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RESEARCH NOTE

Efficacy of pre-and post-emergence herbicides on weed dynamics, growth and yield of soybean

Pranali Kotnake and V.V. Goud*

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ABSTRACT

A field investigation was conducted at AICRP on Weed Management Farm, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The experiment was laid out in a randomized block design with three replications and twelve treatments. Among the herbicidal treatments, diclosulam 84% WDG 0.026 kg/ha and sulfentrazone 28% + clomazone 30% WP 0.725 kg/ha (ready mix) as pre-emergence were found effective in controlling sedges, monocot and dicot weeds across the crop growth period along with lowest weed dry matter accumulation, maximum weed control efficiency, lowest weed index and higher seed yield and economics in soybean. Mulching with wheat straw 5t/ha recorded statistically comparable yield over the application of post-emergence herbicide treatments.

Keywords: Diclosulam, Flumioxazin, Soybean, Sulfentrazone + Clomazone, Weed management

Soybean (*Glycine max* L.) often designated as a miracle crop of the twenty-first century, contains about 20% of oil, 40% high-quality proteins, 23% carbohydrates and reasonable amounts of minerals, vitamins, and dietary fibers. Since the yield per unit for many conventional crops has perhaps come to a plateau, the search for unconventional sources of protein-rich food and edible oil supply is a necessity and soybean seems the only crop at present, that has the potential to meet the present and future needs of the world for protein and edible oil. Among the various factors responsible for the low productivity of soybeans, weed infestation during the early stages of growth is a major concern. The losses caused by weeds exceed the losses from any other category of biotic factors like insects, nematodes, rodents, *etc*. In *Kharif* (rainy) season, there is high rainfall which does not permit hand-weeding operations timely resulting in yield loss of up to 30-80% (Yaduraju 2002). Thus, intense weed competition is one of the main constraints for increasing soybean productivity. Soybean crop grows slowly during the initial period, which results in vigorous growth and proliferation of weeds. Pre- and post-emergence weed control method is becoming popular and regarded potentially as one of the most labour-saving innovations in modern agriculture. Spraying of pre-emergence herbicides helps to minimize the crop weed competition during initial critical growth stages resulting in higher crop yields. Several herbicides used in soybean reported *viz.* broad-spectrum pre-plant incorporation (PPI); pendimethalin (Malik *et al.* 2006), pre-emergence (PE); diclosulam, flumioxazin, (Hosmath *et al.* 2009) and post-emergence (PoE); herbicides imazethapyr, quizalofop-ethyl, sodium acifluorfen. These herbicides could be used in fields with the least risk of crop yield loss. However, in many instances weeds flourish even after a critical period of crop-weed competition and it is difficult to control these weeds through cultural operation due to unfavorable conditions. Hence, it is imperative to give season-long weed control in soybeans.

A field investigation was conducted at AICRP on Weed Management Farm, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola to study the relative performance of different herbicides on weed flora in Soybean. The soil of the experimental field was characterized as clayey in texture, having slightly alkaline pH (7.80), moderate organic carbon status (0.46%), low nitrogen content (178 kg/ha), medium available phosphorus content (17.05 kg/ha) and high potassium status (384 kg/ha). Soybean cv '*PDKV Yellow Gold'* was sown on broad-bed and furrow on 18 June 2021 with row-to-row spacing of 45 cm and fertilizer use of 30:60:30 NPK kg/ha as basal and the crop was harvested on 7 October 2021. The total rainfall received during the crop growth period was 850 mm. The experiment was laid out in a randomized block design with three replications with 12 treatments. The treatments comprised of flumioxazin 50% SC 0.125 kg/ha, diclosulam 84% WDG 0.026 kg/ha, pendimethalin

AICRP on Weed management, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Punjab (444104), India

* Corresponding author email: vikasgoud08@yahoo.com

38.7% CS 0.677 kg/ha, pendimethalin 30% + imazethapyr 2% EC 0.960 kg/ha (ready mix), sulfentrazone 28% + clomazone 30% WP 0.725 kg/ha (ready mix), pendimethalin 30% EC + diclosulam 84% WDG 0.750 + 0.0252 kg/ha (tank mix), sodium acifluorfen 16.5% + clodinafop-propargyl 8% EC 0.245 kg/ha as PoE (ready mix), quizalofop-ethyl 10% EC + chlorimuron-ethyl 25% WP 0.037+0.009 + 0.2% surfactant kg/ha as PoE at (ready mix), fomesafen 12% + quizalofop-ethyl 3% SC 0.225 kg/ha as PoE at (ready mix), mulching (wheat straw) 5 t/ha, farmer's practice (two hand weeding at 15 and 30 DAS and one hoeing 20 DAS) and weedy check. All the pre-emergence herbicides were applied on the same day after sowing of crop seed and post-emergence herbicides were applied at the 2-3 leaf stage (25 DAS). The data on weed density (no./m^2) and weed biomass were assessed on the intensity and growth of the weeds at 20, 40 and 60 DAS. The number of weeds in a quadrate of 0.25 m^2 at two random spots in each plot was counted from net plot area and converted into one m^2. The entire weeds inside the quadrate were uprooted and cut close to the transition of root and shoot in each plot and collected for dry matter accumulation. The samples were first dried in the sun and kept in an oven at 70 ºC for 48 hours. The dried samples were weighed and expressed as dry biomass (g/m^2). Square root transformation was done for weed density and weed biomass by using the formula. Weed control efficiency (WCE) refers to the efficiency of treatment expressed in percent for controlling weeds in comparison to weedy check. Weed index refers to the reduction in the yield due to the presence of weeds in comparison with weed-free check.

Weed Flora: The density of dicot weeds was much higher than that of monocot weeds throughout the crop-growing season. Among dicot, the density of *Euphorbia* sp., *Parthenium hysterophorus*, *Phyllanthus niruri, Acalypha indica, Digeria arvensis* and with respect to monocot *Commelina benghalensis*, *Cynodon dactylon, Digiteria sanguinalis, Euphorbia geniculate, Rottboelia cochinchinensis, Eleusine indica, Dinebra retroflexa* and among sedges, *Cyperus rotundus* were predominant weeds in the experimental plots. Similar findings were recorded in several previous studies reports by Shashidhar *et al*. (2020) regarding weed flora existence in the experimental plots.

Weed density: Weed density at 60 DAS was higher as compared to those recorded at 20 and 40 DAS irrespective of the species. The weed intensity of all species was significantly reduced by the application of herbicides either applied pre- or post-emergence at all stages (20, 40 and 60 DAS) of crop growth over the weedy check (**Table 1**). The results showed that hand weeding at 15 and 30 DAS and one hoeing at 20 DAS was significantly better concerning control of different weed species. Diclosulam was most effective in controlling the broad spectrum of weed flora. It was observed that the application of sulfentrazone 28% + clomazone 30% WP 0.725 kg/ha (RM) as pre-emergence effectively controlled the sedge density. Herbicides initially inhibited the germination of weeds but later these dissipated and deactivated in the soil increasing the next flush of weeds subsequently. These results conformed with the findings of Mansoori *et al*. (2015). Many researchers (Krauz and Young 2003, Andhale and Kathmale 2019) have reported lower sedge densities in soybean with the use of herbicides like sulfentrazone 28% + clomazone 30% WP 0.725 kg/ha. Poornima *et al*. (2018) reported that the application of diclosulam 84% WDG 0.026 kg/ha as pre-emergence effectively controlled both monocot and dicot weeds.

Weed dry matter: The dry matter accumulation of weeds (g/m^2) increased with the increasing weed density as well as the variation of weed species and their growth. The highest weed dry matter was achieved under weedy check at 20, 40 and 60 DAS (**Table 2**) and the lowest weed dry matter was recorded in farmer's practice. Among herbicidal treatments, diclosulam 84% WDG 0.026 kg/ha as pre-emergence resulted in maximum weed dry matter reduction of monocot and dicot. However, the application of sulfentrazone 28% + clomazone 30% WP 0.725 kg/ha (RM) as pre-emergence effectively reduced the dry matter accumulation of sedges. The effect of herbicides applied as pre-emergence was subdued at this belated stage, which might be on account of a longer period after application and restricted effective residual period. These results conform with Gupta *et al*. (2017).

Weed indices: The highest weed control efficiency (%) and minimum weed index (%) were achieved by the application of diclosulam 84% WDG 0.026 kg/ha as pre-emergence which was followed by sulfentrazone 28% + clomazone 30% WP 0.725 kg/ha (RM) (**Table 3**). Higher weed control efficiency and lower weed index in these treatments might be due to the lower dry weight of weeds and higher seed yield, respectively. Weed competition was significantly reduced by pre-emergence use of diclosulam, which was significantly superior to the remaining treatments suggesting that diclosulam offers greater reduction of grasses, sedges and broad-leaved weeds and there is a positive effect of herbicide application on crop yield. It confirms the findings of Singh *et al*. (2019).

Seed yield: Data related to the seed yield of soybeans was significantly influenced by various weed control

Table 1. Weed density (no./m²) as influenced by different weed control treatments

Treatment	Sedges			Monocots			Dicots			Total		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Flumioxazin 0.125 kg/ha	3.24 (10.00)	5.59 (30.70)	5.37 (28.33)	3.24 (9.99)	3.63 (12.67)	5.18 (26.33)	1.35 (1.33)	3.24 (10.0)	2.92 (8.00)	4.67 (21.33)	7.34 (53.38)	7.95 (62.66)
Diclosulam 0.026 kg/ha	2.34 (5.00)	1.55 (1.90)	2.04 (3.67)	2.34 (4.97)	3.54 (12.02)	4.88 (23.31)	0.71 (0.00)	3.85 (14.3)	3.44 (11.33)	3.24 (9.98)	5.36 (28.23)	6.66 (43.81)
Pendimethalin 0.677 kg/ha	4.53 (20.00)	7.31 (33.00)	5.40 (28.67)	4.53 (20.02)	4.1 (16.31)	5.02 (24.70)	3.14 (9.33)	3.54 (12.0)	5.02 (24.67)	7.06 (49.35)	9.04 (81.31)	8.86 (78.04)
Pendimethalin + imazethapyr 0.960 kg/ha (RM)	2.55 (6.00)	1.67 (2.30)	1.78 (2.67)	2.55 (6.00)	5.46 (29.31)	1.58 (1.99)	1.78 (2.67)	4.02 (15.67)	5.05 (25.00)	3.90 (14.67)	6.91 (47.28)	5.24 (27.00)
Sulfentrazone + clomazone 0.725 kg/ha (RM)	2.12 (4.00)	0.83 (0.70)	0.71 (0.00)	2.12 (3.99)	4.3 (17.99)	4.67 (21.30)	0.71 (0.00)	4.06 (16.00)	4.80 (22.50)	2.91 (7.99)	5.93 (34.69)	6.23 (38.81)
Pendimethalin + diclosulam 0.750 + 0.0252 kg/ha (TM)	2.27 (4.67)	1.58 (2.00)	1.47 (1.67)	2.29 (4.74)	4.88 23.31	4.78 (22.34)	0.71 (0.00)	3.44 (11.33)	4.53 (20.00)	3.15 (9.41)	6.09 (36.64)	6.67 (44.02)
Sodium acifluorfen + clodinafop-propargyl 0.245 kg/ha as PoE (RM)	4.30 (18.00)	4.60 (20.70)	5.58 (30.67)	4.53 (20.02)	3.24 (9.99)	3.81 (14.01)	4.81 (22.67)	3.67 (13.00)	5.15 (26.00)	7.82 (60.69)	6.65 (43.70)	8.44 (70.69)
Quizalofop-ethyl + chlorimuron-ethyl WP 0.037+0.009 + 0.2% surfactant kg/ha as PoE at (RM)	4.22 (17.33)	3.35 (10.70)	4.10 (16.33)	4.22 (17.30)	4.3 (17.99)	3.85 (14.32)	5.58 (30.67)	4.95 (24.00)	5.93 (34.67)	8.11 (65.31)	7.29 (52.69)	8.11 (65.32)
Fomesafen + quizalofop-ethyl 0.225 kg/ha as PoE at (RM)	4.60 (20.67)	3.85 (14.33)	4.30 (18.00)	4.6 (20.66)	4.56 (20.29)	4.74 (21.96)	5.58 (30.67)	3.54 (12.00)	5.08 (25.33)	8.51 (72.00)	6.86 (46.62)	8.11 (65.30)
Mulching (wheat straw) 5 t/ha	3.03 (8.67)	2.41 (5.30)	5.12 (25.67)	3.03 (8.68)	4.22 (17.30)	1.96 (3.34)	2.92 (8.00)	4.95 (24.00)	5.37 (28.33)	5.08 (25.35)	6.86 (46.61)	7.61 (57.34)
Farmer's practice (2 HW at 15 and 30 DAS and hoeing 20 DAS)	1.47 (1.67)	1.34 (1.30)	1.70 (2.40)	1.45 (1.60)	1.58 (1.99)	1.78 (2.66)	1.35 (1.33)	1.82 (2.80)	1.70 (2.40)	2.26 (4.60)	2.57 (6.10)	2.82 (7.47)
Weedy check	5.46 (29.33)	6.26 (38.70)	6.10 (36.67)	5.46 (29.31)	5.73 (32.33)	6.10 (36.71)	6.15 (37.33)	7.60 (57.33)	6.79 (45.67)	9.82 (95.97)	11.35 (128.3)	10.93 (119.0)
LSD (p=0.05)	1.45	1.58	0.60	1.16	1.79	1.57	1.83	1.47	2.00	0.44	0.60	0.62

*Data subjected to $\sqrt{x+0.5}$ transformation and figure in parentheses are the original value.

Table 2. Weed dry weight (g/m²) as influenced by different weed control treatments

Treatment	Sedges			Monocots			Dicots			Total		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Flumioxazin 0.125 kg/ha	2.20 (4.33)	4.22 (17.30)	4.93 (23.81)	3.03 (8.67)	2.90 (7.90)	3.43 (11.26)	0.84 (0.20)	2.39 (5.20)	3.07 (8.95)	3.70 (13.20)	5.56 (30.40)	6.67 (44.02)
Diclosulam 0.026 kg/ha	1.94 (3.27)	2.15 (4.11)	2.85 (7.64)	1.97 (3.40)	1.96 (3.33)	3.05 (8.83)	0.71 (0.00)	1.69 (2.34)	2.91 (7.97)	2.68 (6.67)	3.21 (9.78)	4.99 (24.44)
Pendimethalin 0.677 kg/ha	3.68 (13.03)	5.58 (30.61)	5.17 (26.22)	3.13 (9.30)	1.81 (2.79)	3.41 (11.15)	2.61 (6.30)	2.80 (7.34)	3.95 (15.08)	5.40 (28.63)	6.42 (40.74)	7.28 (52.45)
Pendimethalin + imazethapyr 0.960 kg/ha (RM)	1.97 (3.38)	2.19 (4.29)	3.56 (12.14)	2.15 (4.12)	2.17 (4.23)	3.33 (10.60)	1.36 (1.35)	2.76 (7.12)	4.14 (16.60)	3.06 (8.85)	4.02 (15.64)	6.31 (39.34)
Sulfentrazone + clomazone 0.725 kg/ha (RM)	1.82 (2.82)	1.99 (3.45)	0.71 (0.00)	2.50 (5.75)	2.66 (6.59)	4.29 (17.89)	0.71 (0.00)	1.61 (2.09)	4.37 (18.56)	3.01 (8.57)	3.55 (12.13)	6.08 (36.45)
Pendimethalin + diclosulam 0.750 + 0.0252 kg/ha (TM)	2.84 (7.58)	2.51 (5.82)	4.05 (15.92)	2.26 (4.61)	2.68 (6.66)	3.69 (13.14)	0.71 (0.00)	2.00 (3.49)	4.16 (16.80)	3.56 (12.19)	4.06 (15.97)	6.81 (45.86)
Sodium acifluorfen + clodinafop-propargyl 0.245 kg/ha as PoE (RM)	4.14 (16.60)	4.25 (17.60)	5.78 (32.89)	2.48 (5.64)	2.35 (5.04)	2.57 (6.10)	3.35 (10.73)	2.60 (6.25)	2.94 (8.12)	5.79 (32.98)	5.42 (28.89)	6.90 (47.11)
Quizalofop-ethyl + chlorimuron-ethyl WP 0.037+0.009 + 0.2% surfactant kg/ha as PoE at (RM)	3.50 (11.77)	1.70 (2.41)	3.07 (8.90)	2.71 (6.87)	1.08 (0.67)	2.91 (7.96)	3.04 (8.75)	4.32 (18.13)	5.01 (24.58)	5.28 (27.39)	4.66 (21.21)	6.48 (41.44)
Fomesafen + quizalofop-ethyl 0.225 kg/ha as PoE at (RM)	3.86 (14.40)	3.23 (9.93)	3.66 (12.89)	2.43 (5.39)	3.66 (12.88)	3.80 (13.94)	3.04 (8.75)	2.19 (4.31)	2.76 (7.11)	5.39 (28.53)	5.26 (27.13)	5.87 (33.94)
Mulching (wheat straw) 5 t/ha	2.48 (5.65)	2.97 (8.29)	3.92 (14.89)	3.08 (8.98)	3.35 (10.70)	3.46 (11.50)	2.31 (4.84)	1.95 (3.31)	2.75 (7.09)	4.47 (19.47)	4.78 (22.30)	5.83 (33.48)
Farmer's practice (2 HW at 15 and 30 DAS and hoeing 20 DAS)	2.06 (3.67)	3.22 (9.85)	4.75 (22.04)	0.71 (0.00)	0.89 (0.30)	2.56 (6.05)	1.86 (2.95)	1.14 (0.81)	2.78 (7.23)	2.69 (6.71)	3.39 (10.96)	5.98 (35.32)
Weedy check	5.14 (25.90)	5.42 (28.90)	5.63 (31.23)	4.89 (23.44)	5.22 (26.77)	5.79 (32.98)	5.33 (27.89)	5.43 (29.00)	5.86 (33.82)	8.82 (77.23)	9.23 (84.67)	9.93 (98.03)
LSD (p=0.05)	0.39	1.83	2.67	1.07	1.74	1.85	1.11	1.37	1.99	0.36	0.58	0.59

treatments (**Table 3**). Pre-emergence herbicide application of diclosulam 84% WDG 0.026 kg/ha recorded higher seed yield and was found at par with all pre-emergence herbicides namely, sulfentrazone 28% + clomazone 30% WP 0.725 kg/ha (RM), pendimethalin 30% + imazethapyr 2% EC 0.960 kg/ha (RM), flumioxazin 50% SC 0.125 kg/ha and pendimethalin 30% EC + diclosulam 84% WDG 0.750 + 0.0252 kg/ha (TM) excluding pendimethalin 38.7% CS 0.677 kg/ha. However, among pre-emergence herbicide application of quizalofop-ethyl 10% EC + chlorimuron-ethyl 25% WP 0.037+0.009

Table 3. Weed control efficiency (WCE) and weed index, seed yield and economics of different weed control treatments

Treatment	Weed control efficiency (%)		Weed index (%)	Seed yield (t/ha)	Cost of cultivation (x10^3 `/ha)	Net monetary returns (x10^3 `/ha)	B:C
	20 DAS	40 DAS					
Flumioxazin 0.125 kg/ha	82.91	64.10	12.19	2.53	41.64	64.83	2.56
Diclosulam 0.026 kg/ha	91.36	88.45	0.00	2.88	41.70	79.37	2.90
Pendimethalin 0.677 kg/ha	62.93	51.88	16.71	2.40	40.00	60.91	2.52
Pendimethalin + imazethapyr 0.960 kg/ha (RM)	88.54	81.53	8.02	2.65	41.87	69.45	2.66
Sulfentrazone + clomazone 0.725 kg/ha (RM)	88.90	85.67	3.16	2.79	45.42	71.56	2.58
Pendimethalin + diclosulam 0.750 + 0.0252 kg/ha (TM)	84.21	81.14	12.99	2.51	41.48	63.77	2.54
Sodium acifluorfen + clodinafop-propargyl 0.245 kg/ha as PoE (RM)	57.30	65.88	17.33	2.31	40.49	59.71	2.47
Quizalofop-ethyl + chlorimuron-ethyl WP 0.037+0.009 + 0.2% surfactant kg/ha as PoE at (RM)	64.53	74.95	19.94	2.38	39.97	56.97	2.43
Fomesafen + quizalofop-ethyl 0.225 kg/ha as PoE at (RM)	63.05	67.96	18.62	2.34	40.58	58.09	2.43
Mulching (wheat straw) 5 t/ha	74.79	73.66	20.67	2.28	47.16	48.90	2.04
Farmer's practice (2 HW at 15 and 30 DAS and hoeing 20 DAS)	91.31	87.06	30.29	2.01	48.73	36.18	1.74
Weedy check	0.00	0.00	44.66	1.59	35.08	33.19	1.95
LSD (p=0.05)	--	--	--	0.38	--	15.36	--

+ 0.2% surfactant kg/ha (RM) recorded the highest seed yield. The lowest seed yield was recorded in the weedy check. The enhancement in the seed yield due to various weed control measures was because they helped to keep the field comparatively free from weeds. This consequently led to the production of more vigorous and healthy plants having more pod-bearing capacity, more seed per pod and 100-seed weight. The cumulative effect of all these resulted in higher seed yield, making it amply clear that these weed control measures exerted a profound influence in curtailing the weed population and thereby reducing the weed biomass at important growth stages of crop. The results corroborate the findings of Pandya *et al.* (2005).

Economics: Application of diclosulam 84% WDG 0.026 kg/ha as pre-emergence recorded significantly higher net monetary returns followed by sulfentrazone 28% + clomazone 0.725 kg/ha (RM), pendimethalin 30% + imazethapyr 0.960 kg/ha (RM), flumioxazin 0.125 kg/ha, pendimethalin + diclosulam 0.750 + 0.0252 kg/ha (TM) and pendimethalin 0.677 kg/ha (**Table 3**). Among post-emergence herbicides, the maximum net monetary return was recorded with quizalofop-ethyl + chlorimuron-ethyl 0.037+0.009 + 0.2% surfactant kg/ha, followed by fomesafen 12% + quizalofop-ethyl 0.225 kg/ha and sodium acifluorfen 16.5% + clodinafop-propargyl 0.245 kg/ha. The lowest net monetary returns were recorded in a weedy check. The higher net monetary return was mainly due to the lower cost of cultivation especially for labour wages engaged in spraying. Similar results were reported by Shruthi *et al.* (2015).

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