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Efficacy of Propaquizafop and Imazethapyr Mixture against Weeds in Soybean

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Weeds pose serious threat to soybean productivity, and chemical means are usually employed to combat weed menace in field crops. A field study was undertaken at Product Testing Unit, JNKVV, Jabalpur during *Kharif* season 2013 and 2014 to appraise the efficacy of propaquizafop and imazethapyr mixture against weeds and their influence on yield and economics of soybean. The experimental field was dominated by grasses (65.15%) followed by broad leaved weeds (23.51%) and sedges (11.34%). Post-emergence application of propaquizafop (75 g/ha) alone curbed only grassy weeds. However, its efficacy was improved when applied in combination with imazethapyr being higher under propaquizafop + imazethapyr mixture applied at 53 + 80 g/ha or higher rate (56 + 85 g/ha). Yield was superior under propaquizafop + imazethapyr mixture applied at 56 + 85 g/ha followed by 53 + 80 g/ha which were comparable to hand weeding twice at 20 and 40 DAS. Highest marginal benefit-cost ratio (MBCR) was found under propaquizafop + imazethapyr mixture at 53+80 g/ha followed by propaquizafop + imazethapyr mixture at 56+85 g/ha, propaquizafop (75 g/ha), propaquizafop + imazethapyr (50+75 g/ha), propaquizafop + imazethapyr (47+70 g/ha), imazethapyr (100 g/ha) and pendimethalin (1000 g/ha). Weed management index (WMI), agronomic management index (AMI) and integrated weed management index (IWMI) were highest under propaquizafop + imazethapyr mixture applied at 53+80 g/ha followed by propaquizafop + imazethapyr mixture applied at 56+85 g/ha and hand weeding twice at 20 & 40 DAS.

Introduction

Soybean has a good suppressing ability against weeds appearing late in the season. However, the crop suffers severely due to early competitive stress of grasses, sedges and broad-leaved weeds. The weeds cause yield reductions to the extent of 20 to 77% (Tiwari and Kurchania, 1990; Kurchania *et al.,* 2001) depending upon the nature, intensity and duration of infestation. The effective and economical weed control may not be possible through manual or mechanical means due to heavy and continuous rainfall in *kharif.*

In such circumstances, the only alternative that needs to be explored is the use of herbicides. Use of only single herbicides is also not as effective as some weeds escape to control due to their selectivity. Therefore, use of herbicide mixture may broaden the window of weed management by broad-spectrum weed control (Bineet *et al.,* 2001). Propaquizafop and imazethapyr have been found very effective post emergence herbicides for controlling weeds in soybean in different parts of the country. Propaquizafop

controls the grassy weeds and imazethapyr controls both grassy and broad-leaf weeds in soybean. Keeping the above facts in view, the present investigation was under taken to find out the effectiveness and suitable dose of propaquizafop and imazethapyr mixture for control of weeds and higher seed yield of soybean.

Materials and Methods

Site description

Field experiment was conducted at Product Testing Unit of Jawaharlal Nehru Krishi Vishwa Vidyalaya, located at Jabalpur, which comes under Kymore Plateau & Satpura Hills agroclimatic zone of Madhya Pradesh, India. The soil of the experimental site was clayey in texture (24.98 % sand, 19.32 % silt and 55.70 % clay).

The pH of saturated soil paste was 7.2 and total soluble salts were 0.32 dS m^{-1}. It was medium in organic carbon (0.62 %), available nitrogen (365 kg/ha) and phosphorus (16.34 kg/ha), but high in available potassium (327.14 kg/ha). This area receives a total annual rainfall of 1380 mm in 69 rainy days.

Experimental details

The experiment was laid out in randomized complete block design (RCBD) with three replications during *kharif* seasons of 2013 and 2014. It comprised of nine treatments viz. four doses of propaquizafop + imazethapyr mixture (47+70, 50+75, 53+80 and 56+85 g/ha), alone application of propaquizafop (75 g/ha) and imazethapyr (100 g/ha) as post-emergence at 15 days after sowing and pendimethalin (1000 g/ha) as pre-emergence at 2 days after sowing, hand weeding twice at 20 and 40 DAS including weedy check. The gross plot size adopted was (5m x 3.6m) 18 Sq meter. Soybean variety 'JK 97-52' was sown in second week of July and harvested in fourth week of October with recommended packages of practices.

Fertilizers were applied uniformly at 20, 60 and 20 kg N, P_2O_5 and K_2O/ha. Herbicides as per treatment were applied by manually operated knapsack sprayer fitted with flat fan nozzle using spray volume of 500 l/ha.

Data collection

Data on weed (density and dry weight) for each experimental unit was recorded from four randomly selected quadrats (50 × 50 cm) at 45 days after sowing. Weeds were counted and clipped above the ground surface, dried in an oven at 70ºC for 48 h and dry weight recorded.

Data on weed count and dry weights were used to compute different efficiency indices using the formulae of Misra and Misra (1997) and Devasenapathy *et al.,* (2008) as under:

Weed control efficiency

$$WCE\,(\%) = \frac{WDc-WDt}{WDc}\text{ x }100$$

Where,

WCE – Weed control efficiency (per cent);
WDc - Weed density (m^{-2}) in control plot;
WDt – Weed density (m^{-2}) in treated plot;

Weed control index

$$WCI\,(\%) = \frac{WBc-WBt}{WBc}\text{ x }100$$

Where,

WCE – Weed control efficiency (per cent);
WBc - Weed biomass (g.m^{-2}) in control plot;
WBt - Weed biomass (g.m^{-2}) in treated plot;

Weed index (WI)

Weed index represents the reduction in yield due to weeds in comparison with the weed-free plots. It can be calculated by the following equation:

$$WI\,(\%) = \frac{X-Y}{X} \times 100$$

Where, X = weight of seed yield (kg/ha) in treatment which has highest yield and Y = weight of seed yield (kg/ha) in treatment for which weed index is to be calculated.

Herbicide efficiency index (HEI)

This index indicates the potential of herbicides for killing weeds and their phytotoxicity on the crop, computed using the formula:

$$HEI = \frac{Yt - Yc/Yc}{(WBt/WBc) \times 100}$$

Yt = yield in the herbicide-treated plot

Yc = yield in the control plot

WBt = weed biomass in the herbicide-treated plot

WBc = weed biomass in the control plot

Weed persistence index (WPI)

This index indicates the resistance in weeds against the tested treatments and confirms the effectiveness of the selected herbicides, computed using the formula:

$$WPI = \frac{\text{Weed biomass of treated plot}}{\text{Weed biomass of control plot}} \times \frac{\text{Weed density of control plot}}{\text{Weed density of treated plot}}$$

Crop resistance index (CRI)

This indicates the relationship between a proportionate increase in crop biomass and a proportionate decrease in weed biomass in the treated plots, computed using the formula:

$$CRI = \frac{\text{Biomass of crop in treated plot}}{\text{Biomass of crop in control plot}} \times \frac{\text{Biomass of weed in control plot}}{\text{Biomass of weed in treated plot}}$$

Weed management index (WMI)

This index is the ratio of yield increase over the control because of weed management and percent control of weeds by the respective treatment, computed using the formula:

$$WMI = \frac{\text{Percent yield increase over control}}{\text{Percent control of weeds}}$$

Agronomic Management Index (AMI)

$$AMI = \frac{\text{Percent yield increase} - \text{Percent control of weeds}}{\text{Percent control of weeds}}$$

Integrated weed management index (IWMI)

$$IWMI = \frac{WMI + AMI}{2}$$

Number of pods/plant, number of seeds/plant and 1000 seed weight were recorded at harvest. Seed yield was recorded in each plot after harvest. The economics of treatment was computed with minimum support price or prevailing market rate of products.

Statistical analysis

All the data were subjected to statistical analyses by using the techniques of analysis of variance (ANOVA) as suggested by Panse and Sukhatme (1967). The data pertaining to weeds were transformed to square root scale of $\sqrt{X + 0.5}$ and analysed. Whenever significant difference existed, critical difference was constructed at five per cent probability level.

Results and Discussion

The experimental field was dominated by grasses (65.15%) followed by broad leaved weeds (23.51%) and sedges (11.34%). The dominant species in grassy weeds were *Echinochloa colona*, *Dinebra retroflexa* and *Cynadon dactylon*; whereas the dominant broad-leaved weed species were: *Alternanthera philoxeroides*, *Eclipt alba* and *Mollugo pentaphylla* and *Cyperus iria* was the only dominant sedge in the experimental field during both the years.

Postemergence application of propaquizafop (75 g/ha) did not curb the population of broad leaved weeds satisfactorily, but was markedly effective in controlling the grassy weeds. However, its efficacy was improved when applied in combination with imazethapyr from 47+70 to 56+85 g/ha. The results are in corroboration with the findings of Pradhan *et al.,* (2010) and Das (2011) who observed the similar response for propaquizafop. Among the mixed herbicidal treatments, the reduction in weed density and weed biomass was less when propaquizafop was applied with imazethapyr at lower dose (47+70g/ha) but the values of both the parameters were decreased identically with the corresponding increase in dose of both the herbicides in mixture being maximum when propaquizafop and imazethapyr mixture was applied at 53+80g/ha or higher dose(56+85g/ha) and proved significantly superior over weedy check, other mixtures including both the check herbicides propaquizafop 75g/ha and imazethapyr 100g/ha.

Weedy check had the highest weed biomass (535.65 g m^{-2}), which was reduced significantly when weeds were controlled either chemically or mechanically.

The lowest weed biomass was recorded under hand weeding twice, which proved significantly superior to all the herbicidal treatments.

Table.1 Weed population, weed biomass, yield and economics as affected by different treatments (mean data of 2 seasons)

Treatment	Doses	Weed population (No./m^2)			Weed biomass (g/m^2)	Seed yield (kg/h)	Harvest index (%)	CWC (Rs/ha)	NMR (Rs/ha)	NRwc	MBCR
		Grassy weeds	Sedges	BLWs							
T$_1$-Propaquizafop+Imazethapyr	47+70 g/ha	8.73 *(75.67)*	4.49 *(19.67)*	6.31 *(39.33)*	14.41 *(207.08)*	1593	31.46	1706	23682	17638	10.34
T$_2$-Propaquizafop+Imazethapyr	50+75 g/ha	8.19 *(66.67)*	4.22 *(17.33)*	5.73 *(32.33)*	13.25 *(175.13)*	1834	31.50	1800	30320	24276	13.49
T$_3$-Propaquizafop+Imazethapyr	53+80 g/ha	7.38 *(54.00)*	3.81 *(14.00)*	4.97 *(24.33)*	11.79 *(138.53)*	2189	33.59	1893	39663	33619	17.76
T$_4$-Propaquizafop+Imazethapyr	56+85 g/ha	6.12 *(37.00)*	3.29 *(10.33)*	4.38 *(18.67)*	9.95 *(98.60)*	2214	33.73	1987	40234	34190	17.21
T$_5$-Propaquizafop	75 g/ha	8.36 *(69.33)*	4.56 *(20.33)*	6.89 *(47.00)*	14.19 *(200.99)*	1392	30.60	862	19109	13065	15.15
T$_6$-Imazethapyr	100 g/ha	8.95 *(79.67)*	4.05 *(16.00)*	5.34 *(28.00)*	14.04 *(196.71)*	1485	30.74	1550	20976	14932	9.63
T$_7$-Pendimethalin	1000 g/ha	9.69 *(93.33)*	4.88 *(23.33)*	7.31 *(53.00)*	15.77 *(248.16)*	1182	30.35	1950	11956	5921	3.04
T$_8$-Hand weeding	2	2.96 *(8.33)*	1.95 *(3.33)*	2.18 *(4.33)*	2.56 *(6.07)*	2378	34.23	10500	36138	30094	2.87
T$_9$-Weedy check	-	13.51 *(182.00)*	5.67 *(31.67)*	8.13 *(65.67)*	23.15 *(535.63)*	878	26.37	-	6044	-	-
SE.m±	-	**0.12**	**0.12**	**0.13**	**0.09**	0.63	0.15	-	-	-	-
CD (*P*= 0.05)	-	**0.36**	**0.37**	**0.39**	**0.28**	1.89	0.42	-	-	-	-

Values given in the parentheses are the original means. CWC= Cost of weed control (INR/ha); NMR= Net monetary return, NRwc = Net return due to weed control (INR/ha); MBCR= Marginal benefit cost ratio

Table.2 Different indices as affected by different treatments in soybean (mean data of 2 seasons)

Treatment	Doses	WCE (%)	WCI (%)	WI (%)	HEI	WPI	CRI	WMI	AMI	IWMI
T$_1$-Propaquizafop+Imazethapyr	47+70 g/ha	51.79	61.34	33.01	2.11	0.80	4.48	1.33	0.33	0.83
T$_2$-Propaquizafop+Imazethapyr	50+75 g/ha	58.35	67.30	22.86	3.33	0.79	7.01	1.62	0.62	1.12
T$_3$-Propaquizafop+Imazethapyr	53+80 g/ha	66.94	74.14	7.95	5.77	0.78	10.40	2.02	1.02	1.52
T$_4$-Propaquizafop+Imazethapyr	56+85 g/ha	76.37	81.59	6.89	8.27	0.77	14.88	1.87	0.87	1.37
T$_5$-Propaquizafop	75 g/ha	51.07	62.48	41.44	3.18	0.76	4.31	0.94	-0.06	0.44
T$_6$-Imazethapyr	100 g/ha	55.73	63.27	37.54	1.88	0.83	5.53	1.09	0.09	0.59
T$_7$-Pendimethalin	1000 g/ha	39.26	53.67	50.28	0.75	0.76	3.05	0.64	-0.36	0.14
T$_8$-Hand weeding	2	94.27	98.87	0.00	-	0.19	113.06	1.73	0.73	1.23
T$_9$-Weedy check	-	0.00	0.00	63.06	-	-	-	-	-	-

Among the herbicidal treatments, application of propaquizafop + imazethapyr mixture at 53+80 and 56+85 g/ha as post emergence arrested the weed biomass production remarkably and proved superior to its lower rates (47+70 and 50+75 g/ha) and alone application of propaquizafop (75 g/ha), imazethapyr (100 g/ha) and pendimethalin (1000 g/ha). However, none of the herbicidal treatments whether applied alone and in combination, surpassed the manual hand weeding twice which curbed the weed growth to the maximum extent (98.87%).

A treatment having high values of agronomic indices such as HEI, CRI, WMI, AMI, and IWMI should be considered a good treatment with high weed control efficiency (Ramamurthy, 1999; Singh *et al.,* 2008; Suria *et al.,* 2011). Also, an ideal treatment should have low values of WPI and WI (Ramamurthy, 1999; Suria *et al.,* 2011). Among the herbicidal treatments propaquizafop + imazethapyr mixture applied at 56+85 g/ha resulted in higher values of WCE, WCI, HEI, CRI which is followed by propaquizafop + imazethapyr mixture applied at 53+80 g/ha. However, none of the herbicidal treatments surpassed hand weeding twice which recorded the highest WCE (94.27%), WCI (98.87%), CRI (113.06) due to elimination of all sorts of weeds during the course of weeding. Regarding WMI, AMI and IWMI, highest values were obtained under propaquizafop + imazethapyr mixture applied at

53+80 g/ha followed by propaquizafop + imazethapyr mixture applied at 56+85 g/ha and hand weeding twice at 20 & 40 DAS (Table 2).

Weed index is an ideal parameter to describe yield loss caused by weed infestation in comparison with weed free plots (Suria *et al.,* 2011). It reflects the effectiveness of applied herbicide in securing yield loss against weed competition and a lower value of weed index means high herbicide efficiency. Regarding weed index, application of propaquizafop + imazethapyr mixture was more effective as compared to the respective herbicides applied alone. Maximum reduction in yield (63.06 %) occurred in plots where weeds were not controlled throughout the crop season (weedy check plots).

Application of pendimethalin (1000 g/ha), propaquizafop (75 g/ha) and imazethapyr (100 g/ha) scaled down the yield reduction to the tune of 50.28, 41.44 and 37.54 per cent, respectively. But yield reduction was further checked (from 33.01 to 6.89 %) with combined application of propaquizafop and imazethapyr between 47+70 to 56+85 g/ha, respectively, being zero under hand weeding twice. Weed management cost was highest (Rs 10500/ ha) under hand weeding twice at 20 and 40 DAS. Cost of weed control under herbicidal treatments was 16.25-18.92% of that under manual weeding. Due to lower cost of weed

management, propaquizafop + imazethapyr mixture applied at higher doses (53+80 and 56+85 g/ha) gave more net return due to weed control over manual weeding. However, lower rates of propaquizafop + imazethapyr mixture and alone application of propaquizafop (75 g/ha), pendimethalin (1000 g/ha) and imazethapyr (100 g/ha) applied alone, though possessed lower cost of weed management, recorded comparatively less net return due to weed control. This may be due to poor control of associated weeds during critical period. All herbicidal weed management treatments resulted in higher MBCR over manual weeding. MBCR was highest (17.76) under propaquizafop + imazethapyr mixture at 53+80 g/ha followed by propaquizafop + imazethapyr mixture at 56+85 g/ha, propaquizafop (75 g/ha), propaquizafop + imazethapyr (50+75 g/ha), propaquizafop + imazethapyr (47+70 g/ha), imazethapyr (100 g/ha) and pendimethalin (1000 g/ha) (Table 1).

Hand weeding twice at 20 and 40 DAS engaged more labour and had higher cost (Rs 10500/ha) tending to decrease the MBCR more than the herbicidal treatments. Similar findings have also been reported by Kewat *et al.,* (2000) and Tiwari *et al.,* (2007).

Based on the results obtained in the present investigation, it can be concluded that post-emergence application of propaquizafop + imazethapyr mixture at 53 + 80 g/ha found more effective and remunerative compared to alone application of propaquizafop (75 g/ha), imazethapyr (100 g/ha), pendimethalin (1000 g/ha) and even to hand weeding twice.

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