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Vijay Laxmi Yadav
Ph.D., Research Scholar, Department of Agronomy, Rajasthan Agricultural Research Institute, Durgapura, SKNAU, Jobner, Jaipur, Rajasthan, India

UN Shukla
Assistant Professor, Department of Agronomy, College of Agriculture, AU, Jodhpur, Rajasthan, India

Jitendra Kumar Yadav
M.Sc. Agriculture, Department of Agricultural Chemistry and Soil Science, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan, India

Dheeraj Kumar
Ph.D., Research Scholar, Department of Animal Production, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan, India

Anil Swami
M.Sc. Agriculture, Department of Agronomy, College of Agriculture, AU, Jodhpur, Rajasthan, India

Corresponding Author:
Vijay Laxmi Yadav
Ph.D., Research Scholar, Department of Agronomy, Rajasthan Agricultural Research Institute, Durgapura, SKNAU, Jobner, Jaipur, Rajasthan, India

Efficacy of different pre and post-emergence herbicides on growth, yield and economics of chickpea (*Cicer arietinum* L.)

Vijay Laxmi Yadav, UN Shukla, Jitendra Kumar Yadav, Dheeraj Kumar and Anil Swami

Abstract
A field experiment was conducted at Agricultural Research Station, Mandor, Jodhpur during *rabi* season of 2016-17 to evaluate the "Efficacy of pre and post-emergence herbicides on growth and yield of chickpea (*Cicer arietinum* L.)". Sixteen treatments were formulated including pre and post-emergence herbicides and laid out in randomized block design (RBD) and replicated thrice. The results revealed that weed free recorded significantly higher growth and yield attributing characters and yields over rest of the treatments. Among herbicidal treatments, plant height, no. of branches plant^{-1}, dry matter accumulation (g plant^{-1}) as well as yield attributing characters *viz.*, no. of pods plant^{-1}, no. of seeds pod^{-1} and 100-seed weight of chickpea were produced significantly higher under application of pendimethalin @ 0.60 kg *a.i.* ha^{-1} (PE) + imazethapyr @ 60 g *a.i.* ha^{-1} at 20 DAS (W_{12}) as pre and post-emergence herbicides resulted in higher seed and stalk yield, but statistically equally effective with similar combination and lower dose treatment *i.e.* pendimethalin @ 0.60 kg *a.i.* ha^{-1} (PE) + imazethapyr @ 40 g *a.i.* ha^{-1} at 20 DAS (W_{11}). Increase in seed and stalk yield, which subsequently improved gross returns, net returns and B: C ratio also and recorded highest under pendimethalin @ 0.60 kg *a.i.* ha^{-1} (PE) + imazethapyr @ 60 g *a.i.* ha^{-1} at 20 DAS (W_{12}) as pre and post-emergence application, but showed equal economic feasibility with pendimethalin @ 0.60 kg *a.i.* ha^{-1} (PE) + imazethapyr @ 40 g *a.i.* ha^{-1} at 20 DAS (W_{11}) as pre and post-emergence application.

Keywords: Chickpea, herbicide, weed, yield, B: C ratio

Introduction
Chickpea (*Cicer arietinum* L.) is the prime member of leguminosae family and occupies an important position among pulses by virtue of its short growth period, huge tonnage capacity and outstanding nutrient value as food, feed and forage. Chickpea has wide range of adaptability and can be grown under semi-arid to temperate regions of the world; predominantly it is mainly cultivated in India, Pakistan and other parts of the South Asia as well as in Ethiopia, Mexico and Iran (Shukla and Mishra, 2018) [7]. India alone has nearly 52.5 per cent of the world acreage and production of chickpea. It occupies about 38 per cent of area under pulses and contributes about 50 per cent of the total pulse production of India. It is grown on acreage of 8.84 million hectare and producing 8.32 million tonnes with productivity of 942 kg ha^{-1} during 2016-17 in India. In Rajasthan, chickpea is successfully cultivated in arid and semi-arid districts and occupied at second rank in respect of area (1.26 m ha) with low productivity (725 kg ha^{-1}) (Anonymous, 2016) [1]. Chickpea is a short stature crop with slow initial growth and therefore, heavily infested with wide spectrum of weeds. If proper control measures are not taken, then the loss in terms of yield may increase up to 75 per cent in chickpea (Chaudhary *et al*., 2005) [2]. The conventional method of weed control by hoeing and hand weeding are very laborious, expensive and time consuming and needs to be often repeated at different intervals. The high cost and non-availability of labour at right time force the farmers for opting alternative, cheaper and easier method of weed control. To control weed flushes in chickpea, the sequential application of pre and post-emergence herbicides is only the effective ways. Hence, this investigation was taken to find out the effective combination of pre and post-emergence herbicides for control of weeds in chickpea.

Material and Methods

The experiment was conducted at Agricultural Research Station, Mandor, Jodhpur during *rabi* season of 2016-17. The analytical results revealed that soils of the experimental field was sandy loam in texture, slightly alkaline in reaction (pH 8.2), low in organic carbon (0.13%) and available nitrogen (174 kg ha^{-1}), whereas medium in phosphorus (22.2 kg P_2O_5 ha^{-1}) and available potassium (325 kg K_2O ha^{-1}). Sixteen weed management treatments, *viz*., W_1-Weedy Check, W_2-Weed free, W_3-Pendimethalin @ 0.40 kg *a.i.*/ha (PE), W_4-Pendimethalin @ 0.60 kg *a.i.*/ha (PE), W_5- Oxyfluorfen @ 100 g *a.i.*/ha (PE), W_6-Oxyfluorfen @ 200 g *a.i.*/ha (PE), W_7-Imazethapyr @ 40 g *a.i.*/ha at 20 DAS, W_8-Imazethapyr @ 60 g *a.i.*/ha at 20 DAS, W_9-Pendimethalin @ 0.40 kg *a.i.*/ha (PE) + imazethapyr @ 40 g *a.i.*/ha at 20 DAS, W_{10}-Pendimethalin @ 0.40 kg *a.i.*/ha (PE) + imazethapyr @ 60 g *a.i.*/ha at 20 DAS, W_{11}-Pendimethalin @ 0.60 kg *a.i.*/ha (PE) + imazethapyr @ 40 g *a.i.*/ha at 20 DAS, W_{12}-Pendimethalin @ 0.60 kg *a.i.*/ha (PE) + imazethapyr @ 60 g *a.i.*/ha at 20 DAS, W_{13}-Oxyfluorfen @ 100 g *a.i.*/ha (PE + imazethapyr @ 40 g *a.i.*/ha at 20 DAS, W_{14}-Oxyfluorfen @ 100 g *a.i.*/ha (PE) + imazethapyr @ 60 g *a.i.*/ha at 20 DAS, W_{15}-Oxyfluorfen @ 200 g *a.i.*/ha (PE) + imazethapyr @ 40 g *a.i.*/ha at 20 DAS and W_{16}-Oxyfluorfen @ 200 g *a.i.*/ha (PE) + imazethapyr @ 60 g *a.i.*/ha at 20 DAS were studied in randomized block design with three replications. Among different doses of herbicides, pendimethalin and oxyfluorfen were applied as pre-emergence (within 3 DAS), while imazethapyr was applied as post-emergence (20 DAS). These herbicides were sprayed with knapsack sprayer using flat fan nozzle in about 600 litres of water per hectare. The chickpea cv. *Gangour* (GNG-1581) was sown manually keeping the row distance of 30 cm at 60 kg seed/ha. Entire quantity of nitrogen (20 kg/ha) and phosphorous (40 kg/ha) in the form of urea and DAP, respectively were applied at the time of field preparation. All the recommended package of practices was followed to raise the crop. The observations with respect to growth *viz*., plant height, no. of branches and yield attributes were recorded at harvest, while dry matter was taken at 30, 60, 90 DAS and at harvest.

Result and Discussion

Effect on growth attributes

Different weed management practices improved growth attributes of chickpea over weedy check (Table 1). Significant improvement in growth attributes *viz.*, plant height (38.61cm) and number of branches $plant^{-1}$ (7.55), while dry weight $plant^{-1}$ at 30, 60 90 DAS and at harvest (0.48, 4.46, 9.71 and 23.10g, respectively) were recorded under weed free treatment, which was found statistically at par with pendimethalin @ 0.60 kg *a.i.* ha^{-1} (PE) + imazethapyr @ 60 g *a.i.* ha^{-1} at 20 DAS (W_{12}) and pendimethalin @ 0.60 kg *a.i.* ha^{-1} (PE) + imazethapyr @ 40 g *a.i.* ha^{-1} at 20 DAS (W_{11}). Initially the plant height was reduced under treatments where imazethapyr applied as post-emergence, might be due to phytotoxic effect of imazethapyr. After few days, the effect of phtotoxicity was disappeared resulted in good growth of plants at later stages. These results were also reported by Rathod *et al.* (2017) [6] and Pritam *et al.* (2015) [5].

Effect on yield attributes

Growth pattern of a crop in its vegetative phase mainly determines the formation of number and size of sink, which ultimately serves as the base for developing yield attributes. Thus, the yield attributing characters of a plant are closely correlated with growth characters emerged in vegetative phase (Dubey *et al.*, 2018). Among treatments, combined application of pre and post-emergence herbicide *i.e.* pendimethalin @ 0.60 kg *a.i.* ha^{-1} (PE) + imazethapyr @ 60 g *a.i.* ha^{-1} at 20 DAS (W_{12}) and pendimethalin @ 0.60 kg *a.i.* ha^{-1} (PE) + imazethapyr @ 40 g *a.i.* ha^{-1} at 20 DAS (W_{11}) recorded significantly higher no. of pods $plant^{-1}$ (49.83 and 48.10), no. of seeds pod^{-1} (2.02 and 1.95) and 100-seed weight (16.57 and 16.14), respectively over rest of the treatments (Table 2), however these treatments were statistically at par with weed free treatment (W_2). The results were in close conformity with Dewangan *et al.* (2016) [3].

Effect on yield

Improvement in yield attributing characters due to employed herbicide under particular treatment that significantly increases seed yield and stalk yield of chickpea (Table 2). Thus, sequential application of pre and post-emergence herbicides *i.e.* pendimethalin @ 0.60 kg *a.i.* ha^{-1} (PE) + imazethapyr @ 60 g *a.i.* ha^{-1} at 20 DAS (W_{12}) and pendimethalin @ 0.60 kg *a.i.* ha^{-1} (PE) + imazethapyr @ 40 g *a.i.* ha^{-1} at 20 DAS (W_{11}) were recorded significantly higher seed yield (2303.33 and 2231.33 kg ha^{-1}) and stalk yield (3309.08 and 3217.14 kg ha^{-1}), respectively over other weed management treatments, but these treatments were at par with each other and also showed equally effective as weed free treatment (W_2). Similar trend was also observed in harvest index and recorded significantly highest in the weed free treatment followed by W_{12} and W_{11}. Increase in yield might be due to lesser weed counts under W_{12} that favour the plant to utilize agro-inputs efficiently ultimately produced more yield attributing characters. These results were also confirmed by Dubey *et al.* (2018) [4] and Singh *et al.* (2014) [8].

Table 1: Growth attributes of chickpea as influenced by various weed management treatments

Treatments	Growth parameters at harvest		Dry matter (g $plant^{-1}$)			
	Plant height (cm)	Number of branches ($Plant^{-1}$)	30	60	90	At Harvest
W_1	38.61	3.90	0.35	2.18	5.45	10.62
W_2	54.29	7.55	0.48	4.46	9.71	23.10
W_3	45.20	5.30	0.48	3.00	6.85	15.79
W_4	46.06	5.43	0.46	3.04	6.98	15.95
W_5	42.80	4.67	0.45	2.33	6.60	12.83
W_6	44.54	4.70	0.43	2.35	6.64	12.86
W_7	42.55	5.13	0.39	2.48	6.55	14.59
W_8	43.57	5.23	0.38	2.58	6.60	14.68
W_9	50.93	6.80	0.40	3.95	8.73	20.26
W_{10}	51.10	7.00	0.41	3.99	8.89	21.04

W_{11}	53.05	7.47	0.43	4.28	9.62	22.41
W_{12}	54.01	7.50	0.45	4.37	9.64	23.05
W_{13}	47.13	5.50	0.39	3.43	7.24	17.05
W_{14}	48.50	5.60	0.43	3.48	7.45	17.84
W_{15}	49.47	5.80	0.43	3.54	7.53	18.99
W_{16}	50.46	6.03	0.45	3.59	7.74	19.18
S.Em±	1.03	0.17	0.01	0.08	0.18	0.37
CD (*P*=0.05)	2.97	0.49	0.03	0.23	0.53	1.08

Table 2: Yield attributes, yield and harvest index of chickpea as influenced by various weed management treatments

Treatments	Pods plant^{-1} (No.)	Seeds pod^{-1} (No.)	100-seed weight (g)	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Harvest index (%)
W_1	15.73	1.05	10.90	728.33	1396.12	34.28
W_2	50.27	2.05	16.70	2327.33	3316.05	41.24
W_3	27.40	1.42	13.65	1561.33	2748.57	36.23
W_4	28.00	1.38	14.09	1607.33	2803.17	36.44
W_5	19.21	1.20	13.28	1189.00	2154.33	35.56
W_6	19.88	1.24	12.56	1274.67	2292.50	35.73
W_7	22.88	1.30	12.27	1398.67	2489.76	35.97
W_8	23.58	1.33	12.38	1489.00	2634.13	36.11
W_9	42.58	1.72	14.64	1991.33	3061.53	39.41
W_{10}	43.77	1.77	14.90	2077.67	3091.94	40.19
W_{11}	48.10	1.95	16.14	2231.33	3217.14	40.95
W_{12}	49.83	2.02	16.57	2303.33	3309.08	41.04
W_{13}	31.78	1.46	13.93	1715.33	2823.79	37.79
W_{14}	33.17	1.47	14.08	1749.67	2845.85	38.07
W_{15}	37.28	1.56	14.25	1855.33	2971.24	38.44
W_{16}	38.33	1.63	14.33	1872.67	2972.11	38.65
S.Em±	1.29	0.04	0.43	36.91	60.76	0.69
CD (*P*=0.05)	3.72	0.10	1.25	104.23	175.48	1.99

Effect on economics

The gross return obtained by multiplying price of yield of crop (economic and straw yield) which varies due to different treatments that ultimately influences the net return and benefit: cost ratio (Table 3). Cost of cultivation was incurred maximum under weed free treatment and it was mainly due to cost of labour engaged in repeated hand weeding. While weedy check showed minimum cost as no extra cost was involved other than common cost of crop cultivation. It is evident from data that highest gross returns (₹ 105252.15 and ₹ 101968.96 ha^{-1}), net returns (₹ 77919.15 ha^{-1} and ₹ 74855.96) and B: C ratio (3.85 and 3.76) were recorded under sequential application of pre and post-emergence herbicide *i.e.* pendimethalin @ 0.60 kg *a.i.* ha^{-1} (PE) + imazethapyr @ 60 g *a.i.* ha^{-1} at 20 DAS (W_{12}) followed by similar combinations and lower doses treatment *i.e.* pendimethalin @ 0.60 kg *a.i.* ha^{-1} (PE) + imazethapyr @ 40 g *a.i.* ha^{-1} at 20 DAS (W_{11}), respectively as compared to rest of the treatments including weedy check, but both the treatments stand next to weed free (W_1) in this regards and showed fewer monetary differences. These results were supported by Dubey *et al.* (2018).

Table 3: Cost of cultivation, gross return, net return and B: C ratio of chickpea as influenced by various weed management treatments

Treatments	Cost if cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return(₹ ha^{-1})	B: C ratio
W_1	24455	34031.07	9576.07	1.39
W_2	29455	106313.78	76858.78	3.61
W_3	25764	72333.47	46569.47	2.81
W_4	26173	74496.00	48323.00	2.85
W_5	25210	55273.83	30063.83	2.19
W_6	25466	59232.33	33766.33	2.33
W_7	25395	64855.52	39460.52	2.55
W_8	25615	69092.10	43477.10	2.70
W_9	26704	91412.06	64708.06	3.42
W_{10}	26924	95234.72	68310.72	3.54
W_{11}	27113	101968.96	74855.96	3.76
W_{12}	27333	105252.15	77919.15	3.85
W_{13}	26150	79122.57	52972.57	3.03
W_{14}	26370	80625.87	54255.87	3.06
W_{15}	26406	85398.14	58992.14	3.23
W_{16}	26626	86148.55	59522.55	3.24

Regression analysis

The stalk yield and dry matter accumulation (g plant^{-1}) were positively correlated with correlation co-efficient of R^2 = 0.8601. This was further supported by the regression analysis, which revealed that as unit weight of dry weight of crops increases, the stalk yield also increased by 118.47 kg ha^{-1} of chickpea (Fig. 1).

Conclusion

On the basis of above findings, this may concluded that sequential application of pre and post-emergence herbicides *i.e.* pendimethalin @ 0.60 kg *a.i.*/ha (PE) + imazethapyr @ 60 g *a.i.*/ha at 20 DAS significantly recorded higher growth and yield attributes resulted in higher yield (seed and stalk yield) of chickpea. Although, it showed equal efficacy with treatment of pendimethalin @ 0.60 kg *a.i.* ha-1 (PE) + imazethapyr @ 40 g *a.i.* ha-1 at 20 DAS (W11) as pre and post-emergence herbicide combination. As per data, the above results are based on one year trial, which needs to be validated through further experimentation to formulate a concrete recommendation.

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