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Bio-efficacy of different tank mix herbicides for weed control in soybean [*Glycine max* (L.) Merrill]

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ABSTRACT

A field experiment was conducted at the Rajasthan College of Agriculture, MPUAT, Udaipur during *Kharif* season 2015 and 2016 to adjudge the efficacy of different herbicide and herbicide mixtures against weeds in soybean. Monocot weeds were predominant (55.15%) in the experimental field compared with dicot weeds (44.85%). However, *Echinochloa colona* (41.56%) and *Trianthema portulacastrum* (33.16%) were predominant in soybean but, other weeds (*Cyperus rotundus, Cynodon dactylon, Commelina benghalensis, Digera arvensis, Amaranthus viridis, Physalis minima, Corchorus spp.*) were also present at 60 DAS. Among different weed control treatments, post-emergence and tank mix combination of propaquizafop + imazethapyr (75+75 g ha^{-1}) and imazethapyr + quizalofop-ethyl (75+60 g ha^{-1}) at 21 DAS were most effective in respect of reducing weed density, weed biomass, nutrient removal by weed and promote yield attributes and yield and quality of soybean as compared to rest of weed control treatment.

Key words: Weed, Soybean, Propaquizafop, Imazethapyr, Quizalofop-ethyl, Yield.

INTRODUCTION

Soybean is an important pulse as well as oilseed crop of the world and is known for its quality protein and oil. Soybean seeds contain 38-42 per cent good quality protein and 18-20 per cent oil, rich in polyunsaturated fatty acids (linoleic and oleic acid) along with a good amount of minerals (Ca, P, Mg, Fe & K) and vitamins especially B-complex and teco-pherols (Devi *et al*., 2012). Being a rainy season crop, it suffers severely due to weed stress and it causes low productivity that is major problem of soybean cultivation (Jaybhay *et al*., 2018). If weeds are not controlled during critical period of crop-weed competition, there is identical reduction in the yield of soybean from 31- 84% depending upon the types and intensity of weeds. Most of the yield reduction due to weed competition occurs during the first six weeks after planting; therefore, major emphasis on control should be given during this period. Good soybean weed control involves utilizing all methods available and combining them in an integrated weed management system, but considering the present day labour scarcity and their higher wages for cultural and mechanical weed control, the economics and feasibility of soybean cultivation is quiet disturbed. Hence the emphasis should be given to adopt the chemical methods of weed control to solve the problem of minimum available labour and their high cost. In this view, the present investigation was conducted to find out the best suitable combination of different herbicides to control weeds in soybean with lower cost and higher grain yield.

MATERIALS AND METHODS

The field experiment was conducted during rainy season *kharif* of 2015 and 2016 at agriculture research farm, Rajasthan College of Agriculture (altitude of 582.17 m above mean sea level with 24º35’ N latitude and 74°42’ E longitude) Maharana Pratap University of Agriculture & Technology, Udaipur. The experimental soil was well drained, alluvial in nature and clay loam in texture, having pH 7.8, organic carbon 0.75%, available nitrogen 370 kg ha^{-1}, available phosphorus 24 kg ha^{-1} and available potassium 421 kg ha^{-1}, respectively were estimated by Combined glass electrode pH meter method, Walkley and Black’s rapid titration method, Modified macro Kjeldahl method, Olsen’s method and Flame photometer method, respectively (Jackson, 1967). The experimental site belongs to the semi arid climate, the temperature of the experimental period was moderate, ranges from 16.6 to 35.9°C and the mean annual rainfall of the region was 637 mm and maximum and minimum relative humidity was 95% and 30%, respectively. The experiment was laid out with eleven treatments were weedy check (T1), two hand weeding at 15 and 35 DAS (T2), Pendimethalin 1000 g ha^{-1} at pre-emergence (T3), post-emergence application of Quizalofop-ethyl 75 g ha^{-1} at 15 DAS (T4), Imazethapyr 100 g ha^{-1} PoE at 15 DAS (T5), Chlorimuron-ethyl 10 g ha^{-1} PoE at 21 DAS (T6), Propaquizafop 100 g ha-1 PoE 15 DAS (T7), tank mix application of Imazethapyr + Quizalofop ethyl (75 +60 g ha^{-1}) PoE at 21 DAS (T8), Quizalofop ethyl+ Chlorimuron ethyl (60+7 g ha^{-1}) PoE at 21 DAS (T9), Propaquizafop + Imazethapyr (75+75 g ha^{-1}) PoE at 21 DAS

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(T10) and Propaquizafop + Chlorimuron ethyl (75+7 g ha^{-1}) PoE at 21 DAS (T11). Soybean, cv. JS-335 was sown at the end of the June of two consecutive years with the fertilizer dose @ 20-40-30-40 kg ha^{-1} of N-P_2O_5-K_2O-S as basal and thoroughly mixed with the soil. The seeds were inoculation with selected *Rhizobium* culture and sown @ 80 kg ha^{-1} in furrows at 30 cm x 10 cm spacing at a depth of 5 cm below the soil surface. Foliar spray was done with knapsack sprayer using flat fan or flood jet nozzle with spray volume of 500 L ha^{-1}. Species wise predominant weed count, weed biomass, weed control efficiency were recorded at 60 days after post-emergence spray (DAS), and finally the crop yield was measured at the time of harvest.

RESULTS AND DISCUSSION

Weed flora: Nine predominant weed species were observed in experimental field during the rainy *(kharif)* season of 2015 and 2016, monocot weeds were predominant (55.15%) in the experimental field compared with dicot weeds (44.85%). However, *Echinochloa colona (*41.56%) and *Trianthema portulacastrum* (33.16%) were predominant in soybean but, other weeds (*Cyperus rotundus, Cynodon dactylon, Commelina benghalensis, Digera arvensis, Amaranthus viridis, Physalis minima, Corchorus olitorius*) were also present at 60 DAS. Similar observation was also reported by Kushwah and Vyas (2006), Habra *et al.* (2009), Singh *et al.* (2013) and Saharan *et al*. (2016).

Weed density and biomass: Species wise weed density in soybean field *i.e*. number of the weeds m^{-2} of a particular weed species was recorded at 60 DAS, and differed significantly with the different weed management treatments (Table 1 and 2). Density of monocot weeds (*Echinochloa colona, Cyperus rotundus, Cynodon dactylon, Commelina benghalensis*) were much higher than the density of dicot weeds (*Trianthema portulacastrum, Digera arvensis, Amaranthus viridis, Physalis minima, Corchorus olitorius*) at throughout the crop growing season, as because rainy reason is highly favourable for grass and sedge population, similar opinion also reported by Tiwari *et al.* (2007). Again, population of *Echinochloa colona* found to be greater than the other weeds. Weed density at 60 DAP was higher as compared to those recorded at early stages irrespective of species. The treatment T10 treatment showed the maximum reduction of density and weed biomass of all category of weed at 60 DAS and it was closely followed by the treatment T8 [tank mix application of Imazethapyr + Quizalofop ethyl (75 +60 g ha^{-1}) PoE at 21 DAS] and T2 (Two hand weeding at 15 and 35 DAS). The weedy check treatment (T1) showed the highest population and biomass of monocot, dicot and total weeds which was significantly inferior to any other treatments. Amongst sole applied herbicides, T5 registered maximum reduction in density and dry matter of all categories of weeds at 60 DAS. From the findings, it may be stated that post-emergence application of imazethapyr reduced the density and dry matter of broad as well as narrow leaved weeds significantly as compared to pre-emergence herbicides under study (Arregui *et al.*, 2005; Mosjidis and Wehtje, 2011). Whereas propaquizafop is very effective to kill annual monocot weeds. Application of tank mix propaquizafop + imazethapyr (75 + 75 g ha^{-1}) increase range of broad spectrum weed control. The per cent reduction in dry matter of total weeds due to propaquizafop + imazethapyr and imazethapyr + quizalofop-ethyl was 92.32 and 90.51, respectively compared to weedy check (1126.79 g m^{-2}). Results corroborate with the findings of Renjith and Sharma *et al*. (2014), Ramprakash *et al*. (2016), Parmar *et al*. (2016) and Nagre *et al*. (2017).

Weed control efficiency: Maximum weed control efficiency in monocot, dicot and total weeds (90.10, 94.40 and 92.32%, respectively) was observed with the application of propaquizafop + imazethapyr (Table 3). The higher weed control efficiency may be contributed to the lowest weed competition and resulted higher grain yield. The higher weed control efficiency under this treatment could be attributed to the lower weed population and total weed dry matter as well and further it may contributed to higher grain yield. These results corroborated with the finding of Panda *et al*. (2015) and Patel *et al*. (2016).

Nutrient removal by weeds: Nutrient loss through uncontrolled weed (T1) growth throughout the crop season resulted in a loss of 137.86 kg N ha^{-1}, 21.29 kg P_2O_5 ha^{-1}, 132.99 kg K_2O ha^{-1} and 8.76 kg S ha^{-1} (Table 4). The lowest mean total uptake of N, P, K and S by weeds was recorded with propaquizafop + imazethapyr (T10), which was significantly superior over other herbicide treatments. The nutrient uptake by weeds is the function of per cent nutrient content and biomass, thus similar trend in uptake and total weed biomass production was an expected outcome. The results corroborate with the findings of Dhakar *et al*. (2015) and Saharan *et al*. (2016).

Yield attributes and yield: Application of propaquizafop + imazethapyr recorded highest number of pods (43.72) and seeds per pod (3.00), pod yield per plant (10.45 g) followed by imazethapyr + quizalofop-ethyl and two hand weeding (Table 5). Enforcing weed control through hand weeding, individual herbicides and their mixture resulted in significant increase in seed yield, haulm and biological yield.

Application of propaquizafop + imazethapyr achieved significantly higher seed, haulm and biological yields (2271, 3127 and 5398 kg ha^{-1}) over all other weed control treatments. The better expression of yield attributes and yield might be poor resurgence frequency and growth of weeds as evident from weed dry mater studies in these treatments. Hence weeds were unable to compete with the crop plant for different growth factors. Enhanced values of yield attributing characters were the outcome of these effects.

Table 1: Effect of herbicides and nutrient management on monocot weed density in soybean at 60 DAS (Pooled data).

Treatments	*Echinochloa colona*	*Cynodon dactylon*	*Cyperus rotundus*	*Commelina benghalensis*	Other weeds
T1	8.22	5.63	4.92	4.95	4.06
	(67.72)	(31.35)	(23.78)	(24.01)	(16.06)
T2	3.35	2.63	2.16	2.19	2.54
	(10.78)	(6.44)	(4.22)	(4.29)	(5.97)
T3	3.90	3.43	2.51	3.46	2.87
	(14.72)	(11.28)	(5.83)	(11.50)	(7.78)
T4	3.99	3.19	2.31	2.79	2.59
	(15.50)	(9.83)	(4.87)	(7.30)	(6.22)
T5	3.83	3.55	2.27	3.10	2.52
	(14.22)	(12.13)	(4.67)	(9.09)	(5.89)
T6	6.22	4.23	3.81	4.27	2.79
	(38.78)	(17.48)	(14.00)	(17.75)	(7.33)
T7	3.78	3.63	2.03	2.56	2.66
	(13.83)	(12.73)	(3.79)	(6.09)	(6.61)
T8	2.09	2.08	1.62	1.79	2.05
	(3.89)	(3.88)	(2.17)	(2.71)	(3.72)
T9	3.67	3.12	2.11	2.48	2.62
	(13.00)	(9.38)	(3.96)	(5.66)	(6.39)
T10	2.08	1.69	1.61	1.59	1.77
	(3.83)	(2.47)	(2.11)	(2.03)	(2.72)
T11	3.51	3.73	2.38	2.36	2.66
	(11.89)	(13.64)	(5.17)	(5.11)	(6.68)
SEm ±	0.04	0.05	0.03	0.02	0.02
	(0.54)	(0.32)	(0.22)	(0.18)	(0.14)
CD (P=0.05)	0.10	0.14	0.07	0.06	0.07
	(1.55)	(0.91)	(0.62)	(0.50)	(0.39)

Values are $\sqrt{x + 0.5}$ transformed and actual values are in parentheses

Table 2: Effect of herbicides and nutrient management on Dicot weed density in soybean at 60 DAS (Pooled data).

Treatments	*Amaranthus viridis*	*Digera arvensis*	*Physalis minima*	*Corchorus olitorius*	*Trianthema portulacastrum*
T1	4.70	5.24	4.34	4.67	6.66
	(21.72)	(27.00)	(18.47)	(21.34)	(43.94)
T2	1.89	2.19	1.54	2.06	2.20
	(3.15)	(4.31)	(1.89)	(3.78)	(4.41)
T3	2.72	3.20	2.80	3.20	3.91
	(6.94)	(9.78)	(7.33)	(9.77)	(14.86)
T4	3.90	3.96	3.57	3.89	4.72
	(14.72)	(15.17)	(12.25)	(14.61)	(21.83)
T5	2.17	2.61	2.60	1.98	2.53
	(4.26)	(6.39)	(6.28)	(3.44)	(5.91)
T6	2.74	3.48	2.90	3.29	3.91
	(7.01)	(11.64)	(7.92)	(10.35)	(14.78)
T7	3.78	3.98	3.59	3.84	4.56
	(13.83)	(15.39)	(12.38)	(14.28)	(20.83)
T8	1.14	1.28	1.35	1.89	1.51
	(0.81)	(1.17)	(1.37)	(3.10)	(1.80)
T9	2.12	2.24	2.39	2.26	2.15
	(4.00)	(4.56)	(5.22)	(4.61)	(4.11)
T10	1.09	1.21	1.18	1.82	1.45
	(0.72)	(1.00)	(0.90)	(2.83)	(1.61)
T11	2.07	2.28	2.41	2.37	2.18
	(3.83)	(4.72)	(5.35)	(5.16)	(4.28)
SEm ±	0.02	0.03	0.02	0.02	0.02
	(0.17)	(0.16)	(0.18)	(0.14)	(0.29)
CD (P=0.05)	0.06	0.08	0.07	0.06	0.07
	(0.50)	(0.46)	(0.51)	(0.41)	(0.82)

Values are $\sqrt{x + 0.5}$ transformed and actual values are in parentheses.

Table 3: Effect of herbicides and nutrient management on total density, total dry matter and weed control efficiency in soybean at 60 DAS (Pooled data).

Treatments	Weed density (m^{-2}) (root transformed)			Weed dry matter ($g\ m^{-2}$)			WCE (%) at 60 DAS		
	Monocot	Dicot	Total	Monocot	Dicot	Total	Monocot	Dicot	Total
T1	12.76	11.53	17.19	545.86	580.94	1126.79	-	-	-
T2	5.67	4.24	7.05	103.91	52.33	156.24	81.10	91.17	86.30
T3	7.18	7.01	10.01	348.27	225.07	573.34	36.51	61.18	49.23
T4	6.65	8.89	11.08	263.26	322.59	585.85	51.88	44.36	48.02
T5	6.82	5.17	8.53	218.98	185.04	404.02	60.20	68.06	64.25
T6	9.78	7.22	12.14	382.90	289.54	672.43	29.20	49.97	39.94
T7	6.60	8.78	10.96	220.88	316.90	537.78	59.42	45.41	52.23
T8	4.10	2.95	5.01	71.87	34.96	106.83	86.55	94.00	90.39
T9	6.23	4.79	7.83	183.52	119.35	302.87	66.25	79.40	73.06
T10	3.69	2.75	4.55	53.91	32.56	86.48	90.10	94.40	92.32
T11	6.55	4.88	8.14	179.65	121.45	301.10	67.30	79.15	73.43
SEm ±	0.04	0.02	0.04	3.38	1.76	4.10	-	-	-
CD (P=0.05)	0.11	0.07	0.11	9.66	5.02	11.71	-	-	-

Table 4: Effect of herbicides and nutrient management on nutrient removal by weeds at harvest (Pooled data).

Treatments	N uptake ($kg\ ha^{-1}$)			P uptake ($kg\ ha^{-1}$)			K uptake ($kg\ ha^{-1}$)			S uptake ($kg\ ha^{-1}$)		
	Monocot	Dicot	Total	Monocot	Dicot	Total	Monocot	Dicot	Total	Monocot	Dicot	Total
T1	49.38	88.48	137.86	8.27	13.02	21.29	65.50	67.49	132.99	2.36	6.40	8.76
T2	11.95	16.73	28.68	2.09	2.38	4.47	15.74	11.70	27.44	0.57	1.20	1.77
T3	26.50	38.30	64.79	4.77	5.44	10.21	35.90	27.66	63.56	1.29	2.80	4.09
T4	18.88	52.20	71.07	3.32	7.54	10.86	25.14	38.20	63.34	0.85	3.86	4.71
T5	14.58	31.13	45.71	2.68	4.49	7.16	20.24	22.50	42.74	0.74	2.32	3.06
T6	29.55	44.51	74.06	5.13	6.40	11.53	39.63	32.47	72.10	1.42	3.23	4.65
T7	18.92	49.44	68.36	3.26	6.93	10.19	25.68	37.23	62.91	0.93	3.58	4.51
T8	7.77	8.60	16.37	1.35	1.20	2.55	10.29	5.89	16.19	0.33	0.62	0.95
T9	14.62	16.59	31.21	2.69	2.40	5.09	20.20	12.13	32.33	0.80	1.21	2.01
T10	7.06	7.33	14.39	1.20	1.04	2.25	9.52	5.20	14.72	0.32	0.54	0.86
T11	15.58	19.39	34.97	2.81	2.79	5.60	22.12	14.64	36.76	0.82	1.42	2.25
SEm ±	0.46	0.79	0.88	0.11	0.08	0.12	0.48	0.44	0.77	0.04	0.05	0.06
CD (P=0.05)	1.33	2.25	2.51	0.32	0.22	0.33	1.38	1.27	2.22	0.11	0.14	0.18

Table 5: Effect of herbicides and nutrient management on yield attributes, yield and economics of soybean (Pooled data of year 2015 and 2016).

Treatments	Pods $plant^{-1}$	Pod yield (g $plant^{-1}$)	Seeds pod^{-1}	Test weight (g)	Seed yield ($kg\ ha^{-1}$)	Haulm yield ($kg\ ha^{-1}$)	Biological yield ($kg\ ha^{-1}$)	Harvest Index (%)	Net Return (₹ ha^{-1})	B:C Ratio
T1	23.44	5.58	2.17	102.36	934	1291	2225	42.01	9352	0.43
T2	41.11	10.13	2.78	119.67	2034	2842	4876	41.71	39860	1.45
T3	27.83	5.99	2.39	105.04	1494	2028	3522	42.39	20089	0.86
T4	33.06	7.81	2.44	110.97	1711	2399	4111	41.64	33123	1.41
T5	37.61	9.17	2.56	112.67	1829	2528	4357	41.97	36864	1.56
T6	28.67	6.64	2.22	106.65	1557	2143	3700	42.10	29417	1.33
T7	38.11	7.90	2.61	112.39	1818	2425	4243	42.91	37781	1.69
T8	42.06	10.22	2.94	120.32	2046	2885	4931	41.50	43360	1.78
T9	38.61	9.28	2.28	118.81	1879	2692	4572	41.02	41305	1.77
T10	43.72	10.45	3.00	120.82	2271	3127	5398	42.06	51550	2.20
T11	38.56	9.26	2.28	118.75	1862	2602	4464	41.65	39982	1.76
SEm ±	0.30	0.03	0.16	0.74	30	30	50	0.44	915	0.04
CD (P=0.05)	0.86	0.10	NS	2.13	86	86	144	NS	2615	0.12

Various authors have also reported improved yield attributed with reduced weed density and dry matter Peer *et al.*, (2014) and Tuti *et al*. (2015).

CONCLUSION

Tank mix post-emergence application of propaquizafop (75 g ha^{-1}) + Imazethapyr (75 g ha^{-1}) at 21 DAS gave the highest seed yield (2271 kg ha^{-1}), net returns (Rs. 51550 ha^{-1}) and B:C ratio (2.20) on pooled basis (Table 6). Therefore, it is concluded that the soybean crop grown with post-emergence tank mix application of propaquizafop (75 g ha^{-1}) + Imazethapyr (75 g ha^{-1}) at 21 DAS to get maximum grain yield and net return.

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