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Impact of imazethapyr and its ready-mix combination with imazamox to control weeds in blackgram

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ABSTRACT

The bio-efficiency of imazethapyr and its combination with imazamox or pendimethalin in comparison to hand weeding against weeds, their effect on growth, yield and phytotoxicity on black gram and residual effect on succeeding mustard crop were studied during 2014-15 and 2015-16. Hand weeding twice resulted in the highest overall weed control efficiency followed by pre-emergence application of imazethapyr + imazamox 80 g/ha, pre-emergence imazethapyr + imazamox 70 g/ha and pre-emergence imazethapyr + pendimethalin 1000 g/ha. Hand weeding twice and pre-emergence imazethapyr + pendimethalin 1000 g/ha were comparable to pre-emergence imazethapyr + imazamox 70 g/ha for seed yield. With every increase of one weed per square metre, the blackgram seed yield was reduced by 2.1 kg/ha. Similarly with every g/m^2 increase in weed weight, the blackgram yield was subjected to fall by 5.1 kg/ha. The economic threshold levels *i.e.* No/m^2 and g/m^2 with the weed management practices studied varied between 8.3 – 42.0/m^2 and 3.5-17.6 g/m^2. Weed persistence index (WPI) was lowest and crop resistance index (CRI) was highest in the hand weeding twice treatment. Post-emergence application of imazethapyr 70 and 80 g/ha and imazethapyr + imazamox 70 and 80 g/ha caused mild toxicity during 2014 and had therefore lower crop resistance index. Efficiency index was the highest under hand weeding followed by pre-emergence application of imazethapyr + imazamox 80 g/ha, pre-emergence imazethapyr + pendimethalin 1000 g/ha and pre-emergence imazethapyr 80 g/ha. Weed index indicated 55.4% reduction in yield of blackgram due to weeds. Pre-emergence imazethapyr 80 g/ha, imazethapyr + imazamox 80 g/ha, imazethapyr 70 g/ha and imazethapyr + pendimethalin 1000 g/ha had higher overall impact index than hand weeding due to lower cost. Residual effect/phytotoxicity was not observed on succeeding crop of mustard during 2014 and 2015 as well.

INTRODUCTION

Black gram is an important *Kharif* season pulse of Himachal Pradesh, which is grown in an area of 9.4 thousand ha with production of 12 thousand tonnes and productivity of 1286 kg/ha (https://iipr.icar.gov.in/pdf/6.4_270615.pdf). The yield of blackgram in the state is higher than the national average of 555 kg/ha, but below the potential (1600 kg/ha) of top varieties in the state. Among the various constraints to production, weeds so far are the major hindrance in exploiting the full production potential of the crop. Weeds are important biological constraints to production in short statured crops. Due to high rainfall, weeds grow luxuriantly and pose a serious threat to short statured *Kharif* blackgram. Up to 45 per cent yield losses in blackgram due to weeds have been reported (Yadav *et al.* 2015). This crop receives low priority in Himachal Pradesh as it is grown on poor and marginal soils. This crop offers poor competition to weed in early stages of growth especially between 3 and 6 weeks after sowing (Choudhary *et al.* 2012) and therefore, weed control early in the season is essential to ensure proper crop growth and productivity. If the weeding is delayed beyond critical period, the yield losses are reported to be 60-90%.

In Himachal Pradesh, pendimethalin is recommended for the control of weeds in blackgram as pre-emergence, but due to frequent rains, different flushes of weeds come up at later stages, which need

to be controlled to achieve potential productivity. In order to improve weed control efficacy with minimum application costs, the use of formulated or tank mix herbicide mixtures (Chandrakar *et al.* 2014, Patel *et al.* 2014) as well as integration of herbicides with manual or mechanical means (Choudhary *et al.* 2012, Kumar *et al.* 2007 and 2013) seems better option. The present investigation was carried out to assess the economic impacts of new herbicide mixtures in blackgram.

MATERIALS AND METHODS

The field experiment with 12 treatments, *viz.* imazethapyr 70 and 80 g/ha (pre-emergence and at 3-4 leaf stage *i.e.* 20 DAS), ready-mix imazethapyr+ imazamox 70 and 80 g/ha (pre-emergence and at 3-4 leaf stage *i.e.* 20 DAS), pendimethalin 1000 g/ha (pre-emergence), ready-mix imazethapyr + pendimethalin 1000 g/ha (pre-emergence), hoeing (20 and 40 DAS)and weedycheck was conducted during 2014 and 2015. Blackgram variety '*UG-218*' was sown on July 3, 2014 and July 10, 2015 with a spacing of 30 x 10 cm and harvested on October 1, 2014 and October 5, 2015. The herbicide treatments were applied with knapsack power sprayer using 600 litres of water per hectare. The crop was fertilized with 20 kg N, 40 kg P_2O_5 and 20 kg K_2O per hectare. Nutrients were applied through IFFCO 12:32:16 and urea (46%) at the time of sowing. Observations on weed count and dry weight at 40, 60 DAS and at harvest were recorded by using a quadrate measuring 25 x 25 cm at two randomly selected spots in each plot and converted into one square metre area.

Without disturbing the layout, the residual effect of treatments on succeeding brown sarson (*Brassica rapa*) crop was studied. The sarson variety '*BSH 1*' was sown immediately after harvest of blackgram crop.

The economic threshold/economic injury level (*i.e.* the weed density at which the cost of treatment equals the economic benefit obtained from that treatment), was calculated as suggested by Stone and Pedigo (1972) as well as Uygur & Mennan (1995).

Economic threshold = Gain threshold/ Regression coefficient (Stone and Pedigo, 1972)

Where, gain threshold = Cost of weed control (Hc+Ac)/Price of produce (Gp), and regression coefficient (b) is the outcome of simple linear relationship between yield (Y) and weed density/ biomass (x), Y = a + bx; Hc, herbicide cost; Ac, application cost of herbicide; Gp, grain price.

$Y= [\{(100/He*Hc)+A_C\}/(Gp*Yg)]*100$ (Uygur & Mennan, 1995)

Where, Y is percent yield losses at a different weed density; He, herbicide efficiency; and Yg, yield of weed free.

The different impact indices were worked out after Walia (2003) and Rana and Kumar (2014) as follow:

$$\text{Weed control efficiency (WCE)} = \frac{\text{Weed count in control (unweeded)} - \text{Weed count in a treatment}}{\text{Weed count in control (unweeded)}}$$

$$\text{Weed control index (WCI)} = \frac{\text{Weed weight in control (unweeded)} - \text{Weed weight in a treatment}}{\text{Weed weight in control (unweeded)}}$$

$$\text{Weed index} = \frac{\text{Yield from weed free} - \text{Yield of particular treatment}}{\text{Yield of weed free}} x\ 100$$

Weed persistence index (WPI)

$$WPI = \frac{\text{Weed weight in treated plot}}{\text{Weed weight in control plot}} x \frac{\text{Weed count in control plot}}{\text{Weed count in treated plot}}$$

Crop resistance index (CRI)

$$CRI = \frac{\text{Crop weight in treated plot}}{\text{Crop weight in control plot}} x \frac{\text{Weed weight in control plot}}{\text{Weed weight in treated plot}}$$

Weed management index (WMI)

$$WMI = \frac{\text{Per cent yield over control}}{\text{Per cent control of the pest}}$$

Agronomic management index (AMI)

$$AMI = \frac{\text{Per cent yield over control} - \text{Per cent control of the pest}}{\text{Per cent control of the pest (weed)}}$$

Integrated Weed Management index (IWMI)

$$IPMI = \frac{PMI + AMI}{2}$$

Efficiency index (EI)

$$EI = \frac{\frac{\text{Yield of treatment} - \text{Yield of control}}{\text{Yield of control}} x\ 100}{\frac{\text{Weed weight in treatment}}{\text{Weed weight in control}} x\ 100}$$

$$\text{Weed intensity}(\%) = \frac{\text{Weed population}}{\text{Weed + crop population}} x\ 100$$

$$\text{Crop intensity} = 100 - \text{weed intensity}$$

'Overall impact index' was determined, by calculating (i) the 'unit value' where the value under a particular treatment of a parameter was divided by the respective arithmetic mean of treatments for that parameter as given below:

$$U_{ij} = \frac{V_{ij}}{AM_j}$$

Where 'Uij' is the unit value for 'ith' treatment corresponding to 'jth' parameter, 'Vij' is the actual measured value for 'ith' treatment of 'jth' parameter and 'AMj' is the arithmetic mean value for jth parameter.

(ii) the overall impact index was calculated as an average of unit values (Uij) of all the parameters under consideration:

$$OI_i = \frac{1}{N}\sum_{i=1}^{N} U_{ij}$$

where 'OIi' is the overall impact index for 'ith' treatment and 'N' is the number of parameters considered in deriving overall impact index.

The data obtained were subjected to statistical analysis by analysis of variance (ANOVA) for the randomized block design to test the significance of the overall differences among the treatments by the "F" test and conclusion was drawn at 5% probability level.

RESULTS AND DISCUSSIONS

Effect on weeds

During 2014, the experimental field was infested with *Digitaria sanguinalis, Cyperus rotundus*, *Dactyloctenium aegypticum, Echinochloa colona*, *Commelina benghalensis, Eleusine indica* and *Setaria glauca* and in 2015, *Echinochloa* sp., *Dactyloctenium aegypticum* and *Cyperus iria* were dominating weed species. Weed control treatments brought about significant variation in the count and dry weight of weeds at all the stages of observation (**Table 1**). In general pre-emergence application of herbicides was better than their post-emergence application for controlling weeds. Similarly ready mix herbicide combinations had an edge over sole application of herbicides. Pre-emergence application of ready-mix imazethapyr + imazamox 80 g/ha remaining at par with pre-emergence imazethapyr + imazamox 70 g/ha resulted in significantly lower count and dry weight of weeds among the herbicidal treatments in 2015. While in 2014, the application of imazethapyr applied as pre-emergence at 80 g/ha remaining at par with imazethapyr 70 g/ha pre-emergence, imazethapyr 70 and 80 g/ha applied as post-emergence, imazethapyr + imazamox 70 and 80 g/ha applied as post-emergence and imazethapyr + pendimethalin pre-mix as pre-emergence had significantly lower weed count and dry weight. Similar was the trend with respect to total weed count at harvest of the blackgram crop. Chandrakar *et al.* (2014) also reported effectiveness of early post-emergence application (15-20 DAS) of imazethapyr at 40 g/ha and pendimethalin + imazethapyr (ready-mix) at 1.0 kg/ha as pre-emergence against weeds in black gram. Studies conducted by Patel *et al.* (2014) are also in conformity with above results.

Hand weeding twice resulted in the highest overall weed control efficiency followed by pre-emergence application of imazethapyr+imazamox 80g/ha, imazethapyr+imazamox 70 g/ha and imazethapyr + pendimethalin 1000 g/ha (**Table 2**). Post-emergence herbicidal weed control in general was poor. Weed control efficiency was highest *i.e.* 92.5% and 99.2% in 2014 and 2015, respectively, under hand weeding (twice) treatment which was comparable to imazethapyr 80 g/ha pre-emergence during 2014 and imazethapyr + imazamox (pre-mix) 80 g/ha in 2015.

Effect on crop

No toxicity of herbicide was observed with pre-emergence application of imazethapyr 70 and 80 g/ha or imazethapyr + imazamox (pre-mix) or pendi-methalin. However, highest 18% phytotoxicity was observed with pre-mix imazethapyr + imazamox 80 g

Table 1. Effect of treatments on total weed count and total dry weight at different growth stages of blackgram

Treatment	Dose (g/ha)	Time of application (DAS)	Total weed count (no/m^2)				Total weed dry weight (g/m^2)			
			40 DAS	60 DAS	At harvest		40 DAS	60	At harvest	
			2014	2015	2014	2015	2014	2015	2014t	2015
Imazethapyr	70	Pre-	1.97(2.9)	14.2(202.7)	3.53(11.5)	13.8(192)	2.38(4.7)	7.8(60.2)	2.87(7.25)	8.7(75.6)
Imazethapyr	80	Pre-	1.82(2.3)	12.8(165.3)	3.56(11.7)	10.6(112)	1.73(2.0)	6.9(47.4)	2.79(6.8)	7.2(51.7)
Imazethapyr	70	20	2.89(7.3)	17.3(298.7)	3.71(12.8)	15.3(234.7)	2.28(4.2)	10.1(101.5)	2.26(4.1)	11.1(122.6)
Imazethapyr	80	20	2.64(6.0)	16.0(256)	3.73(12.9)	14.2(202.7)	1.92(2.7)	9.4(88.9)	1.84(2.4)	10.3(107)
Imazethapyr + imazamox	70	Pre-	2.61(5.81)	10.3(106.7)	2.43(4.9)	8.6(74.7)	2.26(4.1)	5.4(29)	2.0(3.0)	6.0(35.8)
Imazethapyr + imazamox	80	Pre-	2.57(5.6)	7.6(58.7)	2.41(4.8)	6.8(48)	1.92(2.7)	4.4(19)	1.55(1.4)	4.8(23.3)
Imazethapyr + imazamox	70	20	9.11(82.0)	14.6(213.3)	5.07(24.7)	13.1(170.7)	2.96(7.8)	8.6(73.2)	2.30(4.3)	9.6(92.7)
Imazethapyr + imazamox	80	20	7.03(48.4)	13.7(186.7)	3.51(11.3)	11.8(138.7)	2.36(4.6)	8.2(66.8)	2.24(4.03)	8.6(73.6)
Pendimethalin	1000	Pre-	3.87(14.0)	14.9(224)	3.11(8.7)	13.7(186.7)	2.14(3.6)	8.4(70.1)	2.98(7.9)	9.3(85.9)
Imazethapyr + pendimethalin	1000	Pre-	2.51(5.3)	11.3(128)	2.41(4.8)	9.5(90.7)	1.89(2.6)	5.9(34.8)	2.39*(4.7)	6.6(44)
Hand weeding	-	20 & 40	4.05(15.4)	2.9(10.7)	3.62(12.1)	4.1(16)	1.48(1.2)	1.5(1.9)	2.37 (4.6)	2.3(4.9)
Weedy check	-	-	10.5(110)	25.7(661.3)	9.27(85.0)	22.8(517)	4.12(16.0)	15.7(244.3)	4.44(18.7)	17.1(293.6)
LSD (p=0.05)			1.59	1.8	1.08	1.8	0.57	0.8	1.22	1.3

Pre- Pre-emergence; Values given in the parentheses are the original means

applied on 20 DAS during 2014. However, at harvest of crop no phytotoxicity was observed.

Weed control treatments gave significant variation in plant height and yield of blackgram (**Table 3**). The superior control of weeds was reflected in growth and yield of blackgram. In 2014, significantly the highest seed yield of blackgram was recorded with pre-emergence application of imazethapyr 80 g/ha which remained at par with the pre-emergence imazethapyr 70 g/ha and imazethapyr + pendimethalin 1000 g/ha. Sasikala *et al.* (2014) found that imazethapyr applied at 100 g/ha on 15 DAS provided excellent control of grasses and broad-leaf weeds in blackgram and thereby higher yield. Aggarwal *et al.* (2014) found imazethapyr at 75 and 100 g/ha on 15 DAS effective against weeds in blackgram and gave its higher yield. The lowest seed yield was recorded in weedy check. In 2015, pre-emergence application of imazethapyr + imazamox 80 g/ha remaining at par with pre-emergence application of imazethapyr + imazamox 70 g/ha resulted in significantly higher seed yield of blackgram over other weed control treatments. Tiwari *et al.* (2006) obtained significantly higher soybean seed yield with application of Odyssey (imazethapyr + imazamox) at 2 L/ha. Hand weeding twice and pre-emergence application of

Table 2. Effect of treatments on weed control efficiency (%) and crop phytotoxicity (%) at different growth stages of blackgram

Treatment	Dose (g/ha)	Time of application (DAS)	Weed control efficiency (%)				Crop phytotoxicity (%) in black gram			
			40 DAS	60DAS	At harvest		40 DAS	40 DAS	Harvest	
			2014	2015	2014	2015	2014	2015	2014	2015
Imazethapyr	70	Pre-	70.6	75.4	61.2	71.9	0.0	0.0	0.0	0.0
Imazethapyr	80	Pre-	87.5	80.6	63.6	82.4	0.0	0.0	0.0	0.0
Imazethapyr	70	20	73.7	58.5	78.0	58.2	8.0	0.0	0.0	0.0
Imazethapyr	80	20	83.1	63.7	87.1	63.6	10.0	0.0	0.0	0.0
Imazethapyr + imazamox	70	Pre-	74.3	88.1	83.9	87.8	0.0	0.0	0.0	0.0
Imazethapyr + imazamox	80	Pre-	83.1	92.2	92.5	92.1	0.0	0.0	0.0	0.0
Imazethapyr + imazamox	70	20	51.0	70.1	77.0	68.4	10.0	0.0	0.0	0.0
Imazethapyr + imazamox	80	20	71.2	72.7	78.4	74.9	18.0	0.0	0.0	0.0
Pendimethalin	1000	Pre-	77.5	71.4	57.7	72.3	0.0	0.0	0.0	0.0
Imazethapyr + pendimethalin	1000	Pre-	83.8	85.8	74.8	85	0.0	0.0	0.0	0.0
Hoeing		20 & 40	92.5	99.2	75.4	98.3	0.0	0.0	0.0	0.0
Weedy check	-	-	-		-		-	-	-	-
LSD (p=0.05)	-		6.0	8.4	5.2	8.0	-	-	-	-

Table 3. Effect of different herbicide treatments on growth and yields of blacgram

Treatment	Dose (g/ha)	Time of application (DAS)	Plant height (cm)				Seed yield (kg/ha)	
			40 DAS	60 DAS	At harvest			
			2014	2015	2014	2015	2014	2015
Imazethapyr	70	Pre-	50.1	78.3	64.7	83.9	1100	1175
Imazethapyr	80	Pre-	46.9	84.9	66.3	89.0	1176	1270
Imazethapyr	70	20	42.3	64.9	70.3	67.1	807	762
Imazethapyr	80	20	40.2	68.7	71.2	72.1	869	952
Imazethapyr + imazamox	70	Pre-	51.3	89.0	65.9	92.8	701	1397
Imazethapyr + imazamox	80	Pre-	49.4	90.2	70.3	93.9	795	1492
Imazethapyr + imazamox	70	20	39.3	71.8	74.3	75.0	803	984
Imazethapyr + imazamox	80	20	40.2	75.3	82.3	78.5	612	1048
Pendimethalin	1000	Pre-	53.0	78.3	69.2	82.1	1000	1143
Imazethapyr + pendimethalin	1000	Pre-	48.7	87.1	73.3	90.4	1050	1302
Hand weeding		20 & 40	49.1	85.5	74.1	89.2	877	1333
Weedy check	-	-	49.2	60.8	60.3	63.9	510	476
LSD (p=0.05)			3.70	4.9	6.87	5.5	323	125

The linear relationship between count and dry weight (x) of weeds and yield (Y) of blackgram is given here as under;

Weed count

$Y = 1207 – 2.1x$ ($R^2 = 0.738$).....(1)

Weed dry weight

$Y = 1193 – 5.1x$ ($R^2 = 0.754$).....(2)

imazethapyr + pendimethalin at 1000g/ha were comparable to imazethapyr + imazamox 70 g/ha for seed yield of blackgram.

Equations 1 and 2 explain over 73.8 and 75.4% of the variation in blackgram seed yield due to count and dry weight of weeds, respectively. It further implies that with increase in one weed per square metre, the blackgram seed yield was expected to reduce by 2.1 kg/ha. Similarly with every g/m^2 increase in weed weight, the blackgram yield was subjected to fall by 5.1 kg/ha.

Economics

The highest gross returns, net returns and B: C ratio was recorded under imazethapyr + imazamox applied at 80 g/ha followed by imazethapyr applied at 80 g/ha (pre) (**Table 4**). Ram *et al.* (2013) also reported higher gross and net returns with imazethapyr 75 and 100 g/ha over 50 g/ha in soybean. Aggarwal *et al.* (2014) reported that in blackgram, the application of imazethapyr 100 g/ha at 15 DAS gave the highest gross and net returns, closely followed by imazethapyr at 100 g/ha applied at 25 DAS and hand weeding twice. Mansoori *et al.* (2015) found that imazethapyr + imazamox (pre-mix) at 50 g/ha as post-emergence (20 DAS) registered highest net returns and B: C ratio followed by imazethapyr + pendimethalin (pre-mix) at 1000 g/ha as pre-emergence in blackgram. The minimum gross retunes, net returns and B: C ratio was also recorded under weedy check.

The economic threshold levels of weeds at the current prices of treatment application and the crop production on the basis of weed infestation in blackgram are given in **Table 5**.

The economic threshold levels *i.e.* no./m^2 and g/ m^2 with the weed management practices studied varied between 8.3 – 42.0/m^2 and 3.5-17.6 g/m^2 when determined after Stone and Pedigo (1972) and 2.0 to 8.9 after Uygur and Mennan (1995). It is

Table 4. Effect of treatments on economics of blackgram cultivation

Treatment	Dose (g/ha)	Time of cultivation (DAS)	Gross returns (INR/ha)	Net returns (INR/ha)	B:C
Imazethapyr	70	Pre-	104516	82689	3.87
Imazethapyr	80	Pre-	112717	90794	4.19
Imazethapyr	70	20	69907	48080	2.45
Imazethapyr	80	20	84384	62461	3.00
Imazethapyr + imazamox	70	Pre-	110933	88816	3.87
Imazethapyr + imazamox	80	Pre-	119440	97184	4.18
Imazethapyr + imazamox	70	20	85201	63084	2.97
Imazethapyr + imazamox	80	20	85320	63064	2.87
Pendimethalin	1000	Pre-	100430	78519	3.66
Imazethapyr + pendimethalin	1000	Pre-	112445	90203	4.04
Hand weeding		20 & 40	110561	85745	3.38
Weedy check	-	-	44268	23279	1.45
LSD (p=0.05)			-		

Table 5. Economic threshold of weeds as influenced by different treatments

Treatment	Dose (g/ha)	Time of application (DAS)	NRwc	MBCR	Gt	Et		
						S&P		U&M
						Count	DW	
Imazethapyr	70	Pre-	59410	35.4	17.7	8.3	3.5	2.1
Imazethapyr	80	Pre-	67515	36.1	19.7	9.2	3.9	2.0
Imazethapyr	70	20	24801	14.8	17.7	8.3	3.5	3.1
Imazethapyr	80	20	39182	21.0	19.7	9.2	3.9	2.8
Imazethapyr + imazamox	70	Pre-	65537	29.0	23.8	11.1	4.7	2.6
Imazethapyr + imazamox	80	Pre-	73905	29.1	26.8	12.6	5.3	2.6
Imazethapyr + imazamox	70	20	39805	17.6	23.8	11.1	4.7	3.8
Imazethapyr + imazamox	80	20	39785	15.6	26.8	12.6	5.3	4.2
Pendimethalin	1000	Pre-	55240	29.9	19.4	9.1	3.8	2.5
Imazethapyr + pendimethalin	1000	Pre-	66924	26.7	26.4	12.4	5.2	2.7
Hand weeding		20 & 40	62466	7.3	89.5	42.0	17.6	8.9
Weedy check	-	-	-	-	-	-	-	-
LSD(p=0.05)			-	-	-		-	

NRwc, net returns due to weed control; MBCR marginal benefit cost ratio; Gt gain threshold; Et economic threshold; S&P Stone and Pedigo; U&M Uygur and Mennan

indicated that any increase in cost of weed control would lead to higher values of economic threshold, whereas an increase in price of crop produce would result in lowering of economic threshold. Hand weeding had higher values of economic threshold than the herbicidal treatments due to higher wages. Herbicidal treatments had lower application cost and thus had lower values of economic threshold.

Impact assessment

Weed persistence index (WPI) was lowest and crop resistance index (CRI) was highest in the hoeing and hand weeding treatment (**Table 6**).

Imazethapyr + imazamox 80 g/ha pre-emergence followed by imazethapyr + imazamox 70 g/ha pre and imezethapyr + pendimethalin 1000 g/ha followed the above treatment for crop resistance index. Imezethapyr 70 and 80 g/ha as post- and imazethapyr + imazamox 70 and 80 g/ha post-emergence caused mild toxicity during 2014 and had therefore lower crop resistance index than other treatments. Weed management index (WMI), Agronomic management index (AMI) and integrated weed management index (IWMI) were higher under pendimethalin 1000 g/ha and imazethapyr 70 and 80 g/ha pre-emergence than the other treatments. Efficiency index was highest under hoeing and hand weeding followed by imazethapyr + imazethapyr 80 g/ha pre, imazethapyr + pendimethalin 1000 g/ha pre and imazethapyr 80 g/ha pre. Weed index indicated 55.4% reduction in yield of blackgram due to uncontrolled growth of weeds. Weed intensity was maximum and crop intensity was minimum in weedy check. Hoeing followed by imazethapyr + imazamox 80 g/ha pre, imazethapyr + imazamox 70 g/ha pre- and imazethapyr + pendimethalin 1000 g/ha pre in that order followed the weedy check for weed and crop intensity. In the overall scenario, imazethapyr 80 g/ha

Table 6. Impact indices as influenced by weed control treatments

Treatment	Dose (g/ha)	Time of application (DAS)	WPI	CRI	WMI	AMI	IWMI	HEI	WI	Wi	Ci	Ii
Imazethapyr	70	Pre-	0.9	8.9	3.1	2.1	2.6	5.1	-2.9	77.3	22.7	1.12
Imazethapyr	80	Pre-	0.9	13.2	3.1	2.1	2.6	7.9	-10.7	70.1	29.9	1.22
Imazethapyr	70	20	1.0	3.9	2.7	1.7	2.2	1.5	29.0	81.6	18.4	0.78
Imazethapyr	80	20	1.0	5.3	2.8	1.8	2.3	2.4	17.6	79.7	20.3	0.92
Imazethapyr + imazamox	70	Pre-	0.9	16.9	2.4	1.4	1.9	9.0	5.1	62.0	38.0	1.13
Imazethapyr + imazamox	80	Pre-	1.0	28.6	2.5	1.5	2.0	16.3	-3.5	49.4	50.6	1.23
Imazethapyr + imazamox	70	20	0.9	5.8	2.6	1.6	2.1	2.6	19.1	79.5	20.5	0.90
Imazethapyr + imazamox	80	20	0.9	6.5	2.3	1.3	1.8	2.6	24.9	75.3	24.7	0.89
Pendimethalin	1000	Pre-	0.9	7.4	3.1	2.1	2.6	4.0	3.0	77.7	22.3	1.07
Imazethapyr + pendimethalin	1000	Pre-	0.9	15.9	2.8	1.8	2.3	9.2	-6.4	65.5	34.5	1.20
Hoeing		20 & 40	0.6	101.9	2.3	1.3	1.8	56.4	0.0	31.9	68.1	1.15
Weedy check	-	-	1.0	1.0	0.0	0.0	0.0	0.0	55.4	92.5	7.5	0.39
LSD (p=0.05)	-	-	-	-	-	-	-	-	-	-	-	-

WPI, Weed persistence index; CRI, Crop resistence index; WMI, Weed management index; AMI, Agronomic management index; IWMI, Integrated Weed management index; HEI, Herbicide efficiency index, WI, Weed index; Wi, Weed intensity; Ci, Crop intensity; Ii, overall impact index

Table 7. Residual effect of treatments applied in blackgram on succeeding crop of mustard

Treatment	Dose (g/ha)	Time of application (DAS)	Plant height (cm)	Crop phyto-toxicity (%)		Plants/m^2
				40DAS	At harvest	
Imazethapyr	70	Pre-	15.5	0.0	0.0	95.0
Imazethapyr	80	Pre-	15.8	0.0	0.0	98.7
Imazethapyr	70	20	15.2	0.0	0.0	94.7
Imazethapyr	80	20	15.7	0.0	0.0	96.7
Imazethapyr +imazamox*	70	Pre-	15.5	0.0	0.0	96.7
Imazethapyr +imazamox*	80	Pre-	15.3	0.0	0.0	96.7
Imazethapyr +imazamox*	70	20	15.4	0.0	0.0	95.7
Imazethapyr + imazamox*	80	20	15.7	0.0	0.0	96.3
Pendimethalin	1000	Pre-	15.0	0.0	0.0	96.7
Imazethapyr + pendimethalin*	1000	Pre-	15.9	0.0	0.0	97.0
Hand weeding	20 & 40 DAS	20 & 40	15.2	0.0	0.0	96.3
Weedy check	-	-	15.0	-	-	96.3
LSD (p=0.05)			0.50	-	-	0.17

*(Pre mix)

pre-emergence, imazethapyr + imazamox 80 g/ha pre-emergence, imazethapyr 80 g/ha pre-emergence and imazethapyr + pendimethalin 1000 g/ha pre-emergence were superior to hand weeding and hoeing as is indicated by the impact index because of lower cost of treatment than the later. Imazethapyr + imazethapyr 70 g/ha pre-emergence, imazethapyr 70 g/ha pre-emergence and pendimethalin 1000 g/ha pre-emergence also had higher values of overall impact index than the threshold value of 1. The other treatments had lower values of impact index than the threshold.

Residual studies

The impact of applied herbicide to blackgram crop was studied in succeeding mustard crop.There was no residual effect/phytotoxicity of herbicides on succeeding mustard crop (**Table 7**).

Thus in order of preference, imazethapyr + imazamox 80 g/ha pre, imazethapyr 80 g/ha pre, and imazethapyr + pendimethalin 1000 g/ha pre may be recommended for effective weed control, productivity and profitability in blackgram.

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