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Weed control efficiency and weed index in soybean as influenced by flumioxazin and its effect on succeeding green gram

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Abstract
A field experiment was conducted during *kharif* season, 2018 at Zonal Agricultural and Horticultural Station, Navile, Shivamogga to evaluate the effect of Flumioxazin 50% SC to control weed flora in Soybean as well as to know its phytotoxicity. The results revealed that the pre-emergence application of Flumioxazin @ 125 g.a.i./ha proved effective in reducing weed density thereby increased weed control efficiency up to 96.76 and 80.20 per cent at 30 and 60 DAS respectively followed by pre-emergence application of Flumioxazin @ 100 g.a.i./ha. The maximum grain yield was also recorded by the application of Flumioxazin @ 125 g.a.i./ha next to hand weeding treatment due to better weed control at critical crop growth stages. No phytotoxic symptoms were noticed on Soybean as well as on succeeding green gram crop even at the higher dose of Flumioxazin @ 250 g.a.i./ha thus proving safe to use without residual toxicity.

Keywords: Flumioxazin, pre-emergence, soybean, weed control

Introduction
Soybean (*Glycine max* L.) serves as a dual crop, *i.e.*, both as pulse and oilseed crop contributing 25 per cent of the global edible oil and about 2/3rd of world's protein concentrate for livestock feeding. India ranks fourth with respect to the world's soybean production earning valuable foreign exchange (Agarwal *et al*., 2013) As this crop is preferably grown in *kharif* season, adequate moisture favors weed population to a greater extent. Weed infestation was reported to loses up to 31-84 per cent of grain yield in Soybean (Kachroo *et al*., 2003) [5]. Also weed infestation throughout the crop growth period results in loss up to the extent of 79 per cent (Reddy *et al*., 1998) [10]. The critical period for weed control in Soybean is found to be 30 to 45 days after sowing, which proportionately increases grain yield up to 74 per cent (Chhokar and Balyan, 1999) [3]. The cultural and mechanical methods to control weeds during the early stages may not always prove to be effective due to labour scarcity (Prabhakar *et al*., 1992) [9]. This urges a need for an effective method of weed control without increasing the cost of cultivation. Even though many pre-emergent and post emergent herbicides are recommended to control weeds in Soybean, most of the weeds have developed resistance against these herbicides. This necessitates evaluating a novel herbicide molecule for controlling weeds with broad selectivity and lesser phytotoxicity.
Flumioxazin (N-phenylphthalimide) is a new herbicide molecule that can control different types of weeds by its effective mode of action by inhibiting protophyrinogen oxidase, an enzyme essential to synthesize chlorophyll. Keeping these views, an attempt was made to evaluate the effectiveness of Flumioxazin to control weeds in Soybean and also phytotoxic effects were studied in succeeding crop sequence.

Material and Methods
A field experiment was conducted in *kharif* 2018 at Zonal Agricultural and Horticultural Research Station, Navile, Shivamogga, Karnataka which is situated at 13^0 97' North latitude and 75^0 57' East latitude with an altitude of 650 meters above mean sea level with an average annual rainfall of 850-900 mm. It comes under agro-climatic region-4 and zone-VII (Southern Transition Zone) of Karnataka. The experiment comprising of 8 treatment combinations was laid out in a randomized block design replicated thrice. The treatments consisted of Flumioxazin 50% SC at different doses (75, 100, 125 & 150 g.a.i./ha), Chlorimuron Ethyl 25% WP @ 9 g.a.i./ha, Pendimethalin 30% EC @ 1000 g.a.i./ha, hand weeding and weedy check.

Soybean variety "JS 335" was sown at 30 x 10 cm spacing. The fertilizer dose of 25 kg N, 62.5 kg P and 25 kg K per hectare was applied to the soybean crop. As per treatments, Flumioxazin 50% SC and Pendimethalin 30% EC were sprayed 0-3 days after sowing. The Chlorimuron Ethyl 25% WP was sprayed 15 days after sowing. Herbicides were sprayed with the help of a knapsack sprayer fitted with a water foam nozzle. A spray volume of 500 liters ha-^{1} was used. Hand weeding was done twice at 20 and 40 DAS.

Observations were recorded on weed density, weed dry matter, plant growth parameters and grain yield. A quadrate of 0.25 m^2 size was selected randomly at five spots in each treatment. Species wise weed count was recorded at 30 and 60 days and were expressed as number/m^2. The data was subjected to $\sqrt{x} + 0.5$ transformations to normalize their distribution. Weeds collected at 30 and 60 days after the spray was dried at 70^0 C for 24 hours and weighed. In the succeeding crop sequence, green gram was sown after the harvest of soybean crop. At appropriate moisture, green gram was sown in furrows opened manually at 30 cm and the crop was supplemented with the recommended dose of fertilizer at the time of sowing and irrigated to ensure uniform crop growth.

Weed control efficiency was calculated using the formula (Mani *et al*., 1973)

$$WCE\ (\%) = \frac{WC - WT}{WC} \times 100$$

Where,
WC = Weed in control plot
WT = Weed in treated plot

Weed Index was calculated using the formula (Gill and Kumar, 1969)

$$\text{Weed Index } (\%) = \frac{\text{Yield from weed free plot} - \text{Yield from treated plot}}{\text{Yield from weed free plot}} \times 100$$

Assessment of phytotoxicity effect of Flumioxazin 50% SC on Soybean as well on succeeding green gram crop was recorded at 1, 3, 5, 7 and 10 days after application of herbicide. Observations on the phytotoxic symptoms *viz*., chlorosis, necrosis, wilting, scorching, hyponasty and epinasty were recorded based on a standard phytotoxicity rating scale of 0 to 10 where 0= no phytotoxicity and 10 = 91-100% crop injury. Phytotoxicity was tested at recommended dose of Flumioxazin 50% SC @ 125 g.a.i./ha and at higher dose of 250 g.a.i./ha.

Results and discussion

Effect of Flumioxazin 50% SC on species wise weed flora in Soybean

An assessment of data on effect of Flumioxazin sprayed at 30 DAS indicates that significant reduction in weed density of all species of broadleaf weeds, grasses and sedges were recorded under application of Flumioxazin 50% SC @ 125 g.a.i/ha (0.00, 0.00 and 2.99 no./m^2 of broadleaf weeds, grasses and sedges respectively) followed by Flumioxazin 50% SC @ 100 g.a.i/ha and Chlorimuron ethyl 25% WP @ 9 g.a.i./ha.

Similarly at 60 day after sowing, densities of different species of weeds recorded under application of Flumioxazin 50% SC 125 g.a.i./ha (0.00, 7.97, 6.98 no./m^2 of broadleaf weeds, grasses and sedges respectively) were found statistically significant followed by Flumioxazin 50% SC 100 g.a.i./ha and Chlorimuron ethyl 25% WP @ 9 g.a.i./ha which recorded similar weed count of 4.98, 5.98 and 2.99 no./m^2 of broadleaf weeds, grasses and sedges respectively (Table 1). Similar results were reported by Mahoney *et al*., 2014, who reported that Flumioxazin/Pyroxasulfone could provide effective weed control in Soybean. These findings are also in accordance with the results of the PE application of Flumioxazin in Soybean by Billore *et al*. (2007) [2].

Effect of Flumioxazin 50% SC on total weed density and dry matter

Application of Flumioxazin 50% SC @ 125 g.a.i/ha significantly reduced total weed density (2.99 no./m^2) compared to its other doses as well as with the control (T_8) which recorded as high as 73.75 weed no./m^2 at 30 DAS. However, the density of total weeds failed to record perceptible variation under different treatments of weed management over control at 60 DAS. The dry matter of weeds even though was not found significant, application of Flumioxazin 50% SC 125 g.a.i./ha recorded low dry weed matter (1.10 and 5.78 g/m^2 at 30 and 60 DAS respectively) compared to rest of the treatments. The present investigation results are in corroboration with the findings of Sridhara *et al*., 2016 [11], who reported that Flumioxazin 50% SC @ 125 g.a.i./ha provided a significant reduction in weed density and dry matter.

Weed Control Efficiency (WCE) was high in hand weeded plots at both 30 and 60 DAS. Among the herbicides tested, Flumioxazin 50% SC @ 125 g.a.i./ha application recorded maximum weed control efficiency of 96.76 & 80.20 per cent at 30 and 60 DAS respectively followed by Flumioxazin 50% SC 100 g.a.i./ha (89.73 & 68.93% at 30 and 60 DAS respectively) and Chlorimuron ethyl 25% WP @ 9 g.a.i./ha (88.53 & 77.12% at 30 and 60 DAS respectively) (Table 2). Similar findings were reported by Thirumalaikumar and Kalpana (2017) [12], who reported that pre-emergence application of Flumioxazin @ 250 g/ha recorded higher WCE at all stages of crop growth followed by Flumioxazin @ 150 g/ha.

The maximum weed index was observed in untreated control (61.51%) followed by Flumioxazin @ 150 g.a.i./ha (47.70%). However, the lowest weed index was noticed in application of Flumioxazin @ 125 g.a.i./ha (15.35%) and found on par with Flumioxazin @ 100 g.a.i./ha and Chlorimuron ethyl 25% WP @ 9 g.a.i./ha which recorded similar weed index of 29.21 per cent.

Effect of Flumioxazin 50% SC on growth and yield attributes of Soybean

The plant height recorded was found non-significant however maximum plant height was noticed in hand weeding treatment (17.01 cm and 45.89 cm at 30 and 60 DAS respectively) followed by Flumioxazin 50% SC 125 g.a.i./ha (14.94 cm and 32.89 cm at 30 and 60 DAS respectively). Similar results were noticed with respect to number of leaves, *i.e.*, more number of leaves were recorded in hand weeding (6.73 and 8.87 at 30 & 60 DAS respectively) and it was on par with Flumioxazin 50% SC 125 g.a.i./ha (6.60 and 10.53 at 30 & 60 DAS respectively), Flumioxazin 50% SC 100 g.a.i./ha (6.33 and 9.53 at 30 & 60 DAS respectively) followed by Chlorimuron ethyl 25% WP @ 9 g.a.i. (6.33 and 9.87 at 30 & 60 DAS respectively) as compared to other treatments (Table 3). Nandini Devi *et al*., 2015 [8] reported similar results, who reported that plant height, number of pods per plant and maximum seed yield of Soybean was obtained from weed free environment by different weed control treatments.

A significantly higher number of branches were recorded in hand weeding (3.67 and 6.60 at 30 and 60 DAS respectively) which was found on par with Flumioxazin 50% SC 125 g.a.i./ha (3.33 and 7.00 at 30 and 60 DAS respectively).
Seed yield of Soybean was highest in hand weeding treatment (20.06 q/ha) followed by application of Flumioxazin 50% SC 125 g.a.i./ha which recorded significantly higher grain yield of Soybean (16.98 q/ha) over rest of the treatments however, found at par with Flumioxazin 50% SC 100 g.a.i./ha which recorded grain yield of 14.20 q/ha (Table 3) which might be on account of better control of weeds. The succeeding crop, green gram yield was also more in the plots treated with Flumioxazin 50% SC 125 g.a.i./ha (3.48 q/ha) however failed to record perceptible variation. The enhanced yield attributes could be due to reduced crop-weed competition. These results are in agreement with the findings of Billore *et al*., 2007 [2].

Phytotoxicity effect of Flumoxazine 50% SC on Soybean and succeeding green gram

Visual observation of phytotoxicity symptoms such as leaf injury, stunting, wilting, necrosis, epinasty and hyponasty were taken at 1, 3, 5, 7 and 10 days after application of herbicides as per the phytotoxicity rating scale. No visual symptoms of phytotoxicity were observed on Soybean as well as on succeeding green gram crop treated with Flumioxazin 50% SC @ 125 g.a.i./ha. Normal vegetative or reproductive growth was seen in the crop even at the higher dose of Flumioxazin 50% SC @ 250 g.a.i./ha. These findings are in confirmation with the results of Thirumalaikumar *et al*., 2017 [13] who reported that pre-emergence application of Flumioxazin was found to reduce weed density without any phytotoxic effect on Soybean and residual effect on succeeding crop.

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Table 1: Effect of Flumioxazin 50% SC on species wise weed flora in Soybean

Treatments	30 DAS			60 DAS		
	Broad leaved weeds	Grasses	Sedges	Broad leaved weeds	Grasses	Sedges
T_1: Flumioxazin 50% SC @ 75 g.a.i./ha	1.87 (2.99)	2.34 (4.98)	3.24 (9.97)	2.55 (5.98)	2.91 (7.97)	2.12 (3.99)
T_2: Flumioxazin 50% SC @ 100 g.a.i./ha	0.71 (0.00)	1.58 (1.99)	2.12 (3.99)	2.34 (4.98)	2.55 (5.98)	1.87 (2.99)
T_3: Flumioxazin 50% SC @ 125 g.a.i./ha	0.71 (0.00)	0.71 (0.00)	1.87 (2.99)	0.71 (0.00)	2.91 (7.97)	2.73 (6.98)
T_4: Flumioxazin 50% SC @ 150 g.a.i./ha	3.93 (14.95)	2.91 (7.97)	4.29 (17.94)	5.33 (27.91)	4.63 (20.93)	5.42 (28.90)
T_5: Chlorimuron ethyl 25% WP @ 9 g.a.i./ha	0.71 (0.00)	1.58 (1.99)	2.55 (5.98)	2.34 (4.98)	2.55 (5.98)	1.87 (2.99)
T_6: Pendimethalin 30% EC @ 1000 g.a.i./ha	1.87 (2.99)	2.34 (4.98)	2.55 (5.98)	2.34 (4.98)	2.55 (5.98)	2.12 (3.99)
T_7: Hand weeding	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_8: Untreated control	5.04 (24.92)	4.84 (22.92)	5.14 (25.91)	5.60 (30.90)	5.33 (27.91)	5.95 (34.88)
C.D. (P=0.05%)	0.20	0.16	0.16	0.21	0.16	0.20
SE(m)	0.06	0.05	0.05	0.07	0.05	0.07

Values are √x + 0.5 transformed and actual values are in parentheses

Table 2: Effect of Flumioxazin 50% SC on total weed density and dry matter at different growth stages of crop

Treatments	Total weed density		Dry matter (g/m^2)		Weed Control Efficiency (%)		Weed index (%)
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	
T_1: Flumioxazin 50% SC @ 75 g.a.i./ha	4.29 (17.94)	4.29 (17.94)	4.88	6.88	85.64	76.43	40.77
T_2: Flumioxazin 50% SC @ 100 g.a.i./ha	2.55 (5.98)	3.80 (13.95)	3.49	9.07	89.73	68.93	29.21
T_3: Flumioxazin 50% SC @ 125 g.a.i./ha	1.87 (2.99)	3.93 (14.95)	1.10	5.78	96.76	80.20	15.35
T_4: Flumioxazin 50% SC @ 150 g.a.i./ha	6.43 (40.86)	8.85 (77.74)	16.84	18.44	50.45	36.84	47.70
T_5: Chlorimuron ethyl 25% WP @ 9 g.a.i./ha	2.91 (7.97)	3.80 (13.95)	3.89	6.68	88.53	77.12	29.21
T_6: Pendimethalin 30% EC @ 1000 g.a.i./ha	3.80 (13.95)	3.93 (14.95)	7.77	10.96	77.14	62.46	30.75
T_7: Hand weeding	0.71 (0.00)	1.96 (3.34)	0.00	1.69	100.00	94.21	0.00
T_8: Untreated control	8.62 (73.75)	9.70 (93.69)	33.99	29.20	0.00	0.00	61.51
C.D. (P=0.05%)	0.75	0.95	2.53	9.16	-	-	-
SE(m)	0.25	0.31	0.84	3.02	-	-	-

Values are √x + 0.5 transformed and actual values are in parentheses

Table 3: Effect of different treatment on growth attributes of soybean, yield of soybean and residual green gram crop

Treatments	Plant height (cm)		Number of leaves		Number of branches		Yield	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	Soybean	Residual green gram
T_1: Flumioxazin 50% SC @ 75 g.a.i./ha	12.46	32.15	6.27	10.20	2.67	9.73	11.88	3.04
T_2: Flumioxazin 50% SC @ 100 g.a.i./ha	14.81	32.54	6.33	9.53	2.73	7.27	14.20	3.13
T_3: Flumioxazin 50% SC @ 125 g.a.i./ha	14.94	32.89	6.60	10.53	3.33	7.00	16.98	3.48
T_4: Flumioxazin 50% SC @ 150 g.a.i./ha	11.83	30.94	4.80	10.67	1.87	6.47	10.49	2.78
T_5: Chlorimuron ethyl 25% WP @ 9 g.a.i./ha	14.71	32.27	6.33	9.87	2.53	6.20	14.20	3.03
T_6: Pendimethalin 30% EC @ 1000 g.a.i./ha	12.63	32.35	5.27	9.67	1.67	7.27	13.89	2.89
T_7: Hand weeding	17.01	45.89	6.73	8.87	3.67	6.60	20.06	3.64
T_8: Untreated control	11.13	29.41	5.67	9.20	2.53	6.80	7.72	2.50
CD (P=0.05%)	0.89	2.17	0.38	0.61	0.17	0.44	0.76	0.60
SE(m)	0.29	0.72	0.13	0.20	0.06	0.15	0.25	0.20

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