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Research Article

Evaluation of different post-emergence herbicides in chickpea (*Cicer arietenum* L.)

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ABSTRACT
A field experiment was conducted during *rabi* season of 2018-2019 at research farm of Bihar Agricultural University, Sabour, Bhagalpur to assess the effect of various post-emergence herbicides in chickpea. The results indicated that among different herbicides, post-emergence application of imazethapyr + imazamox @ 60 g a.i. ha^{-1} at 20 days after sowing recorded significantly lowest weed density & weed dry weight at 60 days after sowing and highest weed control efficiency at harvest, which was statistically at par with quizalofop-ethyl + imazethapyr @ 60+50 g a.i. ha^{-1} at 20 days after sowing. As a consequence of effective weed control, quizalofop-ethyl + imazethapyr @ 60+50 g a.i. ha^{-1} at 20 days after sowing recorded significantly highest grain yield, straw yield and harvest index which was significantly superior over hand weeding twice at 30 and 50 days after sowing. In weedy check, uncontrolled weed growth caused significant reduction in grain yield of chickpea. Net returns and B:C ratio was found maximum with quizalofop-ethyl + imazethapyr @ 60+50 g a.i. ha^{-1} at 20 days after sowing which was significantly superior over weedy check.
***Key words**: Chickpea, Economics, Post emergence herbicide, Weed flora, Yield*

INTRODUCTION

Chickpea (*Cicer arietinum* L.), commonly known as gram or Bengal gram is a legume of Asian origin. It is considered a third important food legume and second important pulse. It is widely cultivated in whole India and stands the first rank in pulse area and production in India. In Bihar, it is cultivated in 0.60 lac hectares with a production of 0.68 lac tonnes and productivity 1124 kg ha^{-1} (Anonymous, 2018).

The productivity of chickpea is relatively very low due to many constraints i.e. biotic and abiotic elements. Poor weed management practice is the most yield-limiting factor in chickpea. Weeds can remove the nutrients from the soil more effectively than the crops. Being slow in early vigour and shortened plant, chickpea is highly vulnerable to crop-weed competition leads up to 75% losses in yield due to weeds (Chaudhary *et al*., 2005). Initial 60 days is considered as the period that is too critical for crop-weed competition in chickpea (Singh and Singh, 2000). Under these unfavorable conditions of severe losses caused by the weeds, difficulties in hand weeding, and susceptibility of chickpea to many herbicides, it is imperative to evolve some effective/economical methods of weed control which can effectively adjust with the situation.

In India, besides pendimethalin, a large number of new herbicides i.e. imazethapyr, imazamox, clodinafop-propargyl, quizalofop-ethyl have been available in the market for better weed control associated with pulses and have no any adverse effect on the performance of the crop. Since the action of the herbicide is considerably influenced by the type of soil, nature of crop, dose, and time of application against specific weeds for a particular locality, it will be a practical guide to the farmers.
This present investigation, was, therefore planned at Bihar Agricultural University farm, Sabour during *rabi* 2018-19 with a view to study the relative efficacy of different post-emergence herbicides either alone or in combination with other herbicides at appropriate dose and time of application on growth, the yield of chickpea and associated weeds than hand weeding.

MATERIAL AND METHODS

A field experiment was carried out during *rabi*, 2018-2019 at research farm of Bihar Agricultural University, Sabour, Bhagalpur, Bihar to assess the efficiency of different post-emergence herbicides in chickpea. The soil of the experimental plot was sandy loam with neutral soil pH (7.43), low in available nitrogen (191.88 kg ha^{-1}) and medium in available phosphorus (22.62 kg ha^{-1}) and potassium (192.88 kg ha^{-1}). Experiment was laid out in randomized block design with three replications. The treatments consisted of twelve weed management practices *viz.*, **T_1**- Pendimethalin 30 EC @ 1000 g a.i. ha^{-1} as PE, **T_2**- Oxyfluorfen 23.5 EC @ 150 g a.i. ha^{-1} as PE, **T_3**- Quizalofop-ethyl 5 EC @ 50 g a.i. ha^{-1} as PoE, **T_4**- Imazethapyr 10 SL @ 50 g a.i. ha^{-1} as PoE, **T_5**- Imazethapyr 35% + Imazamox 35% WG @ 60 g a.i. ha^{-1} as PoE, **T_6**- Clodinafop-propargyl 8% + Sodium-acifluorfen 16.5% EC @ 60 g a.i. ha^{-1} as PoE, **T_7**- Propaquizafop 10 EC @ 100 g a.i. ha^{-1} as PoE,**T_8**- Topramezone 33.6 SC @ 40 g a.i. ha^{-1} as PoE, **T_9**- Clodinafop-propargyl 8% EC + Imazethapyr 10% SL @ 60+50 g a.i. ha^{-1} as PoE, **T_{10}**- Quizalofop-ethyl 5% EC + Imazethapyr 10% SL @ 60+50 g a.i. ha^{-1} as PoE, **T_{11}**- Two hand weeding @ 30 and 50 DAS and **T_{12}**- Weedy check. Chickpea cv. GCP-105 was grown on November 10, 2018 with seed rate (80 kg ha^{-1}) and spacing (30 x 10 cm). Crop was uniformly fertilized with 20:40:00 kg N: P_2O_5: K_2O ha^{-1} and entire dose of N and P_2O_5 was applied as basal.

Data on weed density, weed dry weight, and weed control efficiency at 30, 60, 90 days after sowing, and at harvest stage were recorded by 0.5 x 0.5 m size quadrate. Weed control efficiency was worked out on the basis of weed dry matter using the formula suggested by Mani *et al*. (1973). The normality of distribution was not seen in the case of observations on weeds. Hence the values were subjected to square root transformation $\sqrt{x+0.5}$ before statistical analysis to normalize the distribution. Data on grain yield, straw yield, and harvest index were recorded. Economic analysis of data was also done using the cost of inputs and selling price of produce obtained after processing of harvested material. All the data were statistically analyzed using F-test procedure. Critical difference value at P=0.05 were oftenly used to determine the significance of differences between treatment means.

RESULTS AND DISCUSSION

Weed flora

Weed flora present in the experiment during 2018-19 was collected and grouped as broad-leaved weeds, grasses, and sedges. *Cynodon dactylon* L. and *Dactyloctenium aegyptium* L. are grasses. *Cyperus rotundus* L. is sedge. Among broad-leaved weeds, *Euphorbia hirta* L., *Chenopodium album* L., *Solanum nigrum* L., *Amaranthus viridis* L., *Vicia hirsuta* L., *Vicia sativa* L., *Polygonum plebeium* L., *Anagallis arvensis* L., *Argemone mexicana* L., *Melilotus indicus* L., *Fumaria parviflora* and *Coronopus didymus* L.

Table 1: Total weed density (No. m^{-2}), weed dry weight (g m^{-2}) and weed control efficiency (%) as influenced by different weed control treatments

S. No.	Treatments	Weed density (No. m^{-2})		Weed dry weight (g m^{-2})	
		30 DAS	60 DAS	30 DAS	60 DAS
T_1	Pendimethalin @ 1000 g a.i. ha^{-1} PE	5.27 (27.33)	6.20 (38.00)	1.37 (1.37)	4.85 (23.03)
T_2	Oxyfluorfen @ 150 g a.i. ha^{-1} PE	5.39 (28.67)	6.49 (41.67)	1.39 (1.43)	5.07 (25.25)
T_3	Quizalofop-ethyl @ 50 g a.i. ha^{-1} at 20 DAS	7.56 (56.67)	6.34 (39.67)	1.83 (2.83)	4.95 (24.04)
T_4	Imazethapyr @ 50 g a.i. ha^{-1} as at 20 DAS	7.34 (53.33)	5.93 (34.67)	1.78 (2.67)	4.63 (21.01)
T_5	Imazethapyr+Imazamox @ 60 g a.i. ha^{-1} at 20 DAS	7.24 (52.00)	4.52 (20.08)	1.76 (2.60)	3.50 (11.75)
T_6	Clodinafop-propargyl+Sodium-acifluorfen @ 60 g a.i. ha^{-1}at 20 DAS	7.69 (58.67)	5.73 (32.43)	1.85 (2.93)	4.49 (19.65)
T_7	Propaquizafop @ 100 g a.i. ha^{-1} at 20 DAS	8.40 (70.00)	7.09 (49.73)	2.00 (3.50)	5.54 (30.14)
T_8	Topramezone @ 40 g a.i. ha^{-1} at 20 DAS	6.96 (48.00)	5.40 (28.67)	1.70 (2.40)	4.23 (17.37)
T_9	Clodinafop-propargyl+Imazethapyr @ 60+50 g a.i. ha^{-1} at 20 DAS	6.61 (43.33)	4.98 (24.33)	1.63 (2.17)	3.90 (14.75)
T_{10}	Quizalofop-ethyl+ Imazethapyr @ 60+50 g a.i. ha^{-1} at 20 DAS	6.59 (43.00)	4.82 (22.83)	1.63 (2.15)	3.78 (13.84)
T_{11}	Two hand weeding at 30 and 50 DAS	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_{12}	Weedy check	8.99 (80.33)	11.19 (124.67)	2.12 (4.02)	8.72 (75.55)
SEm ±		0.15	0.13	0.03	0.20
CD (P=0.05)		0.46	0.40	0.10	0.60

Weed density and weed dry weight

Data pertinent to total weed density at 30 and 60 days after sowing was significantly influenced by various weed control treatments and is presented in Table 1.
At 30 days after sowing, among weed control treatments, hand weeding twice at 30 and 50 DAS (T_{11}) recorded significantly minimum weed density per m^2 (0.71) whereas weedy exhibited maximum weed density per m^2 (8.99). Among herbicidal treatments, minimum weed density per m^2 (5.27) was recorded with pendimethalin @ 1000 g a.i. ha^{-1} (T_1) being at par with oxyfluorfen @ 150 g a.i. ha^{-1} (T_2) and was found significantly lower over rest of the treatments. At 60 days after sowing, among weed control treatments, hand weeding twice at 30 and 50 DAS (T_{11}) recorded significantly minimum weed density per m^2 (0.71) whereas weedy exhibited maximum weed density per m^2 (11.19). Among herbicidal treatments, minimum weed density per m^2

(4.52) was recorded with imazethapyr + imazamox @ 60 g a.i. ha^{-1} at 20 DAS (T_5) being at par with quizalofop-ethyl + imazethapyr @ 60+50 g a.i.ha^{-1} (T_{10}) and was found significantly lower over rest of the treatments. Hand weeding treatment indicated complete control of weeds was only possible manually. This is in conformity with the findings of Singh and Singh (2005).

Weed dry weight

Data pertaining to weed dry weight at 30 and 60 days after sowing was significantly influenced by different weed control treatments and is presented in Table 1.

At 30 days after sowing, hand weeding twice at 30 and 50 DAS (T_{11}) recorded significantly minimum weed dry weight per m^2 (0.71) whereas weedy exhibited maximum weed dry weight per m^2 (2.12). Among herbicidal treatments, minimum weed dry weight (1.37) was recorded under pendimethalin @ 1000 g a.i.ha^{-1} (T_1) being at par with oxyfluorfen @ 150 g a.i. ha^{-1} (T_2) and was found significantly lower over rest of the treatments.

At 60 days after sowing, among weed control treatments, hand weeding twice at 30 and 50 DAS (T_{11}) recorded significantly minimum weed dry weight per m^2 (0.71) whereas weedy exhibited maximum weed dry weight per m^2 (8.72). Among herbicidal treatments, minimum weed dry weight was recorded with imazethapyr + imazamox @ 60 g a.i. ha^{-1} at 20 DAS (T_5) being at par with quizalofop-ethyl + imazethapyr @ 60+50 g a.i. ha^{-1} at 20 DAS (T_{10}) and clodinafop-propargyl + imazethapyr @ 60+50 g a.i. ha^{-1} at 20 DAS (T_9) and was found significantly lower over rest of the treatments.

At 30 and 60 days stage, weedy check recorded significantly highest weed counts and dry weight that was mainly due to higher and uninterrupted growth of weeds that made best utilization of resources. On the other hand, lowest weed counts and dry weight was noted in hand weeding treatment recorded zero value than rest of the treatments at 30 and 60 days stages that might be attributed to control of weeds manually at 30 and 50 days intervals, which resulted in reduced dry matter accumulation by weeds. These results are in conformity with the findings of Rajib *et al.* (2014) and Chandrakar *et al*. (2015).

Weed control efficiency

Weed control efficiency was calculated at harvest on the basis of weed dry weight and expressed as %. Data related to weed control efficiency was significantly influenced by different weed control treatments and is presented in Table 2. At harvest, among weed control treatments, hand weeding twice at 30 and 50 DAS (T_{11}) recorded maximum weed control efficiency (96.53%) whereas weedy check registered zero value. Among herbicidal treatments, maximum weed control efficiency (80.01%) was recorded with imazethapyr + imazamox @ 60 g a.i. ha^{-1} at 20 DAS (T_5) being at par with quizalofop-ethyl + imazethapyr @ 60+50 g a.i. ha^{-1} at 20 DAS (T_{10}) and was significantly superior over rest of the treatments. Poonia and Pithia (2013) also reported efficient weed control in chickpea through herbicide mixtures. Higher weed control efficiency might be attributed due to lower weed counts and weed dry weight. These results corroborated with the findings of Butter *et al.* (2008). However, lower weed control efficiency was recorded with weedy plot which was largely due to higher weed counts and weed dry weight. These results corroborated with the findings of Sharma (2009) and Singh *et al*. (2008).

Table 2: Weed control efficiency, grain yield, straw yield and harvest index of chickpea as influenced by different weed control treatments

S. No.	Treatments	Weed control efficiency (%)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index (%)
T_1	Pendimethalin @ 1000 g a.i. ha^{-1} PE	62.38	14.58	21.54	40.38
T_2	Oxyfluorfen @ 150 g a.i. ha^{-1} PE	61.08	14.40	21.47	40.18
T_3	Quizalofop-ethyl @ 50 g a.i. ha^{-1} at 20 DAS	45.42	12.94	19.43	39.96
T_4	Imazethapyr @ 50 g a.i. ha^{-1} as at 20 DAS	61.13	14.04	21.41	39.62
T_5	Imazethapyr + Imazamox @ 60 g a.i. ha^{-1} at 20 DAS	80.01	11.88	18.35	39.32
T_6	Clodinafop-propargyl + Sodium-acifluorfen @ 60 g a.i. ha^{-1} at 20 DAS	63.71	15.39	21.77	41.41
T_7	Propaquizafop @ 100 g a.i. ha^{-1} at 20 DAS	47.02	12.46	19.43	39.05
T_8	Topramezone @ 40 g a.i. ha^{-1} at 20 DAS	66.28	15.83	22.10	41.75
T_9	Clodinafop-propargyl + Imazethapyr @ 60+50 g a.i. ha^{-1} at 20 DAS	74.71	15.93	22.13	41.85
T_{10}	Quizalofop-ethyl + Imazethapyr @ 60+50 g a.i. ha^{-1} at 20 DAS	77.02	17.11	22.32	43.40
T_{11}	Two hand weeding at 30 and 50 DAS	96.53	17.52	24.58	41.67
T_{12}	Weedy check	0.00	11.52	18.17	38.84
SEm ±		1.14	0.60	0.85	1.41
CD (P=0.05)		3.42	1.75	2.57	NS

Grain yield

Data on grain yield of chickpea was significantly influenced by different weed control treatments and are presented in Table 2. Among weed control treatments, hand weeding twice at 30 and 50 DAS (T_{11}) recorded highest grain yield (17.52 q ha^{-1}) of chickpea which was statistically at par with quizalofop-ethyl 5 EC + imazethapyr @ 60+50 g a.i. ha^{-1} PoE (T_{10}), clodinafop-propargyl + imazethapyr @ 60+50 g a.i. ha^{-1} PoE (T_9) and topramezone @ 40 g a.i. ha^{-1} PoE (T_8) and was significantly superior over rest of the treatments including a weedy check (11.52 q ha^{-1}). It was largely due to reduced weed crop competition in these treatments, however, weedy check exhibited their lower value.

Table 3: Effect of different weed control treatments on economics in chickpea

S. No.	Treatments	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
T_1	Pendimethalin @ 1000 g a.i. ha^{-1} PE	27121	77051	49930	1.84
T_2	Oxyfluorfen @ 150 g a.i. ha^{-1} PE	26521	76190	49669	1.87
T_3	Quizalofop-ethyl @ 50 g a.i. ha^{-1} at 20 DAS	27556	68526	40970	1.49
T_4	Imazethapyr @ 50 g a.i. ha^{-1} as at 20 DAS	26706	74499	47793	1.79
T_5	Imazethapyr + Imazamox @ 60 g a.i. ha^{-1} at 20 DAS	27017	63143	36126	1.34
T_6	Clodinafop-propargyl+Sodium-acifluorfen @ 60 g a.i. ha^{-1}at 20 DAS	26620	80898	54278	2.04
T_7	Propaquizafop @ 100 g a.i. ha^{-1} at 20 DAS	27206	66309	39103	1.44
T_8	Topramezone @ 40 g a.i. ha^{-1} at 20 DAS	32156	83094	50938	1.58
T_9	Clodinafop-propargyl + Imazethapyr @ 60+50 g a.i. ha^{-1} at 20 DAS	27393	83571	56178	2.05
T_{10}	Quizalofop-ethyl + Imazethapyr @ 60+50 g a.i. ha^{-1} at 20 DAS	28866	89077	60211	2.09
T_{11}	Two hand weeding at 30 and 50 DAS	33466	92002	58536	1.75
T_{12}	Weedy check	25756	61399	35643	1.38
SEm ±		-	2782	2782	0.10
CD (P=0.05)		-	8160	8160	0.29

Straw yield

Data pertinent to the straw yield of chickpea was significantly influenced by various weed control treatments and are presented in Table 2. Maximum straw yield (24.58 q ha^{-1}) was recorded under hand weeding twice at 30 and 50 days after sowing which was found at par with T_{10}, T_9, and T_8 and was significantly superior over rest of the treatments including the weedy check which registered significantly lowest straw yield (18.17 q ha^{-1}).

Harvest Index

Data on the harvest index under the influence of various weed control treatments are presented in Table 3. Data revealed that none of the weed control treatments have any significant effect on harvest index of chickpea though the maximum harvest index (43.40%) was registered with T_{10}.

Gross returns

A perusal of data in Table 3 revealed that the highest gross returns (Rs. 92002 ha^{-1}) was recorded with hand a weeding twice at 30 and 50 DAS (T_{11}) and lowest gross returns (Rs. 61399 ha^{-1}) was recorded with weedy check (T_{12}). Among herbicidal treatments, the highest gross returns (Rs. 89077 ha^{-1}) were recorded with quizalofop-ethyl + imazethapyr @ 60+50 g a.i. ha^{-1} (T_{10}) which was at par with clodinafop-propargyl + imazethapyr @ 60+50 g a.i. ha^{-1} PoE (T_9) and topramezone @ 40 g a.i. ha^{-1} PoE (T_8) and was significantly superior over rest of the treatments.

Net returns

Data on net return was significantly influenced by various weed control treatments and are presented in Table 3. The data revealed that significantly the highest net return (Rs. 60211 ha^{-1}) was accrued with quizalofop-ethyl + imazethapyr @ 60+50 g a.i. ha^{-1} (T_{10}) which was mainly due to higher gross returns recorded in this treatment as a consequence of higher economic yield of chickpea. This was at par with hand weeding twice at 30 and 50 DAS (T_{11}), clodinafop-propargyl +imazethapyr @ 60 + 50 g a.i. ha^{-1} PoE (T_9) and clodinafop-propargyl + sodium-acifluorfen @ 60 g a.i. ha^{-1} PoE (T_6) and was significantly superior over rest of the treatments where it was largely due to lower economic yield of chickpea.

Benefit: cost ratio

Data on benefit: cost ratio as calculated from net return and cost of cultivation of each treatment and was significantly influenced by different weed control treatments and is presented in Table 3. Highest benefit: cost ratio (2.09) was found with quizalofop-ethyl + imazethapyr @ 60+50 g a.i. ha^{-1} PoE (T_{10}) which was found at par with clodinafop-propargyl + imazethapyr @ 60+50 g a.i. ha^{-1} PoE

(T_9), clodinafop-propargyl + sodium-acifluorfen @ 60 g a.i. ha^{-1} PoE (T_6), oxyfluorfen @ 150 g a.i. ha^{-1} as PE (T_2) and pendimethalin @ 1000 g a.i. ha^{-1} as PE (T_1) which was mainly due to higher economic yield and net returns in these treatments and was significantly superior over rest of the treatments and weedy check which showed dissimilarity among themselves. This was largely due to higher phyto-toxicity of imazethapyr + imazamox @ 60 g a.i. ha^{-1} (T_5) reduces the plant population in weeding operations though this attained low economic yield. This result is in conformity with the findings of Singh and Vaishya (2001).

From the results of present investigation, it may be concluded that application of imazethapyr+ imazamox @ 60 g a.i. ha^{-1} at 20 days after sowing recorded significantly lowest weed density & weed dry weight at 60 days after sowing and highest weed control efficiency at harvest, being at par with quizalofop-ethyl+ imazethapyr @ 60+50 g a.i. ha^{-1} at 20 days after sowing which also recorded significantly highest grain yield, net returns and B:C ratio in chickpea.

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