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Bio-efficacy of new molecules of herbicides for weed management in soybean (*Glycine max* L. Merril)

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Abstract
A field experiment was conducted to study the bio-efficacy of new molecules of herbicides for weed management in soybean during two consecutive *rabi s*eason of 2017 and 2018 at AICRP-Weed Management, B. A. College of Agriculture, Anand Agricultural University, Anand on loamy sand soil. IC *fb* HW at 20 and 40 DAS followed by imazethapyr 100 g/ha PoE *fb* IC+HW at 30 DAS, pendimethalin 750 g/ha PE *fb* IC+HW at 30 DAS, quizalofop-ethyl 50 g/ha PoE *fb* IC+HW at 30 DAS, pendimethalin + imazethapyr 960 g/ha PE (PM) *fb* HW at 30 DAS, clomazone 1000 g/ha PE *fb* IC+ HW at 30 DAS and diclosulam 25.2 g/ha PE *fb* IC+HW at 30 DAS recorded significantly lower density and dry weight of weeds and also recorded more than 94 per cent of weed control efficiency at harvest and also found superior in respect of recorded significantly higher growth, yield attributes and yield of soybean.

Keywords: Soybean, WCE, new molecules, yield

Introduction

Soybean (*Glycine max* L. Merril) is the world's most important seed legume, which contributes about 25 per cent of the global edible oil and two-thirds of the world's protein concentrate for livestock feeding. Soybean called as wonder crops because it is richest, cheapest and easiest source of best quality protein and fat and having a multiplicity of uses as food and industrial products. Being a slow growing crop, due to late development of canopy, weeds compete severely during initial growing stage of the crops. Also heavy infestation of weeds in the crops leads to reduce the efficiency of harvest and also reduced the yield. Hence, untimely and poor weed management adversely affects proper growth and yield of soybean. According to the Kundu *et al.* (2011) [5] yield losses of soybean due to the presence of weeds was to the extent of 43 per cent which indicates the necessity of timely control of weed for exploiting the potential yield of soybean. The conventional method of weed control is time consuming, expensive and laborious, under such circumstances it is more favourable to use chemicals due to scarcity of human labour during peak season and to obtain higher weed control efficiency and economic returns from the cultivation of soybean. Tiwari and Mathew (2002) found that application of propaquizafop (50 g/ha) provide an effective control of grassy weeds in soybean. Application of herbicides alone or in combination with mechanical weeding found quite effective in controlling weeds and increasing the yield of soybean. Further, introduction and availability of newer molecules of post-emergence (PoE) herbicide offered options to the farmers for efficient weed management. Keeping in above view the present experiment was conducted to study the bio-efficacy of new molecules of herbicides for weed management in soybean.

Materials and methods

A field investigation was conducted during two consecutive *rabi s*eason of the year 2017 and 2018 at AICRP-Weed Management, B. A. College of Agriculture, Anand Agricultural University, Anand (Gujarat). The soil of the experimental field was loamy sand in texture having low in available nitrogen and medium in available phosphorus and high in potassium with pH 8.0. The experiment was laid out in a randomized lock design with three replications. Experiment comprised of twelve treatment *viz.*, T_1: Pendimethalin 750 g/ha PE *fb* IC+HW at 30 DAS, T_2: Clomazone 1000 g/ha PE *fb* IC+ HW at 30 DAS, T_3: Diclosulam 25.2 g/ha PE *fb*

IC+HW at 30 DAS, T_4: Pendimethalin + imazethapyr 960 g/ha PE (PM) *fb* HW at 30 DAS, T_5: Quizalofop-ethyl 50 g/ha PoE *fb* IC+HW at 30 DAS, T_6: Imazethapyr 100 g/ha PoE *fb* IC+HW at 30 DAS, T_7: Imazethapyr + imazamox 70 g/ha PoE (PM), T_8: Propaquizafop-p-butyl + imazethapyr 125 g/ha PoE (PM), T_9: Sodium acefluorfen + clodinafop propargyl 245 g/ha PoE (PM), T_{10}: Fluazifop-p-butyl + fomesafen 250 g/ha 250 g/ha (PM), T_{11}: IC *fb* HW at 20 & 40 DAS and T_{12}: Weedy check. The soybean variety NRC 37 was sown in the experimental field on 12 and 03 July 2017 and 2018, respectively keeping the row to row distance of 45 cm. The crop was fertilized with 30 kg N/ha and 60 kg P_2O_5/ha wherein, entire quantity of nitrogen and phosphorous were applied as basal dose in the form of urea and single super phosphate at the time of sowing directly in the furrow. Herbicides were applied as per the treatment with the help of a Knapsack sprayer fitted with flat fan nozzle with a spray volume of 600 l/ha. Other mechanical treatment was also imposed as per the treatment. The other recommended packages of practices were followed throughout the growing season to raise the crop during both the years of experimentation. Periodical weed density and dry biomass of weeds were recorded from the randomly selected four spots by using 0.25 m^2 iron quadrate from net plot area. Weed control efficiency (WCE) was calculated on the basis of standard formula as suggested by Maity and Mukherjee (2011) [7].

The weed control efficiency was calculated by using the following formula:

$$\text{WCE (\%)} = \frac{\text{DWC - DWT}}{\text{DWC}} \times 100$$

Where, WCE = Weed control efficiency in percent,
DWC = Dry matter weight of weed in control plot and
DWT = Dry matter weight of weed in treated plot

Observation on seed and haulm yield of soybean was recorded from the net plot area and converted in to hectare. Data on various parameters recorded during the course of investigation was statistically analyzed as per the standard procedure suggested by Cochran and Cox (1957).

Results and discussion

Weed flora

In general, dominancy of monocot weed (59.8%) was observed during both the years of experimental period. Major weeds observed in the experimental field were *Eleusine indica* (29.4%), *Digitaria sanguinalis* (10.6%), *Commelina benghalensis* (7.94%) and *Dactyloctenium aegyptium* (11.2%) in monocot weeds category whereas, *Odlelandia umbellate* (19.8%), *Digera arvensis* (6.61%), *Phyllanthus niruri* (2.65%) and *Trianthema monogyna* (1.85%) in dicot weed category**.**

Effect on weed

The results of an experiment indicated that different weed management practices significantly altered the density and dry biomass of weeds at 25 and 50 DAS (Table 1). Among herbicidal treatments, density of weeds was recorded significantly lower under propaquizafop-p-butyl + imazethapyr 125 g/ha PoE (PM) but it was at par with all other treatments except application of clomazone 1000 g/ha PE *fb* IC +HW at 30 DAS and weedy check at 25 DAS. Among mechanical treatment, IC *fb* HW carried out at 20 and 40 DAS provided cent per cent control of weeds at 25 DAS. However, at 50 DAS significantly lower weed density (3.83/m^2) was recorded under application of imazethapyr 100 g/a PoE *fb* IC +HW at 30 DAS as compared to diclosulam 25.2 g/ha PE *fb* IC + HW at 30 DAS, imazethapyr + imazamox 70 g/ha PoE (PM), propaquizafop-p-butyl + imazethapyr 125 g/ha PoE (PM), sodium acefluorfen + clodinafop propargyl 245 g/ha PoE (PM), fluazifop-p-butyl + fomesafen 250 g/ha PoE (PM) and weedy check. The results are in accordance with the findings of Gupta and Chandrakar (2014) [3] and Bali *et al*. (2016) [1] they reported that post emergence application of imazethapyr followed by hoeing at 35 DAS significantly reduced the density and dry weight of weeds in soybean. With regards to weed dry biomass, application of imazethapyr 100 g/ha *fb* IC +HW at 30 DAS, imazethapyr + imazamox 70 g/ha PoE (PM), propaquizafop-p-butyl + imazethapyr 125 g/ha PoE (PM) and sodium acefluorfen + clodinafop propargyl 245 g/ha PoE (PM) remain at par with each other but recorded significantly lower dry biomass of total weeds as compared to rest of the treatments. Lal *et al*. (2017) [6] also reported that post emergence application of propaquizafop + imazethapyr mixture at the lowest dose caused appreciable reduction in the density and biomass of weeds over weedy check. Among mechanical treatment, IC *fb* HW carried out at 20 and 40 DAS provided cent per cent control of weeds hence, no weed dry biomass was observed under this treatment. At 50 DAS and at harvest, significantly lower dry biomass of total weeds was recorded under imazethapyr 100 g/ha PoE *fb* IC +HW at 30 DAS as compared to rest of the treatments except application of imazethapyr imazamox 70 g/ha PoE (PM), propaquizafop-p-butyl + imazethapyr 125 g/ha PoE (PM), sodium acefluorfen + clodinafop propargyl 245 g/ha PoE (PM), fluazifop-p-butyl + fomesafen 250 g/ha PoE (PM) and weedy check. Effective control of grasses and non-grassy weeds with application of PoE herbicide Fluazifop-p-butyl + Fomesafen was also reported by Singh *et al*. (2014) and Kadam *et al*. (2018). Among all the weed management practices, weedy check recorded significantly the highest dry biomass of total weeds at harvest. All the weed management practices recorded more than 95 per cent weed control efficiency except imazethapyr + imazamox 70 g/ha PoE (PM), propaquizafop-p-butyl + imazethapyr 70 g/ha PoE (PM), sodium acefluorfen + clodinafop propargyl 245 g/ha PoE (PM), fluazifop-p-butyl + fomesafen 250 g/ha PoE (PM) which recorded weed control efficiency range from 50 to 76 per cent.

Table 1: Density, dry biomass of weed and weed control efficiency as influenced by weed management practices (Mean of two years)

Treatment	Weed density (No./m²)		Weed dry biomass (g/m²)			WCE (%)
	25 DAS	50 DAS	25 DAS	50 DAS	At harvest	At harvest
T_1: Pendimethalin 750 g/ha PE *fb* IC+HW at 30 DAS	9.95^{bcd} (101)	7.10^{bcd} (50.0)	8.09^{b} (65.9)	5.75^{d} (36.1)	5.24^{cd} (45.1)	95.3
T_2: Clomazone 1000 g/ha PE *fb* IC+ HW at 30 DAS	12.6^{abc} (159)	7.85^{bcd} (61.4)	6.86^{bcd} (46.7)	5.64^{d} (33.7)	5.51^{cd} (50.0)	94.8
T_3: Diclosulam 25.2 g/ha PE *fb* IC+HW at 30 DAS	12.6^{abc} (161)	8.24^{bc} (67.4)	6.80^{bcd} (49.3)	6.97^{d} (54.9)	5.56^{cd} (51.5)	94.6
T_4: Pendimethalin + imazethapyr 960 g/ha PE (PM) *fb* HW at 30 DAS	8.25^{bcd} (75.5)	7.01^{bcd} (48.7)	5.92^{bcd} (34.4)	4.60^{d} (21.8)	5.44^{cd} (48.6)	94.9
T_5: Quizalofop-ethyl 50 g/ha PoE *fb* IC+HW at 30 DAS	13.9^{ab} (204)	8.02^{bcd} (62.0)	7.67^{bc} (59.0)	5.39^{d} (23.2)	6.63^{cd} (46.7)	95.1
T_6: Imazethapyr 100 g/ha PoE *fb* IC+HW at 30 DAS	5.22^{de} (28.7)	3.83^{d} (14.7)	4.18^{cde} (16.9)	3.58^{d} (12.3)	4.15^{d} (26.6)	97.2
T_7: Imazethapyr + imazamox 70 g/ha PoE (PM)	6.06^{cde} (50.7)	9.58^{b} (96.0)	4.10^{cde} (19.4)	12.2^{bc} (138)	15.1^{b} (353)	63.0
T_8: Propaquizafop-p-butyl + imazethapyr 125 g/ha PoE (PM)	4.57^{de} (25.4)	8.67^{bc} (76.0)	3.70^{de} (14.8)	11.6^{c} (130)	11.8^{bc} (224)	76.5
T_9: Sodium acefluorfen + clodinafop propargyl 245 g/ha PoE (PM)	7.90^{bcd} (62.7)	10.3^{b} (107)	4.91^{bcd} (23.1)	16.0^{b} (255)	17.0^{b} (474)	50.4
T_{10}: Fluazifop-p-butyl + fomesafen 250 g/ha 250 g/ha (PM)	6.31^{cde} (40.0)	10.4^{b} (109)	5.61^{bcd} (31.6)	14.3^{bc} (215)	17.1^{b} (292)	69.4
T_{11}: IC *fb* HW at 20 & 40 DAS	1.00^{e} (0.00)	5.09^{cd} (26.0)	1.00^{e} (0.00)	4.15^{d} (16.6)	4.53^{cd} (22.3)	97.7
T_{12}: Weedy check	19.5^{a} (378)	15.4^{a} (256)	13.4^{a} (181)	21.8^{a} (483)	26.1^{a} (955)	-
S. Em.$\pm$	2.04	1.31	1.15	1.20	2.31	-
CD (P=0.05)	6.34	4.08	3.58	3.72	7.18	-
CV%	8.7	10.2	7.9	9.0	10.6	-

Note: Data subjected to $(\sqrt{x+1})$ transformation. Figures in parentheses are means of original values.

Table 2: Growth, yield attributes and yield of soybean as influenced by weed management practices (Mean of two years)

Treatment	Plant stand (No./m row length)		Plant height (cm)			Number of pods/ plant	Seed index (%)	Seed yield (kg/ha)	Haulm yield (kg/ha)
	15 DAS	At harvest	30 DAS	60 DAS	At harvest				
T_1: Pendimethalin 750 g/ha PE *fb* IC+HW at 30 DAS	8.03	7.00^{a}	24.7	54.9	70.6	144^{ab}	9.33^{ab}	2.58^{ab}	3.27^{a}
T_2: Clomazone 1000 g/ha PE *fb* IC+ HW at 30 DAS	8.00	6.93^{a}	25.0	57.5	74.3	148^{a}	9.20^{ab}	2.63^{ab}	3.34^{a}
T_3: Diclosulam 25.2 g/ha PE *fb* IC+HW at 30 DAS	8.37	7.13^{a}	23.6	54.1	72.3	143^{ab}	9.45^{ab}	2.62^{ab}	3.26^{a}
T_4: Pendimethalin + imazethapyr 960 g/ha PE (PM) *fb* HW at 30 DAS	8.47	7.37^{a}	25.7	60.7	72.0	137^{ab}	9.26^{ab}	2.66^{a}	3.39^{a}
T_5: Quizalofop-ethyl 50 g/ha PoE *fb* IC+HW at 30 DAS	8.10	7.20^{a}	24.1	54.8	65.2	133^{abc}	8.93^{b}	2.36^{abc}	2.90^{ab}
T_6: Imazethapyr 100 g/ha PoE *fb* IC+HW at 30 DAS	8.67	7.43^{a}	24.4	57.9	77.0	135^{ab}	9.43^{ab}	2.68^{a}	3.46^{a}
T_7: Imazethapyr + imazamox 70 g/ha PoE (PM)	8.23	6.90^{a}	24.3	52.6	70.2	126^{bc}	8.86^{b}	2.16^{bc}	2.76^{ab}
T_8: Propaquizafop-p-butyl + imazethapyr 125 g/ha PoE (PM)	8.53	7.47^{a}	23.3	57.3	73.8	138^{ab}	9.42^{ab}	2.58^{ab}	3.25^{a}
T_9: Sodium acefluorfen + clodinafop propargyl 245 g/ha PoE (PM)	8.30	7.17^{a}	22.4	55.2	71.1	116^{c}	8.90^{b}	1.96^{c}	2.38^{b}
T_{10}: Fluazifop-p-butyl + fomesafen 250 g/ha 250 g/ha (PM)	8.17	7.03^{a}	23.2	59.1	74.4	136^{ab}	9.35^{ab}	2.51^{ab}	2.98^{ab}
T_{11}: IC *fb* HW at 20 & 40 DAS	8.73	7.33^{a}	23.4	54.7	75.4	138^{ab}	9.68^{a}	2.73^{a}	3.44^{a}
T_{12}: Weedy check	7.83	4.67^{b}	23.0	59.0	65.3	34.8^{d}	7.63^{c}	0.343^{d}	0.557^{c}
S. Em.$\pm$	0.279	0.358	1.23	2.17	3.59	5.74	0.198	0.142	0.243
CD (P=0.05)	NS	1.11	NS	NS	NS	17.9	0.560	0.440	0.760
CV%	8.0	6.9	4.8	9.3	6.6	5.7	5.7	9.3	11.2

Effect on crop

Plant stand of soybean recorded at 15 DAS was found to be non significant however, it was significant at harvest due to different weed management practices (Table 2). At harvest, plant stand under all the weed management practices was statistically similar however; weedy check recorded significantly the lowest plant stand. Lower plant stand under weedy check might be due to severe infestation of weeds. Plant height of soybean measured periodically was found to be non significant due to different weed management practices. Results further indicated that significantly higher number of pods/plant (148/plant) was recorded under application of clomazone 1000 g/ha PE *fb* IC +HW at 30 DAS as compared to application of imazethapyr + imazamox 70 g/ha PoE (PM), sodium acefluorfen + clodinafop propargyl 245 g/ha PoE (PM) and weedy check. Significantly the lowest number of pods/plant (34.8/plant) was recorded under weedy check. Further, it was observed that seed index (9.68%), seed and haulm yield (2.68 and 3.46 t/ha, respectively) but it was at par with diclosulam 25.2 g/ha PE *fb* IC+HW at 30 DAS, imazethapyr 100 g/ha PoE *fb* IC+HW at 30 DAS, pendimethalin + imazethapyr 960 g/ha PE (PM) *fb* HW at 30 DAS and propaquizafop-p-butyl + imazethapyr 125 g/ha PoE (PM). Parmar *et al*. (2016) [9] also reported that twice hand weeding treatment recorded maximum seed yield of soybean than other treatments. Further, effectiveness of pendimethalin + imazethapyr might be due to pre-emergence application of pendimethalin which prevented emergence of monocot and grassy weeds by inhibiting root and shoot growth while imazethpyr was responsible for inhibition of acetolactate synthases (ALS) or acetohydroxyacide synthesis (AHAS) in broad-leaves which caused destruction of these weeds in 3-4 leaf stage and remaining weeds was control by manual weeding. Meena *et al*. (2018) [8] also observed that application of pendimethalin 30% EC + imazethapyr 2% SL premix 960 g/ha as PE recorded higher seed yield of soybean but it was at par with other herbicidal treatments. Among herbicidal treatment, significantly lower seed and haulm yield (1.96 and 2.38 t/ha, respectively) was recorded under application of sodium acefluorfen + clodinafop propargyl 245 g/ha PoE (PM) but was remain at par with quizalofop-ethyl 50 g/ha PoE *fb* IC +HW at 30 DAS and imazethapyr + imazamox 70 g/ha PoE (PM). Weedy check registered significantly the lowest seed and haulm yield (0.343 and 0.557 t/ha, respectively) of soybean.

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