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Birendra Kumar
Assistant Prof.-Cum-Jr. Scientist, Department of Agronomy, Bihar Agricultural College, Bhagalpur, Bihar, India

Sushanta Sarkar
Technical Officer of Agromet, Bihar Agricultural College, Bhagalpur, Bihar, India

Corresponding Author:
Sushanta Sarkar
Technical Officer of Agromet, Bihar Agricultural College, Bhagalpur, Bihar, India

Efficacy of different post-emergence herbicides in chickpea (*Cicer arietinum*)

Birendra Kumar and Sushanta Sarkar

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Abstract
To study the effect of herbicides on weed dynamics and productivity of chickpea under Bihar situation, a field experiment was carried out at BAU farm, Sabour, Bihar, India. Ten treatments consisted with eight herbicidal treatments, pre-emergence application of pendimethalin 1000 g/ha, oxyfluorfen 150 g/ha; post-emergence application of quizalofop-ethyl 50 g/ha, imazethapyr 50 g/ha, propaquizafop 25.2 g/ha, topramezone 40 g/ha individually and two of different herbicidal combinations as imazethapyr + imazamox (Readymix) 60 g/ha (PoE) and clodinafop-propargyl + na-aciflurofen (Readymix) 220 g/ha (PoE) along with two hand weedings at 30 & 50 DAS and weedy check, were tested in randomized block design with three replications. Two hand weedings recorded significantly reduced weed density and weed dry matter at 60 and 90 DAS with WCE of 91.73 & 93.60% at 60 & 90 DAS respectively and was similar to use of topramezone 40 g/ha. This herbicide treatment resulted in maximum plant height (54.22cm at harvest), number of branches/pant (21.77), number of pods/plant (48.86), test weight (21.62g), grain yield (1.63 t/ha), gross return (Rs. 79,560/ha), net return (Rs. 47,404/ha) and B:C ratio (1.47) compared to other herbicide applications.

Keywords: Chemical control, hand weeding, herbicide combination, weed control efficiency, chickpea

Introduction
Chickpea (*Cicer arietinum* L) is sown on about 8.7 million hectares worldwide. 24% of this area is found in the West Asia and North Africa (WANA) region. They account for 14% of the total world area sown to pulses (Anon, 1992) [2]. Chickpea is a good source of carbohydrates and protein, which together constitute about 80% of the total seed dry weight (Williams and Singh, 1987) [3]. The average seed yield of chickpea is low, about 713 kg/ha (Anon, 1992) [2], because chickpea is usually grown as a spring sown rainfed crop on soils with marginal fertility (Hernandez, 1986) [5], or it is grown in the cooler season (*Rabi* season) of the year when days are short in the Indian subcontinent. Chickpea is one of the most important *rabi* pulse crop of India and occupies first position among the pulses. It is grown on about 84 million hectares and producing 8.32 million tonnes with productivity of 942 kg/ha during 2016- 17 in India. The productivity of chickpea has fallen due to various constraints such as biotic and abiotic factors. Poor weed management is one of the most important yield limiting factors in chickpea. Weeds remove plant nutrients from soil more efficiently than crops. Being slow in its early growth and short statured plant, chickpea is highly susceptible to weed competition (Chaudhary *et al.* 2005) [4]. Chickpea yield losses due to weed competition have been estimated to range between 40 and 87% depending on weed species and density (Bhan and Kukula, 1987) [3]. Initial 60 days is considered as critical period for weed crop competition in chickpea (Singh and Singh, 2000) [12], but continuous facing scarcity of labour and increase in labour cost, manual weed control has become a difficult task. Suitable herbicide for effective control of mixed weed flora is required for better adoption in chickpea. Many research workers from the various parts of the country have reported that the application of pendimethalin as pre-emergence at 1.0 kg/ha (Singh and Jain, 2017) [11] and oxyfluorfen (80 g/ha) as weed control treatment (Patel *et al*., 2006) [8] provided effective control of annual broad leaved and grassy weeds in chickpea field at early stages. However, later flushes of weeds can only be control by application of imazethapyr as post-emergence (Rathod *et al*., 2017) [9].

Keeping in view these facts, the present study was undertaken to test the performance of pre and post-emergence herbicides either alone or combination with other weed management practices for providing effective weed control in chickpea

Materials and Methods

A field experiment was conducted to evaluate the efficiency of herbicides against complex weed flora and their effect on growth, yield and economics of chickpea at BAU farm, Sabour, Bihar, India. The soil of the experimental plot was sandy loam having pH 7.8, organic carbon 0.54%, low in available Nitrogen (179.46 kg/ha), Phosphorus (29.3 kg P_2O_5/ha) and Potassium (194.5 kg K_2O/ha). The chickpea variety 'GCP105' was sown on November 15, 2019 in 5.0 x 4.0 m plots with seed rate 70 kg/ha by seed drill machine in rows 20.0 cm apart. The crop was raised with all recommended package of practices except the herbicidal treatments. The experiment was laid out in a randomized block design, replicated three times, and consisted of 10 treatments including six treatment as pendimethalin 1000 g/ha, oxyfluorfen 150 g/ha as pre-emergence (PE); quizalofop-ethyl 50 g/ha, imazethapyr 50 g/ha, propaquizafop 25.2 g/ha, topramezone 40 g/ha as post-emergence (PoE) used individually and two of different herbicidal combinations as imazethapyr + imazamox (Readymix) 60 g/ha (PoE), clodinafop-propargyl + na-aciflurofen (Readymix) 220 g/ha (PoE) along with two hand weedings at 30 & 50 DAS and weedy check. Herbicides were applied with the help of Knapsack sprayer fitted with flat fan nozzle. The recommended dose of fertilizers i.e. 20-40-0 kg N- P_2O_5-K_2O/ha was applied. Full dose of Nitrogen and Phosphorus were applied as basal. Observations on weed density and dry matter of weeds were recorded from 1.0 m^2 quadrate in each plot to determine weed density and dry weight of weeds at 60, 90 DAS and at harvest. Yield attributes and grain yield was recorded at harvest which was statistically analysed.

Results and Discussion

Plant height (cm)

The data presented in table 1 revealed that plant height was significantly affected by various treatments. During all the three observation dates, maximum plant height (20.05, 44.88 & 56.67 cm at 60, 90 DAS & at harvest respectively) was recorded in hand weeding treatment which is statistically at par with the treatment where topramezone 40 g/ha was applied as post-emergence. While minimum plant height was observed in weedy check (15.96, 36.42 & 46.21cm at 60, 90 DAS & at harvest respectively). The decrease in plant height in weedy check plots clearly showed the weed competition affect on plant growth and development and thus resulted in decrease in their height. The results are contrary to those reported by Khan *et al*. (2000) [6].

Plant drymatter (g/m^2)

Two hand weedings at 30 & 50 DAS produced the highest drymatter of (64.01, 347.72 & 1584.42 g/ha at 60, 90 DAS & at harvest respectively) compared to the lowest in control plot (28.70, 145.50 & 1163.45 g/ha at 60, 90 DAS & at harvest respectively). Post-emergence application of topramezone 40 g/ha produced statistically similar results with Imazethapyr + Imazamox 60 g/ha (Table 1).

Table 1: Effects of weed management practices on crop growth parameters in chickpea.

Herbicides		Plant height (cm)			Dry matter accumulation (g/m^2)		
		60 DAS	90 DAS	At harvest	60 DAS	90 DAS	At harvest
T1	Pendimethalin 1000 g/ha as PE	18.62	40.03	53.53	41.50	270.75	1390.98
T2	Oxyfluorfen 150 g/ha as PE	18.55	38.95	52.31	41.23	263.63	1375.46
T3	Quizalofop-ethyl 50 g/ha as PoE	17.46	39.76	50.36	37.27	224.56	1234.57
T4	Imazethapyr 50 g /ha as PoE	17.93	39.90	51.43	39.41	245.52	1269.45
T5	Imazethapyr + Imazamox 60 g /ha as PoE	18.96	40.23	53.98	58.03	299.68	1533.00
T6	Clodinafop-propargyl + Na-aciflurofen 220 g/ha as PoE	16.71	39.28	49.99	22.66	160.92	1086.54
T7	Propaquizafop 25.2 g/ha as PoE	16.64	38.26	48.62	36.28	212.34	1197.61
T8	Topramezone 40 g/ha as PoE	19.03	40.31	54.22	59.65	305.57	1558.61
T9	Two hand weeding at 30 and 50 DAS	20.05	44.88	56.67	64.01	347.72	1584.42
T10	Weedy check	15.96	36.42	46.21	28.70	145.50	1163.45
S. Em (±)		0.95	1.47	1.79	1.36	8.14	38.12
CD (P=0.05)		2.44	4.58	5.11	3.89	25.73	125.41

Number of branches per plant

Number of branches/plant was significantly affected by various treatments (Table 2). Significantly higher number of branches of 21.98 was recorded in hand weeding treatment (At 30 and 50 DAS) which is almost similar to chemical control measures against the minimum of 16.14 branches/plant recorded in weedy check. More number of fruit bearing branches/plant in hand weeding treatment was the result of absence of weeds and better utilization of resources i.e. moisture, light, nutrients, space etc by the crop plants and thus produced more number of brunches. While, it is true for weedy check treatment due to the result of more weed infestation. These findings are similar with the results of Althahi *et al*. (1994) [1].

Number of pods per plant

As the branches increase, number of pods/plant also increases. The data presented in Table-2 clearly indicated that number of pods/plant was significantly affected by various herbicides treatments. Significantly, maximum number of pods/plant (49.82) was recorded from hand weeding treatment against the minimum number of pods/plant of 30.15 in weedy check control treatment. Hand weeding was followed by application of topramezone 40 g/ha (48.86/plant) as PoE. The other herbicide applications showed almost statistically similar results.

100-seed weight (g)

Significantly higher 100 seed weight of 22.13g (Table 2) was obtained from two hand weedings at 30 & 50 DAS followed by topramezone 40 g/ha (21.62g) against the lowest individual seed weight of 14.13g recorded from weedy check treatment. The other chemical treatments statistically remain at par with each other but significantly higher 100 seed weight than the weedy check treatment.

Seed Yield (t/ha)

Data presented in Table-2 showed statistically significant effect of different treatments on seed yield. The highest grain yield of 1.69 t/ha was recorded from hand weeding (At 30 & 50 DAS) treatment followed by topramezone 40 g/ha (1.63 t/ha) against the minimum yield of 0.87 t/ha obtained from the weedy check treatment. The higher yield in hand weeding treatment and in topramezone 40 g/ha is the result of greater number of branches/plant, number of pods/plant and increased individual grain weight than the control treatment where the weeds competed with the crop plants for growth and development and thus resulted in poor yield. These results are in line with Shah *et al.* (2000) [10] and Malik *et al.* (2001) [7] who concluded that weedy check plots had lesser yield than the weed free treatments.

Table 2: Effects of weed management practices on yield attributes and yield of chickpea

Herbicides		No. of branches/ plant (At harvest)	No. of pods/ plant (At harvest)	100 seed weight (g)	Seed yield (t/ ha)
T1	Pendimethalin 1000 g/ha as PE	19.60	35.82	18.00	1.23
T2	Oxyfluorfen 150 g/ha as PE	19.74	36.78	18.15	1.26
T3	Quizalofop-ethyl 50 g/ha as PoE	19.10	36.10	17.43	1.13
T4	Imazethapyr 50 g /ha as PoE	21.49	37.12	18.17	1.32
T5	Imazethapyr + Imazamox 60 g/ha as PoE	21.36	36.58	18.12	1.26
T6	Clodinafop-propargyl + Na-aciflurofen 220 g/ha as PoE	18.78	35.52	17.41	1.08
T7	Propaquizafop 25.2 g /ha as PoE	19.56	35.11	17.00	1.13
T8	Topramezone 40 g/ha as PoE	21.77	48.86	21.62	1.63
T9	Two hand weeding at 30 and 50 DAS	21.98	49.82	22.13	1.69
T10	Weedy check	16.14	30.15	14.24	0.87
S. Em (±)		0.13	2.41	1.13	0.07
CD (P=0.05)		0.42	7.49	3.11	0.22

Weed densty (weed no./m^2) and dry mater (g/m^2)

Chickpea field was infested with grassy (*Cynodon dactylon, Avena fatua* and *Polygonum plebium*) and broadleaved weeds (*Argemone mexicana, Solanum nigrum, Anagallis arvensis, Chenopodium album, Physalis minima, Fumaria parviflora, Rumex dentatus, Melilotu sindica, Circium arvense* and *Vicia sativa*). The density and dry mater of weeds decreased significantly due to all treatments as compared to un-weeded control plot (Table 3). During all the three observation periods, the lowest weed density and weed dry weight was recorded in cultural method of weed control where two hand weeding were done at 30 and 50 DAS.

Table 3: Effects of weed management practices on weed flora in chickpea

Herbicides		Weed density (no./m^2)			Weed dry matter (g/m^2)		
		60 DAS	90 DAS	At harvest	60 DAS	90 DAS	At harvest
T1	Pendimethalin 1000 g/ha as PE	9.86 (3.22)	14.35 (3.85)	12.69 (3.63)	7.68 (2.86)	10.96 (3.39)	8.97 (3.08)
T2	Oxyfluorfen 150 g/ha as PE	10.77 (3.36)	13.32 (3.72)	11.93 (3.53)	6.25 (2.60)	9.49 (3.16)	8.13 (2.94)
T3	Quizalofop-ethyl 50 g/ha as PoE	9.51 (3.16)	11.12 (3.41)	8.77 (3.04)	6.32 (2.61)	9.69 (3.19)	8.94 (3.07)
T4	Imazethapyr 50 g/ha as PoE	7.91 (2.90)	5.56 (2.46)	4.82 (2.31)	4.51 (2.24)	4.1 (2.14)	3.18 (1.92)
T5	Imazethapyr + Imazamox 60 g/ha as PoE	8.02 (2.92)	9.73 (3.20)	9.05 (3.09)	5.58 (2.47)	6.41 (2.63)	5.6 (2.47)
T6	Clodinafop-propargyl+Na-aciflurofen 220 g/ha as PoE	2.72 (1.79)	3.21(1.93)	1.67 (1.47)	1.54 (1.43)	1.57 (1.44)	1.48 (1.41)
T7	Propaquizafop 25.2 g/ha as POE	12.49 (3.60)	15.01 (3.94)	10.89 (3.37)	5.35 (2.42)	10.19 (3.27)	9.53 (3.17)
T8	Topramezone 40 g/ha as PoE	6.1 (2.57)	5.33 (2.41)	3.32 (1.95)	3.68 (2.02)	3.74 (2.06)	2.7 (1.79)
T9	Two hand weeding at 30 and 50 DAS	3.65 (2.04)	5.16 (2.38)	3.25 (1.94)	2.63 (1.77)	3.28 (1.94)	2.66 (1.78)
T10	Weedy check	36.09 (6.05)	47.89 (6.96)	39.41 (6.32)	31.81 (5.61)	41.14 (6.45)	32.38 (5.73)
S. Em (±)		0.91	1.95	1.28	0.69	0.77	0.74
CD (P=0.05)		2.92	4.04	3.52	2.19	2.79	2.72

Data subjected to sq. root ($\sqrt{x+0.5}$) transformation. Figure in parentheses are Transformed value.

Weed control efficiency

The weed control efficiency showed the efficacy of herbicides with respect to controlling weed over weedy check. Data (Table 4) revealed that higher weed control efficiency (95.16 and 96.18% at 60 and 90 DAS respectively) brought up by the application of clodinafop-propargyl + na-aciflurofen (Readymix) 220 g/ha (PoE) followed by two hand weeding at 30 and 50 DAS (91.73 & 93.60% at 60 & 90 DAS respectively) and topramezone (88.43 & 90.91% at 60 & 90 DAS respectively). However, the lowest weed control efficiency (75.86 & 73.36% at 60 & 90 DAS respectively) was recorded under pre-emergence application of pendimethalin 1000 g/ha.

Weed index

Weed index is the measure of crop yield reduction due to weed competition in comparison to weed free. Weed index indicates the loss of yield caused by weeds under particular treatment as compared to weed free plot (Table 4). However, minimum losses in yield i.e. weed index was associated with post-emergence application of pramezone (3.32%) followed byimazethapyr (21.62%) in respect to weed free plot. The loss of yield as measured in terms of weed index was recorded maximum under weedy check (48.40%) due to heavy infestation of weeds.

Table 4: Effects of weed management practices on WCE and Weed Index in chickpea.

Herbicides		Weed control efficiency (%)		Weed Index (%)
		60 DAS	90 DAS	At harvest
T1	Pendimethalin 1000 g/ha as PE	75.86	73.36	27.43
T2	Oxyfluorfen 150 g /ha as PE	80.35	76.93	25.18
T3	Quizalofop-ethyl 50 g /ha as PoE	80.13	76.45	33.29
T4	Imazethapyr 50 g/ha as PoE	85.82	90.03	21.62
T5	Imazethapyr + Imazamox 60 g /ha as PoE	82.46	84.42	25.41
T6	Clodinafop-propargyl + Na-aciflurofen 220 g/ha as PoE	95.16	96.18	36.32
T7	Propaquizafop 25.2 g/ha as PoE	83.18	75.23	33.12
T8	Topramezone 40 g/ha as PoE	88.43	90.91	3.32
T9	Two hand weeding at 30 and 50 DAS	91.73	93.60	-
T10	Weedy check	-	-	48.40
S. Em (±)		-	-	-
CD (P=0.05)		-	-	-

Economics

All the weed control treatments were significantly superior over un-weeded control plot in terms of monetary returns (Table 5). The highest gross return (Rs. 82,290/ha) and net return (Rs. 48,824/ha) were recorded by two hand weeding which was statistically at par with topramezone (Gross return- Rs. 79,560/ha) & (Net return- Rs. 47,404/ha) and followed by imazethapyr (Gross return- Rs. 64,496/ha) & (Net return- Rs. 37,790/ha). The highest B:C ratio (1.47) was recorded by topramezone followed by two hand weeding (1.46), imazethapyr (1.42) and lowest net return (Rs.16,705/ha) and B:C ratio (0.65) was recorded in weedy check.

Table 5: Effects of weed management practices on cost of cultivation, gross return, net return and B: C ratio in chickpea.

Herbicides		Cost of cultivation (Rs.)	Gross return (Rs.)	Net return (Rs.)	B:C ratio (Rs.)
T1	Pendimethalin 1000 g/ha as PE	27121	59719	32598	1.20
T2	Oxyfluorfen 150 g/ha as PE	26521	61571	35050	1.32
T3	Quizalofop-ethyl 50 g/ha as PoE	27556	54893	27337	0.99
T4	Imazethapyr 50 g/ha as PoE	26706	64496	37790	1.42
T5	Imazethapyr + Imazamox 60 g/ha as PoE	27017	61376	34359	1.27
T6	Clodinafop-propargyl + Na-aciflurofen 220 g/ha as PoE	26123	52406	26283	1.01
T7	Propaquizafop 25.2 g/ha as PoE	27206	55039	27833	1.02
T8	Topramezone 40 g/ha as PoE	32156	79560	47404	1.47
T9	Two hand weeding at 30 and 50 DAS	33466	82290	48824	1.46
T10	Weedy check	25756	42461	16705	0.65
S. Em (±)		-	3735	2682	0.11
CD (P=0.05)		-	11209	8012	0.35

Conclusion

Post-emergence application of topramezone (40 g/ha) resulted in maximum plant height (54.22cm at harvest), number of branches/pant (21.77), number of pods/plant (48.86), test weight (21.62g), grain yield (1.63 t/ha), gross return (Rs. 79,560/ha), net return (Rs. 47,404/ha) and B:C ratio (1.47) compared to other herbicide applications. So, it is concluded that application of topramezone as post-emergence (40 g/ha) was as good as two hand weedings (At 30 and 50 DAS) for better weed control, higher crop yields and benefits.

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