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Effect of propaquizafop alone and in mixture with other herbicides on weed dry weight and growth and yield of soybean

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ABSTRACT

A field experiment was conducted on acidic soils of Palampur to study the effect of propaquizafop alone and in mixture with other herbicides on growth and yield of soybean and associated weeds. The experiment consisted of eleven treatments including unweeded check were tested in randomized block design and replicated thrice. Propaquizafop significantly reduced the dry weight of E. colona, C. banghalensis and C. iria but not of A. conyzoides and P. alatum. Post-emergence tank mix combination of propaquizafop 50 g + imazethapyr 100 g ha^{-1} at 20 DAS and quizalofop ethyl 60 g + chlorimuron-ethyl 4 g ha^{-1} at 15 DAS being comparable were more effective in reducing the dry weight of weeds and were comparable to hand weeding (20 and 40 DAS) in improving growth and yield of soybean. Uninterrupted growth of weeds reduced seed yield of soybean by 56.72 per cent.

***Keywords*:** Propaquizafop, soybean, seed yield, weed growth, weed index

Soybean (*Glycine max* L.) is a wonder crop of twentieth century. It is an excellent source of proteins, fats, amino acids (lysine, leucine) and phosphorus. Non-adoption of the package and practices especially proper weed control is the major reason for its low productivity. Being a rainy season crop, it suffers severely due to weed stress. If weeds are not controlled during critical period of crop-weed competition, there is substantial reduction in the yield of soybean ranging from 58 to 85 per cent, depending upon the types and intensity of weeds (Kewat *et al.,* 2000). Weeds compete with the crop in initial stages for limited essential resources and seriously depress the crop growth and development (Singh and Kharwara, 1984). Weeds increase cost of cultivation and deplete resource base (Buriro *et al.,* 2003). Application of suitable weed control measures is the most important factor for improving the productivity of this crop. However, pre-emergence herbicides have some limitations like limited period of application. Hence, use of the post-emergence herbicides has better prospects. Keeping these facts in mind, the present investigation was carried out to study the effect of propaquizafop alone and in mixture with other herbicides on weeds and growth and yield of soybean.

MATERIALS AND METHODS

The field experiment was conducted at Palampur during the rainy season of 2016 (32^{0}6' N latitude, 76^{0}3' E longitude and 1290.8 m attitude) to study the effect of post-emergence application of propaquizafop on soybean and associated weeds. The soil of the experimental field was silty clay loam in texture, acidic in reaction (pH 5.7) with sand (20.1%), silt (42.5%) and clay (32.6%) along with available N 128 kg ha^{-1} (Subbiah and Asija, 1956), available P_2O_5 13.9 kg ha^{-1} (Olsen *et al*., 1954) and available K_2O 155 kg ha^{-1} (Jackson, 1967). The experiment was laid out in Randomized Block Design with eleven treatments *viz.* T_1: Propaquizafop 60 g ha^{-1} at 15 DAS (Days after sowing), T_2: Propaquizafop 60 g ha^{-1} at 25 DAS, T_3: Propaquizafop 75 g ha^{-1} at 15 DAS, $T_{4:}$ Propaquizafop 75 g ha^{-1} at 25 DAS, T_5: Propaquizafop 50 g + imazethapyr 100 g ha^{-1} at 20 DAS, T_6: Propaquizafop 50 g + chlorimuron- ethyl 4 g ha^{-1} at 20 DAS, T_7: Quizalofop ethyl 60 g + chlorimuron-ethyl 4 g ha^{-1} at 15 DAS, T_8: Pendimethalin 1500 g ha^{-1} as pre-emergence, T_9: Hand weeding (20 and 40 DAS), T_{10}: Mechanical weeding (20 & 40 DAS) and T_{11}: Unweeded check with three replications. Soybean cultivar 'Harit Soya' was sown on 22nd June 2016 and harvested on 28th October 2016. The recommended dose of fertilizer was 20:60:40 NPK kg ha^{-1} and spacing for soybean was 45 x 10 cm under all the treatments. Full dose of nitrogen, phosphorus, potassium through urea, single super phosphate and muriate of potash was applied at the time of sowing. The herbicides were applied using Knapsack sprayer fitted with flat fan nozzle by mixing 500 litres of water per ha. All the other recommended agronomic and plant protection measures were adopted to raise the crop and intercultural practices were taken as per needed. The data on weed dry weight were recorded at 30, 60, 90 DAS and at harvest. Observations for growth parameters were recorded at different growth stages of the crop. Yield was obtained from the net plot. The data were subjected to statistical analysis as per Gomez and Gomez (1984) and were tested at 5 per cent level of significance

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to interpret the treatment differences. The data on weed dry weight were subjected to square root transformation $\left(\sqrt{x+0.5}\right)$ before statistical treatment.

RESULTS AND DISCUSSION

Effect on weed dry weight

Cyperus iria (28.2%), *Echinochloa colona* (22.3%), *Commelina benghalensis* (19.2%), *Polygonum alatum* (11.8%) and *Ageratum conyzoides* (10.2%) were the major weeds found growing in association with soybean crop. Weed dry weight is the most important parameter to assess the weed competitiveness for the crop growth and productivity. All weed control treatments were significantly superior in reducing dry weight of *E. colona, C. benghalensis* and *C. iria* as compared to weedy check. Hand weeding (20 and 40 DAS) being at par with the post-emergence application of propaquizafop 50 g + imazethapyr 100 g ha^{-1} was significantly superior to rest of the treatments and was followed by quizalofop ethyl 60 g + chlorimuron-ethyl 4 g ha^{-1} and propaquizafop 50 g + chlorimuron-ethyl 4 g ha^{-1}. Kundu *et al.* (2011) also obtained higher reduction in biomass of *Echinochloa colona* and *Echinochloa crusgalli* with hand weeding at 20 and 40 DAS and imazethapyr 100-150 g ha^{-1} (10 DAS) in soybean.

Hand weeding (20 and 40 DAS) was statistically at par with post-emergence application of propaquizafop 50 g + imazethapyr 100 g ha^{-1} which resulted in significantly lower dry weight of *C. benghalensis*. This was followed by quizalofop ethyl 60 g + chlorimuron-ethyl 4 g ha^{-1}. Post-emergence application of tank mix quizalofop ethyl 60 g + chlorimuron-ethyl 4 g ha^{-1} was the best in reducing the dry weight of *C. iria* closely followed by hand weeding (20 and 40 DAS) and post-emergence application of tank mix propaquizafop 50 g + imazethapyr 100 g ha^{-1}. Propaquizafop could not significantly reduce the dry weight of *A. conyzoides* and *P. alatum* over weedy check (Table 1). However, hand weeding (20 and 40 DAS) remaining at par with post-emergence application of propaquizafop 50 g + imazethapyr 100 g ha^{-1} and post-emergence application of propaquizafop 50 g + chlorimuron-ethyl 4 g ha^{-1} and quizalofop ethyl 60 g + chlorimuron-ethyl 4 g ha^{-1} in controlling *A. conyzoides*. Post-emergence application of propaquizafop 50 g + imazethapyr 100 g ha^{-1} resulted in complete elimination of *P. alatum.* Post-emergence application of quizalofop ethyl 60 g + chlorimuron-ethyl 4 g ha^{-1} was statistically similar to hand weeding (20 & 40 DAS) and post-emergence application of propaquizafop 50 g + chlorimuron-ethyl 4 g ha^{-1} in controlling *P. alatum*.

Effect on crop growth

The emergence count of soybean was not significantly affected due to weed control treatments (Table 3) indicating that herbicides at the rate and time applied were selective to soybean. Plant height was significantly affected at all the stages of observations (Table 2) owing to variable response of herbicidal treatments on weeds. At 90 DAS, plant height was minimum under weedy check and increased significantly with reduction in competition due to weed control treatments. Maximum plant height was recorded under hand weeding (20 and 40 DAS) which was at par with propaquizafop 50 g + imazethapyr 100 g ha^{-1}. This difference in plant height might be due to competition between the crop plants and weeds for the growth factors. Unweeded control resulted in shorter plants of soybean, obviously due to the effect of weeds (Sangeetha *et al.*, 2012).

Dry matter accumulation increased consistently with advancement of crop growth. Data pertaining to crop biomass at maximum biomass stage are presented in table 2. Crop biomass was minimum (41.5 g m^{-2}) under weedy check and significantly increased with the post-emergence application of propaquizafop alone and in combination with other herbicides at harvest of the crop due to better control of the weed flora at harvest. However, hand weeding (20 and 40 DAS) excelled all the herbicide treatments in relation to crop dry matter accumulation. Among herbicidal treatments, propaquizafop 50 g + imazethapyr 100 g ha^{-1} applied on 20 DAS and quizalofop ethyl 60 g + chlorimuron-ethyl 4 g ha^{-1} on 20 DAS were significantly superior to other treatments. The reduction in dry weight of weeds under these treatments created favourable micro-environment for growth and development of soybean and thus increased the dry matter accumulation of soybean. In general, the assimilation area over the ground area was minimum during early period of crop growth which increased thereafter under all the treatments. LAI was minimum (5.63) under weedy check plots, which increased significantly with the application of weed control measures.

Hand weeding (20 and 40 DAS) remaining statistically alike to post emergence application of propaquizafop 50 g + imazethapyr 100 g ha^{-1}, and quizalofop ethyl 60 g + chlorimuron-ethyl 4 g ha^{-1} applied on 15 DAS and propaquizafop 50 g + chlorimuron ethyl 4 g ha^{-1} on 20 DAS resulted in significantly higher LAI over other treatments. Crop growth rate (CGR) at 30-60 DAS was significantly affected due to different weed control treatments. Among weed control treatments, hand weeding twice and post-emergence application of propaquizafop 50 g + imazethapyr 100 g ha^{-1} had significantly higher CGR over other treatments. Quizalofop ethyl 60 g + chlorimuron ethyl 4g ha^{-1} was

Table 1: Effect of weed control treatments on weed dry weight (g m^{-2}) at maximum dry matter stage i.e. at 90 DAS

Treatments	Dose (g ha^{-1})	TOA (DAS)	*E. colona*	*C. benghalensis*	*C. iria*	*A. conyzoides*	*P. alatum*	Other weeds*
Propaquizafop	60	15	6.0 (36.3)	4.8 (22.9)	9.1 (82.7)	7.7 (58.1)	6.6 (43.7)	5.0 (24.5)
Propaquizafop	60	25	5.9 (34.7)	4.6 (21.3)	9.0 (80.0)	7.6 (57.3)	6.5 (41.6)	4.9 (23.8)
Propaquizafop	75	15	5.8 (33.6)	4.4 (18.7)	8.9 (78.9)	7.6 (56.8)	6.4 (40.5)	4.8 (22.9)
Propaquizafop	75	25	5.7 (32.0)	4.1 (16.0)	8.8 (77.6)	7.5 (55.8)	6.3 (38.9)	4.7 (21.3)
Propaquizafop + imazethapyr	50+100	20	4.1 (16.0)	2.8 (7.5)	4.1 (16.3)	2.8 (7.5)	0.7 (0.0)	2.1 (3.9)
Propaquizafop + chlorimuron-ethyl	50+4	20	4.4 (18.7)	3.4 (11.2)	4.7 (21.9)	3.1 (8.9)	3.2 (9.6)	2.4 (5.4)
Quizalofop ethyl + chlorimuron-ethyl	60+4	15	4.1 (17.6)	3.1 (9.6)	4.2 (17.0)	3.2 (10.0)	2.9 (8.0)	2.2 (4.5)
Pendimethalin	1500	Pre-	4.7 (21.3)	3.6 (12.8)	5.2 (26.2)	3.8 (13.9)	3.4 (11.2)	2.7 (6.6)
Hand weeding	-	20 & 40	3.6 (12.8)	2.2 (5.3)	4.0 (15.7)	2.5 (5.8)	2.3 (4.8)	1.5 (1.8)
Mechanical weeding	-	20 & 40	5.2 (26.7)	3.8 (13.9)	5.0 (24.3)	4.5 (19.8)	5.2 (26.7)	3.8 (13.7)
Unweeded check	-	-	8.7 (74.7)	6.3 (40.0)	9.2 (83.5)	7.8 (60.3)	6.8 (45.3)	5.9 (33.8)
LSD (0.05)			**1.0**	**1.1**	**1.1**	**1.3**	**0.9**	**1.4**

*Note: *Value in parentheses are the means of original values. Data transformed to square root transformation* $\left(\sqrt{x+0.5}\right)$*; TOA= Time of application; *Panicum dichotomiflorum, Bidens pilosa and Euphorbia sp*

Table 2: Effect of treatments on plant height (cm) at different stages of observation

Treatments	Dose (g ha^{-1})	TOA (DAS)	Observation stages (DAS)			
			30	60	90	At harvest
Propaquizafop	60	15	26.3	48.1	63.9	58.2
Propaquizafop	60	25	28.0	52.2	65.7	60.7
Propaquizafop	75	15	29.3	54.0	68.5	65.8
Propaquizafop	75	25	30.9	57.7	70.4	67.6
Propaquizafop + imazethapyr	50+100	20	44.1	69.2	88.7	82.2
Propaquizafop + chlorimuron-ethyl	50+4	20	39.2	68.8	80.5	75.3
Quizalofop ethyl + chlorimuron-ethyl	60+4	15	37.9	66.5	83.3	78.2
Pendimethalin	1500	Pre-	37.0	64.8	76.5	73.5
Hand weeding twice	-	20 and 40	41.5	68.4	86.8	79.3
Mechanical weeding	-	20 and 40	34.3	63.0	73.9	70.5
Unweeded check	-	-	24.2	45.4	59.2	54.6
LSD (0.05)			**2.0**	**8.2**	**4.5**	**6.7**

the next better treatment. Relative growth rate (RGR) at 60-90 DAS was not significantly affected due to different weed control treatments. Similarly days to 50 per cent flowering and maturity were not significantly affected due to weed control treatments (Table 3).

Effect on crop yield

Weed control treatments brought about significant variation in the seed yield of soybean (Table 3). The seed yield under weedy check which was 10.23 q ha^{-1}, increased significantly when weed control measures were

Table 3: Effect of treatments on growth parameters of soybean

Treatment	Dose (g ha^{-1})	TOA (DAS)	Emergence count (No. m^{-2})	Crop dry matter (g m^{-2})	LAI (90 DAS)	CGR (30-60 DAS)	RGR (60-90 DAS)
Propaquizafop	60	15	17.0	51.1	5.97	0.432	0.101
Propaquizafop	60	25	17.8	53.7	6.17	0.494	0.101
Propaquizafop	75	15	18.5	57.4	6.31	0.605	0.104
Propaquizafop	75	25	19.3	61.9	6.38	0.659	0.108
Propaquizafop + imazethapyr	50+100	20	22.2	84.8	6.78	1.012	0.117
Propaquizafop + Chlorimuron-ethyl	50+4	20	20.7	71.1	6.70	0.765	0.111
Quizalofop ethyl + chlorimuron-ethyl	60+4	15	21.5	76.5	6.75	0.852	0.116
Pendimethalin	1500	Pre-	20.0	67.8	6.60	0.741	0.112
Hand weeding	-	20 & 40	22.2	93.3	6.87	1.136	0.116
Mechanical weeding	-	20 & 40	21.5	64.8	6.48	0.686	0.110
Unweeded check	-	-	20.0	41.5	5.63	0.284	0.089
LSD (0.05)			**NS**	**3.3**	**0.20**	**0.236**	**NS**

Table 4: Effect of treatments on days to flowering & maturity and yield of soybean

Treatment	Dose (g ha^{-1})	TOA (DAS)	Days to flowering	Days to maturity	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index (%)	Weed Index
Propaquizafop	60	15	58.7	108.3	1164	3845	23.1	50.75
Propaquizafop	60	25	58.0	108.0	1340	4056	24.9	43.28
Propaquizafop	75	15	57.7	107.7	1411	4233	27.7	40.30
Propaquizafop	75	25	57.3	107.7	1481	4374	25.3	37.31
Propaquizafop + imazethapyr	50 + 100 5.97	20	55.7	107.3	2222	5820	27.7	
Propaquizafop + chlorimuron-ethyl	50+4	20	56.7	108.0	1834	5115	26.3	22.39
Quizalofop ethyl + chlorimuron-ethyl	60+4	15	57.0	107.7	2063	5397	27.6	12.69
Pendimethalin	1500	Pre-	57.7	108.3	1675	4832	25.4	29.10
Hand weeding	-	20 & 40	60.0	107.3	2363	6102	27.9	0.00
Mechanical weeding	-	20 & 40	60.3	107.7	1570	4515	25.8	33.58
Unweeded check	-	-	60.0	109.0	1023	2857	27.1	56.72
LSD (0.05)			**NS**	**NS**	**450**	**1250**	**NS**	**-**

adopted. Application of propaquizafop 75 g ha^{-1} as post-emergence on 25 DAS and propaquizafop 75 g ha^{-1} on 15 DAS significantly enhanced the seed yield than the other treatments of propaquizafop in soybean. But, combined tank-mix application of propaquizafop + imazethapyr had more seed yield than other chemical treatments. However, none of the herbicidal treatments surpassed hand weeding (20 and 40 DAS) though tank mixed propaquizafop 50 g + imazethapyr 100 g ha^{-1} and quizalofop-ethyl 60 g + chlorimuron-ethyl 4 g ha^{-1} applied on 20 DAS were at par to the former. Lal *et al.*, (2017) also reported that tank mixture of propaquizafop + imazethapyr at 53 + 74 g ha^{-1} or higher rate (56 + 78 g ha^{-1}) being comparable to hand weeding twice (20 and 40 DAS) proved significantly superior over alone application of propaquizafop (75 g ha^{-1}) and imazethapyr (100 g ha^{-1}). The higher seed yield in these treatments could be attributed to improved growth as a consequence of lower weed competition, which shifted the balance in favour of crop in utilization of nutrients, moisture, light and space. Weed control treatments significantly influenced straw yield. Among all the treatments, the minimum straw yield was recorded under weedy check (2.9t ha^{-1}), which was significantly increased when weed

control measures were adopted. Hand weeding (20 and 40 DAS) had significantly higher straw yield which was statistically alike with post-emergence propaquizafop 50 g + imazethapyr 100 g ha^{-1} and quizalofop ethyl 60 g + chlorimuron-ethyl 4 g ha^{-1} followed by propaquizafop 50 g + chlorimuron-ethyl 4 g ha^{-1} on 20 DAS. The harvest index of soybean remained unaffected due to weed control treatments. Weed index is the efficiency of a particular treatment as compared to weed free treatment was lowest in propaquizafop 50 g + imazethapyr 100 g ha^{-1} followed by quizalofop ethyl 60 g + chlorimuron-ethyl 4 g ha^{-1}. Weed index under unweeded check was 56.72 per cent. It indicated that weeds reduced seed yield of soybean by 56.72 per cent when allowed to grow uninterrupted till harvest. It can be concluded from the present study that propaquizafop 75 g ha^{-1} on 25 DAS was an effective alternative to pre-emergence pendimethalin and/or mechanical weeding in reducing weed dry weight and increasing growth and yield of soybean. However, post-emergence tank mixed herbicide combinations *viz*. propaquizafop 50 g + imazethapyr 100 g ha^{-1}, quizalofop ethyl 60 g + chlorimuron-ethyl 4 g ha^{-1} and propaquizafop 50 g + chlorimuron-ethyl 4 g ha^{-1} in that order were far superior in reducing crop weed competition and increasing grain and straw yield of soybean.

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