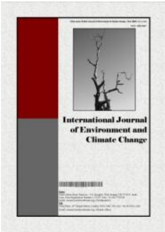

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Effect of Combined Application of Herbicides on Weed Flora, Yield Attributes, Yield and Profitability of Chickpea (*Cicer arietinum* L.)

Vinod Kumar [a*¥], Rajesh Kumar [a#], Vikash Singh [a], Shikhar Verma [b], Vivek Kumar [c] and Durgesh Kumar Maurya [b]

[a] *Department of Agronomy COA, Acharya Narendra Deva University of Agriculture and Technology, Ayodhya (U.P.), 224229, India.*
[b] *Department of Agronomy COA, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur (U.P.), 208002, India.*
[c] *Department of Soil Science and Agricultural Chemistry COA, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.), 250110, India.*

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 (*Cicer arietinum* L.) commonly known as gram or Bengal gram belongs to the family Leguminaceae (Fabaceae). It's one of the most important *rabi* season pulse crops grown in India for economic importance and to improve soil fertility. The productivity of chickpea is low despite of having high-yielding varieties and new agronomic practices. One of the causes of poor productivity is the infestation of weeds in the field of chickpea. It is a poor competitor to weeds because of its slow growth rate and limited leaf area development at early stages. To overcome this, a field experiment was conducted during the *rabi* seasons of 2021-22 at the Agronomy Research Farm of the Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (UP). Replicated thrice set of eleven treatments (T_1) Pendimethalin 30 EC @ 1.0 kg a.i./ha PE,(T_2) Imazethapyr 10% SL @ 0.06 kg a.i./ha PoE,(T_3) Clodinafop propargyl 15 WP @ 0.06 kg a.i./ha PoE, (T_4) Propaquizafop 10 EC @ 0.075 kg a.i./ha PoE,(T_5) Quizalfop ethyl 5 EC @ 40 g a.i./ha

[¥] *M.Sc. Scholar;*
[#] *Assistant Professor;*
**Corresponding author: E-mail: vinodkumar201500@gmail.com;*

PoE, (T_6) Pendimethalin 30 EC @ 1.0 kg a.i./ha PE followed by (Fb) Imazethapyr 10% SL @ 0.06 kg a.i./ha PoE, (T_7) Pendimethalin 30 EC @ 1.0 kg a.i./ha PE fb by Propaquizafop 10 EC @ 0.075 kg a.i./ha PoE, (T_8) Pendimethalin 30 EC @ 1.0 kg a.i./ha PE fb by Clodinafop propargyl 15 WP @ 0.06 kg a.i./ha PoE, (T_9) Pendimethalin 30 EC @ 1.0 kg a.i./ha pE fb by Quizalfop ethyl 5 EC @ 40 g a.i./ha PoE, (T_{10}) Weed free and (T_{11}) Weedy check, was laid out in randomized block design. Weed management was done as per treatment. Other crop management practices were followed as per the recommendation of the area. Pendimethalin @1.0 kg a.i./ha PE fb Clodinafop propargyl 15 WP @ 0.06 kg a.i./ha as PoE during the experiment recorded significantly less weed density, weed dry matter, and higher weed control efficiency, yield attributes (number of pods/plant, number of seeds/pod and test weight), yield (grain yield, stover yield, biological yield, and harvest yield). Economically it recorded higher gross returns, the net return, and B:C ratio was noted and proved to be more remunerative as compared to other herbicide applications used in chickpea crop.

Keywords: Herbicide combination; chickpea; weed management; clodinafop propargyl.

1. INTRODUCATION

Pulses are an integral part of Indian agriculture. Chickpea (*Cicer arietinum* L.) commonly known as gram or Bengal gram belongs to the family Leguminaceae (Fabaceae). It's one of the most important *rabi* season pulse crops grown in India for economic importance and to improve soil fertility [1]. In Indian pulses, chickpea is the second most important component of the diet after cereals. The net availability of food grains per capita increased day by day from 144.1 kg/year in1951 to 179.6 kg/year in 2019 despite population growth however the net obtainability of pulses crop has reduced from 25 kg/year in 1961 to 17.5 kg/year in 2019 [2]. Chickpea is a major pulse in India which contributed about 71% of the world's area (13.57 million hectares) and 67% of the world's production. India ranked first in the area with 9.93 million hectares (34%) and first in production with 9.53 million tones (26%) in the world, followed by Pakistan, Australia, and Iran. In India, during 2019-20, pulses were cultivated over more than 29 million hectares of area and registered the highest ever production of 25.90 mt with a productivity level of 908 kg/hectares. The exponential growth rate in pulse production over the past year has been more than 9 percent [2]. The highest production of 6120 kg/ha is observed in Israel followed by Yemen, Canada, and Egypt. India's productivity was 920 kg/ha yields, [2]. Today, 80% of total pulses production, in India, is realized in six states namely, Madhya Pradesh, Maharashtra, Rajasthan, Andhra Pradesh, Karnataka, and Uttar Pradesh. The productivity of chickpea is low despite of having high-yielding varieties and new agronomic practices. One of the causes of poor productivity is the infestation of weeds in the field of chickpea. It is a poor competitor to weeds because of its slow growth rate and limited leaf area development at early stages [3]. Crop yield losses due to non-adoption of weed management practices particularly in irrigated conditions. Poonia and Pithia [4] reported a 54.7% loss in grain yield due to weed competition in chickpea under rainfed conditions. Major weeds associated with chickpea vary with crops and locations. The Directorate of Weed Research (DWR), Jabalpur, has created a Weed Atlas for major weeds in major crops in 435 districts across 19 states, as well as a weed identification handbook [5]. Its findings concluded that weeds have economic significance in specific crops [6]. Weeds for Chickpea are*; Chenopodium album* L*., Avena fatua* L*., Medicago denticulata, Chicorium intybus, Convolvulus arvensis* L*., Lathyrus aphaca* L*. Lathyrus sativus* L*., Vicia sativa, Cyperus rotundus* L*., Phalaris minor, Avena ludoviciana, Euphorbia geniculata, and Melelotus species.* In the total annual loss of agricultural produce from various pests in India, weeds roughly account for 37%, insects for 29%, diseases for 22%, and other pests for 12% [7]. Weed emergence with the *rabi* sown chickpea crop creates competition unless controlled timely and effectively. Therefore, it is need of our move from the expensive manual and mechanical weed control to chemical weed control practices [8]. The predominant method of weed control by mechanical hoeing and manual weeding over an extensive scale is declining because availability of labor due to shifted from agricultural fields to industries for better and assured wages. Eradication of weed through manual weeding and hoeing is expensive, tedious, and time-consuming, on the other hand use of single herbicides cannot achieve complete weed control due to their selective destruction. Therefore use of herbicide will be more effective if supplemented by manual weeding and hoeing. It is a well-known fact that relying on a single weed control method is ineffective, and an integrated approach may be required. Among several herbicides in the market *viz.* Pendimethalin, Clodinafop propargyl, Quizalofop-ethyl, Propaquizafop, and Imazethapyr are currently being used for controlling both grassy and broad-leaved weeds but their effects under various climatic conditions are not well defined. It was recently found that the herbicide Clodinafop propargyl is very effective in controlling weeds in chickpea [9]. This herbicide is active against grasses but their effects may differ in different locations depending on soil type, intensity, and weed flora type, among other factors. As a result, it is important to compare the effectiveness of various promising herbicides in terms of chickpea productivity and weed competition in weed-free environments, where weed free environment can be achieved by effective hand weeding. Vaishya et al., [10] reported that integrated weed management (pre-emergence application of Pendimethalin @ 1.0 kg/ha Followed by (*fb)* one hand weeding) was found to be the most economical. Among the chemical weed control treatments, Pendimethalin @ 1.0 kg a.i./ha produced the highest yield, net monetary returns, and B: C ratio, and was found to be the most effective and economical in controlling weeds and increasing chickpea yield. A suitable herbicide for effective control of mixed weed flora is required for better adoption in this crop by farmers. The introduction of herbicides has made it possible to control a broad spectrum of weeds in pulses effectively at a reasonable cost. Weed management in chickpea is a crucial component of plant protection thus improving the production potential of the crop.

2. MATERIALS AND METHODS

A field experiment was conducted during 2021-22 *rabi* season at Agronomy Research Farm of the Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (UP) India, which falls in a subtropical climate and situated at 26^0 47′ North latitude, 82^0 12′ East longitudes with an altitude of 113 meters above sea level. During the crop growing season of the year 2021-22, the weekly maximum and minimum temperatures, relative humidity, sunshine hours, wind velocity, evaporation ranged between 32.0°C and 5.7°C, 87.40 and 74.70%, 9.0 and 4.7 hours, 5.5 and 2.0 kmph, 6.4 and 2.1 mm respectively. The soil of the experimental site was homogeneous in fertility with uniform textural makeup. The alluvial soils of Indo-Gangetic plains in general are deep, flat, and well drained with low available nitrogen and medium in available phosphorus and potassium [11]. Chickpea variety RVG 202 was used at seed rate of 80 kg $ha^{-1.}$

2.1 Observation on Weed

Weed observations were recorded at 30, 60, and 90 Days after sowing (DAS). The quadrate of 1 m sq. was randomly placed at three places in each lot and then species-wise and total weed counts were recorded. In weed biomass, all the associated weeds were collected, randomly from 0.25 m^2 quadrate at four places in each plot. The weeds were kept in paper bags and dried in the oven at 60±$2^{\mathbf{0}}$C for 24-25 hours (up to constant weight) and dry weight was recorded at 30, 60, and 90 DAS and expressed as g m^{-2}. For weeds, the original values were transformed using the square root of X+0.5 transformations and analyzed statistically. Weed control efficiency (%) of treatment expressed in percentage for controlling weeds in comparison to weedy check and based on the given formula.

$$\text{WCE (\%)} = \frac{\text{Dry weight of weeds in control plot} - \text{Dry weight of weeds in treated plot}}{\text{Dry weight of weeds in control plot}} \times 100$$

2.2 Observation on Crop

Crop yield and yield attributing characters were recorded as the number of pods $plant^{-1}$ on five randomly selected plants per plot were counted and averaged. The total number of pods from each five sample plants was threshed and the average number of seeds $pods^{-1}$ was recorded. From a lot of threshed clean seeds of each plot, a random seed sample was taken and one hundred seeds were counted from the samples of each plot, and the weight of seeds was recorded on an electronic balance. Seed yield and Stover yield obtained from each plot were added to obtain biological yield in kilogram from each plot and converted to quintal per hectare. On a double pan balance, the weight of clean seeds received from each plot was recorded. Finally, the seed yield $plot^{-1}$ was multiplied by the required value to produce ha^{-1}. The residual yield was calculated by subtracting the seed yield from the biological yield of each net plot under each treatment. Using the same conversion factor, the results were then translated into stover yields ha^{-1}. Harvest Index (%) refers to the ratio of economic yield (seed yield) to the biological (seed + stover) yield under a particular treatment and it was expressed in percentage:

$$\text{Harvest Index} = \frac{\text{Economic Yield}}{\text{Biological Yield}} \times 100$$

Regarding economic analysis of study, the cost of cultivation was calculated treatment-wise, based on prevailing local market prices of different inputs used in the cultivation. Gross returns of grain yield and stover yield were computed in Rs ha^{-1} by using the minimum support prices for grains and prevailing local market price for stover. The gross return in each treatment was obtained by adding the monetary value of grain and stover yield in Rs ha^{-1}. The net return for each treatment was calculated by deducting the cost of cultivation from the respective gross returns. Benefit: The cost ratio in terms of net return per rupee investment was calculated by using the following formula.

$$\text{B: C ratio} = \frac{\text{net return (Rs/ha)}}{\text{Cost of cultivation (Rs/ha)}}$$

2.3 Statistical Analysis

The data obtained were subjected to statistical analysis as outlined by Gomez & Gomez [12]. The treatment differences were tested by the least significant difference at a 5% level of significance.

3. RESULTS AND DISCUSSION

3.1 Weed Indices/ Attributes

The data on total weed density (no. m^{-2}) given in Table 1 indicate that the effect of various weed management practices was significant on the density of weeds at 30, 60, and 90 DAS. Weed management practices exerted a significant effect on the density of total weeds. Weedy check recorded a significantly higher density of total weeds (8.96, 11.62, and 12.42) over the rest of the treatments at all stages of crop growth while weed-free treatments registered the least density of total weeds (0.71, 0.71, and 0.71). Among the herbicidal treatments at 30, 60, and 90 DAS the application of Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* Clodinafop propargyl 15 WP @ 0.060 kg a.i./ha PoE recorded minimum density (5.23, 3.83, and 3.97) of weeds which were statistically at par with Pendimethalin EC @ 1.0 kg a.i./ha PE *fb* Imazethapyr 10% SL @ 0.06 kg a.i./ha PoE These two treatments reduced the weed density significantly than the rest of the treatments. This might be due to effective weed control by both herbicides at all stages of crop growth whereas weedy check treatment recorded significantly highest density of weeds (80.00, 135.00, and 154.00 m^{-2}) at 30, 60, and 90 DAS respectively. These results were in agreement with the results of Yadav et al. [13] and Jaswal and Menon [14]. Data on dry matter of total weeds recorded at 30, 60, and 90, DAS in Table 1 indicated that weedy check recorded maximum weed dry matter of total weeds (4.05, 9.38 and 10.09) at 30, 60 and 90, DAS respectively. While weed-free treatment recorded the lowest dry matter of total weeds at 30, 60, and 90, DAS due to better control of weeds where weeds free condition were maintained by hand weeding. Among the herbicidal treatments, at 30 DAS application of Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* Clodinafop propargyl15 WP @ 0.060 kg a.i./ha as PoE recorded significantly lesser dry matter (2.34, 3.12 and 3.26 g m^{-2}) which was statistically at par with Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* Imazethapyr 10% SL @ 0.060 kg a.i./ha PoE while significantly lesser than the rest of the treatments. A similar trend was observed at 60 and 90 DAS also during the experimentation. Which might be due to effective control of weeds leading to reduction in dry weight. In the weedy check treatment, the dry matter of weeds was significantly higher because of the high weed population and greater capacity of weeds in utilizing the sunlight, nutrients, moisture, CO_2, space, *etc*., over the rest of the treatments. In treatment, weed-free for up to 90 days and application of pre-emergence herbicides in combination with PoE application of herbicides recorded the less weed population at a critical stage of crop growth resulting in lower weed dry matter. These results were also reported by Singh et al. [15], Bhutada and Bhale [16], Kumar et al. [17], and Kumar et al. [18]. The data regarding weed control efficiency as influenced by various weed control treatments are given in Table 1. At harvest, the weed control efficiency was highest in the weed-free (100%) treatment which was significantly superior to all other treatments. Among herbicidal treatments the application of Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* Clodinafop propargyl 15 WP @ 0.060 kg a.i./ha noted significantly higher value (90.00%) of weed control efficiency which was found at par with Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* Imazethapyr 10% SL @ 0.060 kg a.i./ha (POE) (89.61) and significantly higher than the rest of the herbicidal treatments. Due to the herbicide's maximal uptake and higher assimilation occurring right after weed emergence, the application of the herbicides

Pendimethalin and oxyfluorfen before emergence reduces the density of the weeds and results in high efficiency of weed control. Due to their higher weed control effectiveness, Clodinafop propargyl and Imazethapyr PoE applications reduced weed intensity and dry weight more than weedy check. These findings were parallel to the conclusions of Singh and Jain [19], Rathod et al. [20], and Singh et al. [21].

3.2 Yield Attributes

The data on yield contributing characters *viz.* numbers of pods plant^{-1}, the number of seeds pod^{-1}, and the weight of 1000 seeds (g) are presented in Table 2. It is obvious from the results that the number of pods plants^{-1} was affected significantly due to different weed management practices.

Among different weed management practices the maximum number of pods plant^{-1} (57.00) was recorded with weed-free treatments and the minimum (33.00) was the weedy check. Herbicidal treatments also significantly influenced the number of pods plant^{-1}. The maximum number of pods plant^{-1} (54.60) was recorded with the application of Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* by Clodinafop propargyl 15 WP @ 0.06 kg a.i./ha PoE which was at par with the application of Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* Imazethapyr 10% SL @ 0.06 kg a.i./ha PoE (53.4) and significantly higher than the rest of the chemical treatments. The number of seeds/pod was also affected significantly due to different weed management practices of the chickpea crop. The maximum number of seeds pod^{-1} (1.96) was recorded with weed-free treatments and the minimum (1.32) with the weedy check. Among the herbicidal treatments, the maximum number of seeds/pod (1.88) was recorded with the application of Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* by Clodinafop propargyl 15 WP @ 0.06 kg a.i./ha PoE being at par with the application of Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* Imazethapyr 10% SL @ 0.06 kg a.i./ha PoE (1.85) and proved significantly higher than the rest of the treatments. Maximum test weight (200.40 g) was recorded with weed-free treatments and minimum (178.80 g) with the weedy check. Among the herbicidal treatments, the maximum test weight (197.70 g) was recorded with the application of Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* Clodinafop propargyl 15 WP @ 0.06 kg a.i./ha PoE. All parameters related to yield *viz,* number of pods/plant, number of seeds/pod (Table 2) were significantly influenced by weed management practices while the test weight failed to reach the level of significance. Significantly higher values for yield attributes (Table 2) were observed with the application of Pendimethalin30 EC @ 1.0 kg a.i./ha PE *fb* Clodinafop propargyl 15 WP @ 0.060 kg a.i./ha PoE. This might be due to effective control of weeds reducing the weed competition leading to the better expression of yield attributes. Similar findings were reported by Kachhadiya et al. [22], Khope et al. [23], and Singh et al. [24].

3.3 Yield

Grain yield is a function of the source and sinks relationship, where the source is the various growth parameters and the sink is yield attribute parameters such as dry matter accumulation, nodule number per plant, pod number plant^{-1}, seed number pod^{-1}, and test weight. Different weed management treatments influenced significantly the seed, and stover yield of chickpea and the data are embodied in Table 2. The weed-free treatment recorded maximum seed yield (20.60 q ha^{-1}) and minimum seed yield (13.80 q ha^{-1}) was noted with weedy check Severe crop weed competition in weedy check might have effected crop growth and recorded low yields as weeds utilize a large amount of moisture and nutrients than crop due to no weed management practice. Among the herbicidal treatments the application of Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* by Clodinafop propargyl 15 WP @ 0.06 kg a.i./ha PoE recorded a significantly higher seed yield (19.80 q ha^{-1}) being at par with Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* Imazethapyr 10% SL @ 0.06 kg a.i./ha PoE, while significantly higher than the rest of the herbicidal treatments. This might be due to effective control of weeds resulting in higher yield. Similar findings were reported by Punia et al. [25] and Singh et al. [26]. Weed management practices showed a significant variation in stover yield of chickpea. Weed-free treatment recorded maximum stover yield (37.43 kg ha^{-1}) and minimum was with the weedy check (26.50 q ha^{-1}). Data further reveals that among herbicidal treatments the maximum stover yield (36.27 q ha^{-1}) was recorded with Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* by Clodinafop propargyl 15 WP @ 0.06 kg a.i./ha PoE which was statistically at par with the application of Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* Imazethapyr 10% SL 0.06 kg a.i./ha PoE while significantly higher than the rest of the herbicidal treatments. These results were in

Table 1. Effect of herbicide combination on weed density, weed dry weight (g) at 30, 60, 90 DAS, and Weed control efficiency (%) of Chickpea

S. No.	Treatments	Weed density (no m^{-2})			Weed dry weight (g m^{-2})			Weed control efficiency (%)
		30 (DAS)	60 (DAS)	90 (DAS)	30 (DAS)	60 (DAS)	90 (DAS)	
T_1	Pendimethalin 30 EC @ 1.0 kg a.i./ha PE	5.54 (30.30)	6.35 (40.00)	6.67 (44.00)	2.55 (6.06)	5.14 (26.00)	5.43 (29.04)	71.43
T_2	Imazethapyr 10% SL @ 0.06 kg a.i./ha PoE	7.46 (55.40)	5.95 (35.20)	6.20 (38.00)	3.40 (11.08)	4.82 (22.88)	5.05 (25.08)	75.32
T_3	Clodinafop propargyl 15 WP @ 0.06 kg a.i./ha PoE	7.83 (61.20)	5.83 (33.60)	6.12 (37.00)	3.56 (12.24)	4.72 (21.84)	4.97 (24.42)	75.97
T_4	Propaquizafop 10 EC @ 0.075 kg a.i./ha PoE	8.51 (72.00)	7.12 (50.40)	7.43 (55.00)	3.85 (14.40)	5.76 (32.76)	6.06 (36.30)	64.29
T_5	Quizalfop ethyl 5 EC @ 40 g a.i./ha PoE	7.66 (58.40)	6.39 (40.40)	6.63 (43.80)	3.48 (11.68)	5.17 (26.26)	5.41 (28.91)	71.56
T_6	Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* by Imazethapyr 10% SL @ 0.06 kg a.i./ha PoE	5.29 (27.60)	3.93 (15.00)	4.06 (16.00)	2.36 (5.10)	3.19 (9.75)	3.31 (10.56)	89.61
T_7	Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* by Propaquizafop 10 EC @ 0.075 kg a.i./ha PoE	5.42 (29.00)	4.45 (19.31)	4.67 (21.40)	2.51 (5.80)	3.62 (12.63)	3.69 (13.95)	75.13
T_8	Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* by Clodinafop propargyl 15 WP @ 0.06 kg a.i./ha PoE	5.23 (27.00)	3.83 (14.20)	3.97 (15.40)	2.34 (5.02)	3.12 (9.23)	3.26 (10.16)	90.00
T_9	Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* by Quizalfop ethyl 5 EC @ 40 g a.i./ha PoE	5.47 (29.40)	4.51 (20.00)	4.73 (22.00)	2.52 (5.88)	3.67 (13.00)	3.87 (14.52)	76.34
T_{10}	Weed free	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	100.00
T_{11}	Weedy check	8.96 (80.00)	11.62 (135.0)	12.42 (154.00)	4.05 (16.00)	9.38 (87.75)	10.09 (101.64)	0.00
	SEm±	**0.29**	**1.00**	**0.51**	**0.17**	**0.61**	**0.76**	**0.89**
	CD (p = 0.05)	**0.88**	**2.89**	**1.53**	**0.53**	**1.83**	**2.26**	**2.52**

Table 2. Effect of herbicide combination on yield attribute, yields, and harvest index (%) of chickpea

S. No.	Treatments	Yield attribute			Yield (q ha^{-1})			Harvest Index (%)
		Pods/plant	Seeds/pod	Test Weight (g)	Grain Yield	Stover Yield	Biological yield	
T_1	Pendimethalin 30 EC @ 1.0 kg a.i./ha PE	45.03	1.42	180.00	16.50	30.78	47.28	34.89
T_2	Imazethapyr 10% SL @ 0.06 kg a.i./ha PoE	46.80	1.40	180.60	17.00	31.63	48.63	34.95
T_3	Clodinafop propargyl 15 WP @ 0.06 kg a.i./ha PoE	47.00	1.38	181.80	17.20	31.44	49.15	34.99
T_4	Propaquizafop 10 EC @ 0.075 kg a.i/ha PoE	43.60	1.46	179.20	16.00	30.05	46.02	34.82
T_5	Quizalfop ethyl 5 EC @ 40 g a.i./ha PoE	44.00	1.44	179.80	16.30	30.47	46.77	34.85
T_6	Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* by Imazethapyr 10% SL @ 0.06 kg a.i./ha PoE	53.40	1.85	196.00	19.60	35.83	55.43	35.35
T_7	Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* by Propaquizafop 10 EC @ 0.075 kg a.i./ha PoE	47.90	1.45	192.00	16.78	31.07	48.19	35.30
T_8	Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* by Clodinafop propargyl 15 WP @ 0.06 kg a.i. /ha PoE	54.60	1.88	197.70	19.80	36.27	55.95	35.38
T_9	Pendimethalin 30 EC @ 1.0 kg a.i. /ha PE *fb* by Quizalfop ethyl 5 EC @ 40 g a.i./ha PoE	48.00	1.47	190.70	16.83	30.66	47.79	35.19
T_{10}	Weed free	57.00	1.96	200.40	20.60	37.43	58.03	35.49
T_{11}	Weedy check	33.00	1.32	178.80	13.80	26.05	39.85	34.62
	SEm±	**0.65**	**0.12**	**9.41**	**0.87**	**1.49**	**1.34**	**1.25**
	CD (p = 0.05)	**1.95**	**0.38**	**NS**	**2.58**	**4.41**	**4.00**	**NS**

Table 3. Effect of herbicide combination on cost of cultivation, gross return, net return, and B: C ratio of Chickpea

S. No.	Treatments	Cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B: C ratio
T_1	Pendimethalin 30 EC @ 1.0 kg a.i./ha PE	38004	87228	49224	1.29
T_2	Imazethapyr 10% SL @ 0.06 kg a.i./ha PoE	36905	89863	52958	1.43
T_3	Clodinafop propargyl 15 WP @ 0.06 kg a.i./ha PoE	36584	90915	54331	1.48
T_4	Propaquizafop 10 EC @ 0.075 kg a.i./ha PoE	36976	84595	47619	1.28
T_5	Quizalfop ethyl 5 EC @ 40 g a.i./ha PoE	36944	86177	49233	1.33
T_6	Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* by Imazethapyr 10% SL @ 0.06 kg a.i./ha PoE	38885	103543	64658	1.66
T_7	Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* by Propaquizafop 10 EC @ 0.075 kg a.i./ha PoE	38956	100382	61426	1.57
T_8	Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* by Clodinafop propargyl 15 WP @ 0.06 kg a.i./ha PoE	38564	104595	66031	1.71
T_9	Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* by Quizalfop ethyl 5 EC @ 40 g a.i./ha PoE	38924	99342	60418	1.55
T_{10}	Weed free	46024	108803	69779	1.51
T_{11}	Weedy check	36024	72985	36961	1.02

agreement with those of Poonia et al. [4], Chavada et al. [27], and Singh et al. [21]. Among weed management practices significantly higher biological yield (58.03 q ha^{-1}) was observed with weed-free treatments and least biological yield (39.85 q ha^{-1}) with weedy check treatment. In the case of herbicidal treatments the application of Pendimethalin 30 EC @1.0 kg a.i./ha PE *fb* Clodinafop propargyl 15 WP @ 0.060 kg a.i./ha PoE was statistically at par with the application of Pendimethalin 30 EC@ 1.0 kg a.i./ha PE *fb* Imazethapyr 10% SL @ 0.06 kg a.i./ha PoE but significantly higher than the rest of herbicidal treatments. This might be due to effective control of weeds by avoiding weed competition and resulting in higher biomass production. Similar results were reported by Kumar et al. [28] and Singh et al. [21]. Among the weed management treatments, the maximum harvest index was recorded with weed-free (35.49%) and minimum with the weedy check (34.62%). Among herbicidal treatments the application of Pendimethalin 30 EC @ 1.0 kg a.i./ha PE fb Clodinafop propargyl 15 WP @ 0.060 kg a.i./ha PoE recorded a maximum harvest index of 35.38%. The similar result was obtained by Chavada et al. [27].

3.4 Economics Analysis

The economic analysis of the weed control treatments was worked out based on input-output analysis. The cost of cultivation (Rs ha^{-1}) incurred on weed control treatments was added to the common cost of treatments and arrived the total cost of cultivation. The data on economic analysis presented in Table 3 showed that the highest cost of cultivation (39024 Rs ha^{-1}) was recorded under the treatment weed free and the lowest was with the weedy check (36024 Rs ha^{-1}). Among herbicide treatments, the higher cost (38564 Rs ha^{-1}) was recorded with the application of Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* by Clodinafop propargyl 15 WP @ 0.06 kg a.i./ha PoE. In Table 3 the data on gross return computed under different treatments showed that the highest gross return (108803 Rs/ha) was achieved with weed-free treatments and the lowest with the weedy check (72985 Rs ha^{-1}). Among herbicidal treatments, the highest gross return (104595 Rs ha^{-1}) was recorded with the application of Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* by Clodinafop propargyl 15 WP @ 0.06 kg a.i./ha PoE. Data on net return computed under different treatments showed that the highest net return (66031 Rs ha^{-1}) was obtained with the application of Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* by Clodinafop propargyl 15 WP @ 0.06 kg a.i./ha PoE. The data on B:C ratio computed under different treatments showed that the highest B:C ratio (1.71 Rs/Rupees investment) was recorded with the application of Pendimethalin 30 EC @ 1.0 kg a.i./ha PE *fb* by Clodinafop propargyl 15 WP @ 0.06 kg a.i./ha PoE and lowest with the weedy check (1.02 Rs/Rupees investment). The present finding conforms with the finding of Dungarwal et al. [29], Ratnam et al. [30], Meena et al. [31], and Dubey et al. [32].

4. CONCLUSION

The study on effect of different weed management practices in chickpea, revealed that application of pendimethalin @1.0 kg a.i./ha followed by post-emergence Clodinafop propargyl 15 WP @ 0.06 kg a.i./ha as PoE proved to be the best way to control weed as it has recorded significantly less weed density, weed dry matter, higher weed control efficiency, yield attributes (number of pods $plant^{-1}$, number of seeds pod^{-1} and test weight), and culminated in, yield (grain yield, stover yield, biological yield, and harvest index). Economically it also recorded higher gross returns, net return, and benefit cost ratio.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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