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RESEARCH ARTICLE

Imazethapyr as post-emergent herbicide in common-bean (*Phaseolus vulgaris* L.) under rainfed temperate condition of Kashmir, India

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ABSTRACT

A research trial was carried out over the course of two years in *Kharif* (rainy) season of 2021 and 2022 at the Agronomic Research Farm of the Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, India to study the bio-efficacy of imazethapyr as post-emergent herbicide at 25 days after sowing to control weeds and yield of common bean. The herbicide was applied at different doses *i.e.* 25, 50, 75, 100 and 125 g/ha and were compared under randomized completely block design. Application of imazethapyr 75-125 g/ha remarkably decreased the weed density and the weed biomass. The growth and yield parameters were significantly higher with imazethapyr 100 g/ha and were at par to 2 manual weeding. The common bean seed yield was reduced by 67.91% and 72.11% in 2021 and 2022, respectively, due to weed infestation in weedy check plots. Maximum weed control efficiency and index was obtained with application of imazethapyr 125 g/ha. However, imazethapyr 100 to 125 g/ha resulted in considerably higher benefit: cost ratios of 2.52 (2021) and 2.7 (2022) followed by imazethapyr 75 g/ha with benefit: cost ratios of 2.45 (2021) and 2.6 (2022). The results lead to the conclusion that imazethapyr application 100 g/ha as post-emergent herbicide applied at 25 days after sowing was found efficient for weed control with economically higher seed yield of common bean.

Keywords: Common bean, Economics, Growth, Imazethapyr, *Phaseolus vulgaris*, Weed control efficiency, Yield

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is extensively grown due to its short duration and nutritional value (Longkumar and Singh 2016) as it contains a high level of protein (25.40 g/100g) with considerable amounts of minerals *i.e*., phosphorus (463 mg/100 g), calcium (167 mg/100 g) and iron (6.24 mg/ 100g). The common bean is an essential grain legume crop that is mostly used for its pods and dry edible seeds around the world (Nadeem *et al*. 2020) and is extremely profitable legume in hilly areas of Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh and some places of Maharashtra by virtue of its distinct adaptation to a cold and extended growth season (Sood *et al*. 2003). It also occupies a significant position among many *Kharif* (rainy) pulses grown in temperate hills of North-Western India. An area of 33.1 million hectares of common beans were harvested worldwide, and 28.9 million tons were produced in 2019 according to FAO (WHO 2020). In Jammu and Kashmir, common beans have acquired the popularity due to its superior taste, texture, flavor and palatability (Choudhary *et al*. 2018, Mir *et al*. 2021). Despite its widespread use, the productivity of this crop in India is very low at 450.90 kg/ha as compared to the global average of 777.40 kg/ha (Anonymous 2010). This is because, the majority of these crops are cultivated in rainfed areas with poor management and are subjected to a variety of biotic and abiotic stresses.

High weed infestation is one of the key biotic constraints that hampers overall crop development and yield as reported by Panotra *et al*. (2018). In addition to lowering the quantity and quality of yield, weeds can make harvesting harder and serve as habitats for pests and pathogen and also compete with crops for natural and applied resources (Rao *et al*. 2015). The first 30-45 days after sowing (DAS) of the growth of common bean is most crucial period for crop-weed competition. At this stage, the growth of the crop is slow and is overrun by weeds, which causes yields to decline by 20-60% (Anonymous

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2009). Therefore, maintaining a weed-free crop environment is crucial for both improving production and revenue and ensuring the crop's security. Pendimethalin, a herbicide from the aniline group, is generally used as a pre-emergence to manage the early weed flush in most pulses including common bean. It suppresses the first flush of annual grasses and some of the broad-leaf weeds but found to be ineffective against sedges and also against grasses and broad-leaf weeds 20 days after application (Singh 2011). Therefore, using pendimethalin alone is insufficient to curb distinct category of weed flora in common bean. Usually pendimethalin 1.0 kg/ha followed by a manual weeding at 25-30 DAS are recommended (Singh 2011, Akter *et al.* 2013) in most of the growing regions. Manual weeding is efficient in controlling weeds, but owing to intermittent rains during *Kharif* season, it is not feasible in addition to time consuming and labour expensive. So, there is an urgent need to go for evaluation of broad spectrum post-emergent herbicide for common bean grown during *Kharif* season of Kashmir valley to optimize production and weed control. Application of post-emergence herbicides controls late emerging weeds and obtain higher yields against timely weed clearance (Pratap Singh *et al.* 2016).

The imidazolinone group of herbicides offers a broad spectrum of weed control with low consumption rates and low toxicity to humans (Tan *et al*. 2005). Imazethapyr, a herbicide from the imidazolinone family is applied as pre-emergence and soon after emergence to control annual grasses, broad-leaf weeds and perennial sedges in numerous pulse crops (Rathod *et al.* 2017, Kumar *et al.* 2020). The selectivity of imazethapyr to control post-emergent weeds in pulses was also reported by Rathod *et al.* (2017). In these conditions, pre- and post-emergent herbicides administered in succession will successfully suppress the weeds. The study was carried out to determine the bio-efficacy of imazethapyr as post-emergence with an objective of optimizing dose of imazethapyr for effective and economically control of weeds and higher seed yield in common bean.

MATERIAL AND METHODS

A research trial was carried out at Agronomic Research Farm, of the Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, India during *Kharif* season of 2021 and 2022. The soil of the research trial had a silty-clay loam texture with pH of 6.8, 0.74% of soil organic carbon and 275.5 kg/ha, 17.5 kg/ha and 174.2 kg/ha of available nitrogen, phosphorus and potassium respectively. The research trial was laid out in randomized completely block design having eight treatments of weed management, replicated thrice. The treatments of herbicide were applied at different doses *i.e.*, imazethapyr 25 g/ha, imazethapyr 50 g/ha, imazethapyr 75 g/ha, imazethapyr100 g/ha, imazethapyr 125 g/ha. Treatments of two manual weeding (20 and 40 DAS), weed free (20, 40 and 60 DAS) and weedy check were also included. Pendimethalin 1000 g/ha was sprayed as pre-emergence (2 DAS) in all the treatments except weed free and weedy check. Imazethapyr was sprayed as post-emergence (25 DAS) as per treatment of doses using knapsack sprayer equipped with flat-fan nozzle. The seeds of common bean were sown in furrows at 30 × 10 cm apart using 60 kg seed per hectare at 25^{th} and 27^{th} standard meteorological weeks during crop growing period of 2021 and 2022, respectively. The mean weekly maximum and minimum temperature was 32.56 ^{0}C and 11.74 ^{0}C, respectively in 2021, while 32.16 ^{0}C and 4.53 ^{0}C in 2022, respectively. The total rainfalls were 157.8 mm and 295.2 mm during 2021 ND 2022, respectively. The soil moisture at the time of sowing was sufficient for germination and emergence. At the time of sowing, uniform doses of 30, 50 and 30 kg N, P and K, respectively were applied. The data on weed density and weed biomass at 40 and 60 DAS during both the years were recorded by using quadrant (25 × 25 cm) in all the treatments. Five randomly plants from each experimental plot were chosen to record observations on plant height, leaf area index, and dry matter accumulation at 40 and 60 DAS in both years. While observations on grain yield and yield attributing parameters, *viz*. number of pod/plant, seed/pod, seed index were recorded at harvest.

Following indices of weed control performance were recorded:

1. Weed control efficiency (WCE) reflects per cent reduction in weed density by a treatment (Nath *et al.* 2016).

$$WCE (\%) = [(WD_C – WD_T)*100] / WD_C.$$

Where, WD_C and WD_T are, respectively, the weed densities in the control and treated plots.

2. Weed control index (WCI) reflects per cent reduction in weed dry weight by a treatment (Nath *et al.* 2016).

$$WCI (\%) = [(WM_C – WM_T)*100] / WM_C.$$

Where, WM_C and WM_T are the corresponding dry weights of weeds in the control and treated plots.

3. Weed index (WI) is a measure of the efficacy of particular treatment in terms of yield output when compared with weed free treatment. It reflects per cent yield loss. (Asres and Das 2011).

WI (%) = $(Y_F - Y_T) / Y_F$

Where, Y_F and Y_T, respectively, stand for yields in weed-free and treated plots.

With the help of the minimum support price and the current market price of the products, the economics of treatment was computed. The B: C ratio, which is the ratio of net returns to total cost of cultivation, was determined to evaluate the treatments' economic viability. Prior to statistical analysis, the density and biomass of weed were subjected to square root transformation using ($\sqrt{x+0.5}$). The data were subjected to analysis of variance and significant differences among treatments were tested by calculating CD at 5% level of significance differences evaluated by using one-way ANOVA (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Weed density

Weed flora in research trial consisted of grasses namely *Cynodon dactylon*, *Digitaria sanguinalis*, *Sorghum halepense*; sedges namely *Cyperus rotundus* and Broad-leaf weeds namely *Convolvulus arvensis*, *Euphorbia* spp., *Digera arvensis*, *Portulaca oleracea*, *Ipomoea* spp. *Sorghum halepense*, *Cyperus rotundus*, *Convolvulus arvensis* and *Digera arvensis* dominated in the weedy check plots of common bean. The weed density was significantly lower in the weed free plot at 40 and 60 DAS during 2021 and 2022. In 2021, imazethapyr 0.075 to 125 g/ha was at par at 40 and 60 DAS. However, two manual weeding (20 and 40 DAS) was significantly superior than the herbicide imazethapyr 75 to 125 g/ha. In 2022, the doses of imazethapyr 75 to 125 g/ha at 40 DAS were at par to weed free plots and significantly superior to two manual weeding. At 60 DAS, imazethapyr 100 and 125 g/ha were at par to weed free plots. The remarkable reduction in weed population might be due to increasing the doses of herbicide imazethapyr. Similar findings were also reported by Raj *et al.* (2010) and Chaudhary *et al.* (2016). *Cyperus rotundus* had the highest weed density, followed by *Digitaria* spp. and *Convolvulus* spp., while imazethapyr 75 to 125 g/ha significantly decreased the weed density of all the major weeds (**Table 1**).

Weed biomass

All the herbicide treatments proved very effective against weeds. The minimum dry weight of weeds was recorded in weed-free treatment which was significantly lower than other treatments at 40 DAS during both years. Among different herbicide treatments at 40 DAS during both years, lowest weed dry weight was recorded with imazethapyr 125 g/ha however, it was at par with imazethapyr 100 and 75 g/ha. At 60 DAS, minimum dry weight of weed was observed in weed free treatment which was at par with imazethapyr 125, and 100 g/ha during both years. Imazethapyr 75 g/ha were also at par to 100 and 125 g/ha. Similar findings were also reported by Meena *et al.* (2011) and Ram and Singh (2011). Kumar *et al.* (2016) reported that grasses, broad-leaf weeds and *Cyperus* spp. were controlled effectively at 100 g/ha of imazethapyr (**Table 1**).

Weed control performance

In 2021, the WCE was maximum with imazethapyr 125 g/ha followed by the dose of 100 and 75 g/ha at 40 DAS. At 60 DAS, the WCE was maximum with 100 to 125 g/ha followed by75 g/ha. In 2022, the doses of imazethapyr 75 to 125 g/ha registered above 90% close to weed free plot at 40 DAS. At 60 DAS, the doses of imazethapyr 100 to 125 g/ha registered more than 85% of weed control efficiency. Weed control index (WCI) was found highest with imazethapyr 125 g/ha followed by doses of 100 and 75 g/ha at 40 and 60 DAS during both

Table 1. Effect of imazethapyr as post-emergent herbicide on weed density and weed biomass in common bean

Treatment	Weed density (no./m²)*				Weed biomass (g/m²)*			
	40 DAS		60 DAS		40 DAS		60 DAS	
	2021	2022	2021	2022	2021	2021	2021	2022
Imazethapyr 25 g/ha	6.41(40.7)	6.12(37.3)	7.60(57.3)	8.63(74.7)	2.97(8.3)	2.71(6.9)	16.18(261.5)	16.05(257.3)
Imazethapyr 50 g/ha	5.93(34.7)	5.68(32.0)	7.24(52.0)	8.27(69.3)	2.36(5.1)	2.35(5.0)	11.61(134.6)	10.49(110.0)
Imazethapyr 75 g/ha	5.11(25.7)	4.65(21.3)	5.68(32.0)	7.68(58.7)	2.30 (4.8)	2.24(4.5)	8.03(64.0)	7.95(63.0)
Imazethapyr 100 g/ha	5.10(25.7)	4.63(21.3)	5.69(32.0)	6.90(48.0)	2.20(4.3)	2.17(4.2)	7.23 (52.3)	7.17(51.0)
Imazethapyr 125 g/ha	4.84(23.0)	4.61(21.3)	5.69(32.0)	6.90(48.0)	2.16(4.1)	2.15(4.1)	7.02(49.1)	6.91(48.3)
Two manual weeding (20 and 40 DAS)	4.88(23.3)	5.70(32.0)	4.66(21.7)	7.32(53.3)	2.98(8.4)	2.72(6.9)	13.87(192.0)	11.78(138.7)
Weed free (20, 40 and 60 DAS)	3.97(15.3)	4.06(16.0)	3.72(13.7)	5.58(32.0)	1.73(2.5)	1.66(2.3)	6.28(39.8)	6.14 (38.0)
Weedy check	9.68(93.3)	15.5(240.0)	9.99(99.3)	18.19(330.7)	5.40(28.7)	5.15(26.0)	21.73(472.0)	19.53(381.0)
LSD (p=0.05)	0.65	0.91	0.75	1.65		0.19 0.31	1.30	1.38

Note: * values presented in parentheses were original and are subjected to square root transformation.

years. Treatments with the herbicide imazethapyr 75 to 125 g/ha efficiently suppress the weeds. The lower value of WI was recorded with imazethapyr 125 g/ha followed by imazethapyr 100 and 75 g/ha. Similar findings were also reported by Singh (2011) (**Table 2**)

Growth parameters

The plant height was significantly taller with weed free treatment during both years at 40 and 60 DAS than weedy check treatment. The plant height was at par with all the doses of imazethapyr at 40 and 60 DAS during 2021 but during 2022 at 40 DAS significantly taller plant were observed with imazethapyr 125 and 100 g/ha than the doses of 25, 50 and 75 g/ha. All the doses of imazethapyr were at par at 60 DAS. It may be due to reduction in weed competitiveness with the crop which ultimately favoured better environment for growth and development of crop. Singh *et al.* (2014 a.) reported similar results. These outcomes are very close to those of Chattha *et al*. (2009) and Raman and Krishnamorthy (2005).

Leaf area index was significantly maximum in weed free treatment during 2021 at 40 DAS, which were at par with imazethapyr 100 g/ha and two manual weeding and at 60 DAS, LAI was maximum in weed free plot which were at par with two manual weeding followed by imazethapyr 125 g/ha.

Weed free treatment recorded significantly highest leaf area index during 2022 at 40 DAS, which was at par with doses of imazethapyr 100 and 125 g/ ha and two manual weeding, but at 60 DAS it was at par with doses of imazethapyr 75 to 125 g/ha and two manual weeding. Dry matter accumulation was significantly maximum in weed free plot during 2021 at 40 DAS, which was at par with doses of imazethapyr 75 to 125 g/ha and two manual weeding at 60 DAS. It was at par with imazethapyr 100 and 125 g/ha. During 2022, highest dry-matter accumulation was observed in weed free treatment, which were at par with remaining herbicidal treatments at 40 and 60 DAS (**Table 3**).

Yield attributing characters

The use of herbicides in respective treatments over weed control throughout both years considerably boosted the yield features of common bean, including number of pods per plant, number of seeds per pod, and seed index. The weed-free treatment recorded significantly maximum number of yield attributes in terms of pods per plant during 2021 and seeds per pod during both years. Amongst the post-emergent herbicide applied treatments; maximum number of yield attributes were observed with imazethapyr 125 g/ha, which were at par with rest of herbicide applied treatments. Seed index is also observed maximum in weed free treatment which

Table 2. Effect of imazethapyr as post-emergent herbicide on weed control performance in common bean

Treatment	Weed control efficiency (%)				Weed control index (%)				Weed index (%)	
	40 DAS		60 DAS		40 DAS		60 DAS			
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Imazethapyr 25 g/ha	55.88	84.54	42.26	77.27	70.90	73.38	44.45	32.48	32.64	23.78
Imazethapyr 50 g/ha	62.32	86.74	47.67	78.94	82.16	80.76	71.31	71.13	22.56	16.61
Imazethapyr 75 g/ha	72.22	91.14	67.78	82.27	83.24	82.56	86.45	83.53	14.95	10.49
Imazethapyr 100 g/ha	72.58	91.21	67.82	85.30	84.85	83.78	88.77	86.58	12.54	8.33
Imazethapyr 125 g/ha	75.04	91.09	67.82	85.30	85.52	84.19	89.61	87.20	11.64	8.28
Two manual weeding (20 and 40 DAS)	74.89	86.63	78.20	83.94	70.65	73.36	59.04	63.69	19.53	11.20
Weed free (20, 40 and 60 DAS)	83.16	93.31	86.27	90.45	91.30	91.15	91.66	90.11	0.00	0.00
Weedy check	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	67.91	72.11

Table 3. Effect of imazethapyr as post-emergent herbicide on growth parameters in common bean

Treatment	Plant height (cm)				Leaf area index				Dry-matter accumulation (g/plant)			
	40 DAS		60 DAS		40 DAS		60 DAS		40 DAS		60 DAS	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Imazethapyr 25 g/ha	31.8	26.9	52.9	46.0	1.31	1.03	4.61	5.10	4.89	3.23	11.11	11.04
Imazethapyr 50 g/ha	33.5	27.5	53.1	46.9	1.37	1.15	4.65	5.17	5.06	3.34	12.31	11.56
Imazethapyr 75 g/ha	33.6	27.6	53.8	47.0	1.48	1.25	4.67	5.24	5.36	3.89	13.32	12.46
Imazethapyr 100 g/ha	34.0	28.4	54.3	47.2	1.49	1.59	4.69	5.27	5.37	3.72	13.40	12.91
Imazethapyr 125 g/ha	36.7	30.5	55.4	49.3	1.49	1.60	4.82	5.29	5.38	3.67	13.52	12.45
Two manual weeding (20 and 40 DAS)	34.0	28.0	53.9	47.4	1.58	1.56	5.04	5.54	5.38	3.81	12.67	12.75
Weed free (20, 40 and 60 DAS)	37.6	28.8	58.3	51.9	1.68	1.66	5.07	5.84	5.73	3.84	14.36	12.79
Weedy check	25.0	22.9	38.8	41.4	1.19	0.98	3.21	3.83	4.03	2.14	8.55	6.08
LSD (p=0.05)	5.1	2.5	6.8	3.7	0.19	0.30	0.12	0.66	0.51	0.76	1.02	2.09

Table. 4. Effect of imazethapyr as post-emergent herbicide on yield attributes in common bean

Treatment	No. pods/plant		No. seeds/pod		Seed index	
	2021	2022	2021	2022	2021	2022
Imazethapyr 25 g/ha	9.75	9.40	4.67	4.378	39.53	40.13
Imazethapyr 50 g/ha	9.91	9.47	4.84	4.60	40.94	40.97
Imazethapyr 75 g/ha	9.95	9.53	4.86	4.73	41.86	42.47
Imazethapyr 100 g/ha	9.97	9.57	4.88	4.77	42.40	43.80
Imazethapyr 125 g/ha	9.99	9.60	4.95	4.83	42.86	43.87
2 Manual Weeding (20 and 40 DAS)	9.96	9.57	4.91	4.82	44.47	47.12
Weed free (20, 40 and 60 DAS)	10.67	10.10	5.34	5.30	45.00	47.87
Weedy check	7.30	7.20	4.32	3.97	35.40	30.57
LSD (p=0.05)	0.31	1.14	0.38	0.31	5.28	4.25

Table 5. Effect of imazethapyr as post-emergent herbicide on yield and economics in common-bean

Treatment	Seed yield (t/ha)		Stover yield (t/ha)		Harvest index (%)		B: C ratio	
	2021	2022	2021	2022	2021	2022	2021	2022
Imazethapyr 25 g/ha	1.44	1.61	3.09	3.54	31.67	31.25	1.79	2.11
Imazethapyr 50 g/ha	1.65	1.70	3.35	3.56	33.00	32.28	2.18	2.26
Imazethapyr 75 g/ha	1.81	1.90	3.57	3.80	33.67	33.46	2.45	2.62
Imazethapyr 100 g/ha	1.87	1.95	3.62	3.84	34.00	33.71	2.52	2.66
Imazethapyr 125 g/ha	1.89	1.97	3.61	3.99	34.33	32.77	2.52	2.66
Two manual weeding (20 and 40 DAS)	1.72	1.82	3.47	3.63	33.07	32.37	1.40	1.54
Weed free (20, 40 and 60 DAS)	2.14	2.36	3.97	4.26	35.00	35.63	1.67	1.94
Weedy check	0.69	0.67	2.53	2.52	21.33	21.00	0.48	0.43
LSD (p=0.05)	0.19	0.32	0.15	0.29	2.78	3.39	-	-

were at par with doses of 100 and 125 g/ha and two manual weeding. This increment in yield attributes was attributed to higher growth parameter, enhanced root development and nodule formation which might have favoured for significant development of yield attributes. Awan *et al*. (2009) and Madukwe *et al*. (2012) showed similar results (**Table 4**).

Yield

Seed yield and stover yield were varied significantly with the different herbicide treatments. Seed yield was significantly highest with weed free plots during both years. Among the weed management practices, herbicidal imazethapyr with doses of 75 to 125 g/ha were at par but significantly lower than weed free in 2021. However, in 2022, these herbicide treatments were also at par to 2 manual weeding (20 and 40 DAS). Among all the treatments, the weedy check treatment had the noticeably lowest seed output. Stover yield followed the same trend. It can be clearly expressed that higher weed infestation was responsible for reducing seed yield of common bean which faced tremendous competition with vigorous weed infestation. The same observations were made by Vollmann *et al*. (2010). Akter *et al.* (2013) also reported that effective weed management techniques increased yield. Imazethapyr at lower doses (25 to 50 g/ha) was ineffective in controlling weeds and improving the productivity of common bean. However, imazethapyr 75 to 125 g/ha was found to be efficient for managing sedges, grasses and BLW's as well as in improving yield of common bean than at lower doses due to its high WCE. Harvest index was found significantly highest in weed free treatment than weedy check and imazethapyr 25 g/ha. Rest of the treatments were found statistically at par with weed free (**Table 5**).

Economics

Imazethapyr was found to have the highest B: C ratio at 125 and 100 g/ha, followed by 75 g/ha. Imazethapyr treatments at 125, 100, and 75 g/ha had the highest net return and B: C ratio, which was primarily the result of superior weed control at low cost and increased yield. Singh (2011) and Kumar *et al.* (2010) both noted similarities. (**Table 5**).

Conclusion

Under rainfed temperate conditions in Kashmir, post-emergence application of imazethapyr 100 g/ha at 25 days after sowing was found to be more economically viable than other treatments for controlling weeds.

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