yield attributes. The lowest seed yield of chickpea was reported in imazethapyr treated plots (POE) at 75 and 100 g ha^{-1}, which was 61 to 62 per cent lower than weed free, which was due to change in the plant architecture which ultimately led to reductions in the plant population. Similar results were reported by Yadav et al. [20].

3.7 Economics

For recommendation of any treatment to the farmers, the best criteria is to evaluate the economics. The benefit-cost ratio was calculated to ascertain the economic viability of different treatments used in this experiment. Comparative economics of different weed control treatments (Table 3) revealed that PRE application of pendimethalin + imazethapyr (RM) at 1000 g ha^{-1} provided highest net returns of ₹59757 ha^{-1}. Kalyani [21] and Gupta et al. [22] also reported higher net returns and B: C with pendimethalin + imazethapyr (RM) applied as PRE. Application of different pre-emergence herbicides had significant effect on B: C. Among various herbicidal treatments, the highest B: C (2.8) was observed in case of PRE application of pendimethalin + imazethapyr (RM) at 1000 g ha^{-1} while the lowest net returns were recorded with POE application of imazethapyr at 75 and 100 g ha^{-1} *i.e.* INR 6287 ha^{-1} and INR 5669 ha^{-1}, respectively. Minimum of all economic parameters were recorded with POE application of imazethapyr at 75 and 100 g ha^{-1}. Amongst different weed control treatments, two hand hoeing at 30 and 50 DAS was more economical treatment. The net return recorded under this treatment was 30 per cent higher than that of weed free. This might be due to the lower cost of cultivation as only two hand hoeing were carried out in this treatment as compared to six weeding in weed free treatment. RM treatments recorded higher net return than that of imazethapyr and pendimethalin treated plots. This might be due to higher grain and straw yield produced by this treatment, as compared to imazethapyr and pendimethalin. Imazethapyr treated plots resulted in the lowest net return as compared to pendimethalin which was due to phytotoxic effect of this herbicide on chickpea crop resulting in to lower seed as well as straw yield [21,22].

4. CONCLUSION

In conclusion, the maximum seed yield was produced under weed free treatment (1968 kg ha^{-1}) followed by two hand hoeing and RM at 1000 g ha^{-1} applied as PPI and PRE. Weedy produced 55 per cent lower grain yield as compared to weed free. RM applied at 100 g ha^{-1} as PPI and PRE proved efficient in controlling *Chenopodium album*, *Fumaria parviflora*, *Anagallis arvensis* and other miscellaneous weeds. POE application of imazethapyr at 75 and 100 g ha^{-1} respectively, proved phytotoxic and caused mortality of chickpea plants. Among various herbicidal treatments, the highest B: C (2.8) was observed in case of PRE application of pendimethalin + imazethapyr (RM) at 1000 g ha^{-1} while the lowest net returns were recorded with POE application of imazethapyr at 75 and 100 g ha^{-1} *i.e.* INR 6287 ha^{-1} and INR 5669 ha^{-1}, respectively. Two hand hoeing was more economical and profitable as it fetched the highest net return among different weed control treatments. Thus, PPI and PRE application of pendimethalin + imazethapyr (RM) @ 1000 g a.i. ha^{-1} is recommended as the RM gave excellent control of complex weed flora and increased the yield of chickpea significantly over the weedy check. However, if there is no shortage of labour, then hand weeding at 30 and 50 DAS is most desirable and effective.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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