BIO-EFFICACY EVALUATION OF FLUMIOXAZINE 50%SC COMPARE WITH VARIANT HERBICIDES IN GROWTH AND YIELD OF SOYBEAN AND IT'S RESIDUAL EFFECT ON SUCCEEDING CROPS

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Abstract: A field experiment was conducted at ARS, Bhavanisagar, Tamil Nadu during *Rabi* 2013-14. Weed flora of the experimental field comprised of five species of grasses, a sedge and ten species of broad leaved weeds. At all the stages of crop growth, the major proportion of the weed flora was dominated by grasses. Pre-emergence application of flumioxazine at 250, 150 and 125 g ha^{-1} and pendimethalin at 1.0 kg ha^{-1} reduced the grass weed density and dry weight. Broad leaved weed density and dry weight were lower in PE application of flumioxazine at 250, 150 and 125 g ha^{-1} and EPOE application of chlorimuron ethyl at 9 g ha^{-1}. Whereas the herbicides had no significant influence of herbicides on sedge weed control. Among the treatments, pre-emergence application of flumioxazine at 112.5 g ha^{-1} recorded increased yield and economic returns in soybean. Hence, the pre-emergence application of flumioxazine at 112.5 g ha^{-1} can reduce the weed density and dry weight below the economic threshold level and increase the yield and net return in soybean without any phytotoxic effect on the crop and residual effect on the succeeding crop, it can be considered as the best option for weed management in soybean.

Keywords: Weed management, Flumioxazine, Soybean, Residual effect, Succeeding crop.

Introduction: Soybean [*Glycine max* (L.) Merrill] is being a rainy season crop, it has high yielding capacity but weed infestation is one of the major constraints in the cultivation of soybean. It weeds, are not controlled during critical period of weed-crop competition, there is reduction in the yield of soybean from 35 to 50% depending upon the weed flora and density (Mahendrasingh *et al.,* 2013). Hand weeding is a traditional and effective method of weed control, but untimely and continuous rains as well as unavailability of labour during peak period of demand, are the main limitations of manual weeding. Due to the critical period of crop weed completion at early stage of soybean, there is need for pre emergence herbicides for prolonged effective weed control. There is a need to identify newer molecules for selective management of weeds and to overcome the problem of acquiring resistance by certain weeds against recommended herbicides. In view of this, an attempt has been made to find the effectiveness of flumioxazine, a contact herbicide to control broadleaved weeds and some grassy weeds in soybean. Flumioxazine (N-phenylphthalimide) is a new molecule which acts on weeds by inhibiting protoporphyrinogen oxidase, an enzyme important in the synthesis of chlorophyll. Keeping these points in view, the experiment was taken with flumioxazine 50% SC with the following experimental objective, to compare the effect of flumioxazine with different herbicides on growth, yield and economics of soybean and its residual effect on succeeding crop.

Methodology : The experiment was conducted at Agricultural Research Station, Bhavanisagar, in the Western zone of Tamil Nadu. The experiment was laid out in a Randomized Block Design replicated thrice with eleven treatments. The experimental field is located at 11^{o} 29'N latitude and 77^{o} 08'E longitude with an altitude of 256m above MSL. The soil of the experimental field was red sandy clay loam in texture belonging to *Typic Paleustalfs*, pH 7.4, EC 0.14 (dS m^{-1}) and organic carbon (%) 0.55. Low in available nitrogen (215 kg ha^{-1}), medium in available phosphorus (17.5 kg ha^{-1}) and high in available potassium (260 kg ha^{-1}). Soybean variety CO (Soy) 3 with duration of 85-90 days released by TNAU was selected for this study. The recommended package and practices was followed, TNAU, Crop production guide 2012.

After the harvest of the main crop of soybean in the monsoon season, two test crops viz., sunflower and pearl millet were raised. The observations such as germination percentage at 10 DAS, plant height and dry matter production at 30 DAS were taken for these test crops. Statistical analysis for all the data pertaining to crop and weeds carried out using the method suggested by Gomez and Gomez (1984). For weeds, the original values were transformed using square root transformation and analysed statistically. Wherever statistical significance was observed, leastsignificant difference (LSD) at 5 per cent level of probability was worked out for comparison.

Result and Discussion: Weed flora: The weed flora of the experimental field during the cropping period in given in table 1. The dominated predominant grass weeds were *Panicum flavidum, Bracharia reptans and Dactyloctenium aegyptium*. The predominant among broad leaved weeds were *Euphorbhia hirta, Trianthema portulacastrum, Portulaca quadrifida, Boerhaavia diffusa, Digera arvensis, Parthenium hysterophorous* and *Tridax procumbens* and *Cyperus* *rotundus* was the only sedge present. Similar type of weed flora was reported by Priya (2011) in groundnut field of red sandy loam soil at Bhavanisagar, Tamil Nadu.

Weed density: Chemical weed control methods significantly reduced the weed density over unweeded control. PE application of flumioxazine at 250, 150, 125 g ha^{-1} and PE application of pendimethalin 1.0 kg ha^{-1}recorded lower grass weed density. It was followed by PE application of flumioxazine at 112.5 g ha^{-1} (Table 2). This might be due to control of grass weeds at germination phase by the pre emergence application of herbicides.

Lower sedge weed density was recorded in PE application of flumioxazine at 250 and 150 g ha^{-1}. But during the later stages, hand weeding twice recorded lower sedge weed density (Table 2). This could be due to the efficiency of hand weeding to control sedge during the later stage.

PE application of flumioxazine at 250 and 150 g ha^{-1} recorded lower broad leaved weed density, over the pre emergence application of pendimethalin, oxyfluorfen and early post emergence of chlorimuron ethyl. Obviously unweeded control resulted in higher grasses, sedge and broadleaved weed densities due to unchecked weed growth at all the growth stages of the crop (table 2). The reason might be the PE control of broadleaved at all stages. It is in conformity with the results of Sangeetha *et al.* (2011).

Weed dry weight: Weed dry weight is one of the most important parameter to assess the weed competitiveness for the crop growth and development. Sparse weeds with high biomass might be more competitive than dense weed with lesser biomass.

Dry weight of grass weeds was considerably reduced in PE application of flumioxazine at 250 and 150 g ha^{-1} (Table 2). Similarly broadleaved weed dry weight was recorded in PE application of flumioxazine at 250,150 and 125 g ha^{-1} and EPOE chlorimuron ethyl at 9 g ha^{-1} (Fig.8). The reason for the lower weed dry weight might be due to the lesser number of total weeds with lower biomass during the cropping period. These findings corroborate with the findings of Grichar and Dotray (2013) in groundnut.

Weed control efficiency: Weed control efficiency indicated the extent of effectiveness of weed dry weight reduction by weed control treatments over unweeded control. Different weed control treatments significantly influenced the weed control efficiency.

Weed control treatments *viz.,* PE application of flumioxazine at 250, 150, 125, 112.5 and 100 g ha^{-1} and PE application of pendimethalin at 1.0 kg ha^{-1} recorded more than 70 per cent WCE. During the cropping period higher weed control efficiency was obtained with PE application of flumioxazine at 250 g ha^{-1}, followed by PE application of flumioxazine at 150 g ha^{-1}. More reduction of weed dry weight by reducing the weed density in these treatments might have resulted in higher WCE. These finding are in accordance with the results of PE application of flumioxazine in soybean by Billore *et al.* (2007).

Effect of weed control treatments on crop growth attributes: Growth attributes such as germination, plant height, leaf area index and dry matter production are the indicators of effective utilization of environment resources. Biotic factors like lesser weed competition reflect on the growth attributes of the crops. Significant variation in growth was noticed under different weed control methods.

Plant height: Plant height was significantly lower in unweeded check due to smothering effect of weeds. Similar findings were reported by Bergland (1972) and Leguizamon *et al.* (1983). Among the treatments, the taller plants were recorded in PE application flumioxazine at 112.5 g ha^{-1}, followed by PE application flumioxazine at 100 and 75 g ha^{-1}, PE pendimethalin at 1.0 kg ha^{-1} and hand weeding (Table 3). Better weed control might have resulted in reduced crop weed competition for growth factors such as light, space and nutrients which in turn helped in efficient photosynthetic activity. Parker and Riches (1993) reported that the weed control with various herbicides increased the plant height markedly.

Leaf area index: Leaf area index was inversely proportional to weed population. An increase in LAI is the result of better utilization of solar energy and depends upon number of leaves per plant and rate of leaf expansion. The results of the experiment showed that weed management treatments had increased LAI. Pre emergence application flumioxazine at 112.5 g ha^{-1} recorded higher leaf area index at 45 DAS. Similarly, PE application flumioxazine at 100 and 75 g ha^{-1}, PE pendimethalin at 1.0 kg ha^{-1} and hand weeding recorded higher leaf area index (Table 3). Lesser weed competition might have contributed to more photosynthetic activity and thus helped in the expansion of leaves.

Whereas, LAI was lower in unweeded check. Hagood *et al.* (1981) and Chemale and Fleck (1982) also reported that LAI of soybean was appreciably reduced with increasing weed density

Dry matter production: Dry matter production (DMP) was significantly higher at 45 days after sowing in pre emergence application flumioxazine at 112.5 g ha^{-1} (Table 3). Reason could be due to increased plant height, which in turn promoted the vegetative growth and more number of branches under these treatments as a result of lesser weed competition and consequently increased the supply of resources like nutrient, moisture and light. The crop DMP was significantly lesser under unweeded check due to intense weed competition and suppression of growth of soybean. Similar decreased crop DMP by increased weed population was reported by Beckett and Stoller (1983) and Leguizamon *et al.* (1983).

Effect of treatments on yield attributes and yield: The main yield contributing factors *viz.,* number of pods per plant, number seeds per pod and hundred grain weight were significantly influenced by different weed control treatments. Among the treatments unweeded check recorded significantly lower number of pods and seeds per pod due to weed competition. Durigan *et al.* (1983) reported that number of pods per plant was the most affected character among yield parameters due to heavy infestation of weeds. Pre emergence application of flumioxazine at 112.5 g ha^{-1} recorded higher value for yield attributes (Table 3). This enhanced yield attributes could be due to reduced weed-crop and interplant competition, which resulted in higher availability of moisture and nutrients to the crop and increased light interception. These results were in line with earlier finding of Billore *et al.* (2007) in soybean.

Yield: Among the weed control treatment pre emergence application of flumioxazine 112.5 g ha^{-1} at recorded higher grain and haulm yields. Pre emergence application of pendimethalin at 1.0 kg ha^{-1}, PE flumioxazine at 100 g ha^{-1} and hand weeding twice also recorded higher yield (Table 3). The increased yield may be due to lesser competition and no phytotoxity resulted in better vegetative growth and favorable yield attributes. Similar results were reported by Sunil Kumar *et al.* (1996) who obtained maximum seed yield of soybean crop from weed free environment by different weed control treatments. Also Sharma *et al.* (1992) reported that grain yield of soybean significantly increased with the use of various herbicides over the control.

Effect of weed control treatments on economics: Net return and B:C ratio were higher in pre emergence application of flumioxazine at 112.5 g ha^{-1} (Table 3). This could be due to higher growth parameters and yield attributes as a result of reduced competition between weeds and crop for water and nutrients. Similar findings were reported by Kushwah and Kushwaha (2001) who reported that highest B:C ratio and monetary returns per rupee invested was obtained by the use of herbicides. And also, Mishra and Singh (2009) reported that among weed control treatments a higher net return was obtained from herbicide + hand weeding.

Residual effect of herbicides on succeeding crop: Residual effect of herbicide is one of the important factors for recommending it to the farmers in order to avoid the residual phytotoxity in the succeeding crops. Germination percentage at 10 DAS, plant height and dry matter production at 30 DAS of succeeding crops such as sunflower and pearl millet was recorded to study the residual effect of flumioxazine.

Results indicated that there was no significant difference among the treatments and it was evident that there is no residual toxicity due to the application of flumioxazine at all doses in the succeeding crops. It is in conformity with the results by Raskar and Bhoi (2002) who reported no carry over effect of soybean PE application of various herbicides on succeeding crop of potato.

Conclusion: On the basis of results, it could be concluded that the application of flumioxazine at 112.5 g ha^{-1} as pre-emergence herbicide provides an option to farmers to manage weeds effectively along with improved growth leading to higher productivity of soybean, besides no residual effect on succeeding crop.

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Table 1. Weed flora of the experimental field

S. No	Botanical Name	Common Name	Habit	Family
A.	**Grasses**			
1.	*Bracharia reptans* L.	Running grass	Annual	Poaceae
2.	*Chloris barbata*,Swasts	Swollen finger grass	Annual	Poaceae
3.	*Dactyloctenium aegyptium* L.	Crowfoot grass	Annual	Poaceae
4.	*Dinebra retroflexa (Vahl)Panzer*	Viper grass	Annual	Poaceae
5.	*Panicum flavidum Retz*	Yellow water crown	Annual	Poaceae
B.	**Sedges**			
1.	*Cyperus rotundus* L.	Purple nutsedge	Perennial	Cyperaceae
C.	**Broad leaved weeds**			
1.	*Boerhaavia diffusa* L.	Spreading hog weed	Annual	Nyctaginaceae
2.	*Cleome viscose* L.	Wild mustard	Annual	Capparaceae
3.	*Digeria arvensis* L.	False amaranth	Annual	Amaranthaceae
4.	*Euphorbhia hirta,* L.	Pill pod spurge	Annual	Euphorbiaceae
5.	*Parthenium hysterophorous* L.	Carrot weed	Annual	Asteraceae
6.	*Phyllanthus niruri* L.	Stonebreaker	Annual	Euphorbiaceae
7.	*Portulaca oleracea* L.	Indian Purslane	Annual	Portulacaceae
8.	*Portulaca quadrifida* L.	Chicken weed	Annual	Portulacaceae
9.	*Trianthema portulacastrum* L.	Horse purslane	Annual	Aizoceae
10.	*Tridax procumbens* L.	Coatbuttons	Annual	Asteraceae

Table.2. Effect of treatments on weed growth and weed control efficiency Figures in parenthesis are mean of original values; Data is subjected to square root transformation

Treatments	Weed density at 45 DAS			Weed dry weight at 45 DAS			Weed Control Efficiency (%)		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW	25 DAS	45 DAS	60 DAS
T_{1}- PE Flumioxazine 50% SC 75 g a.i. /ha	8.15(64.7)	3.36(9.33)	5.79(31.7)	5.57(29.1)	2.74(5.49)	3.46(9.95)	76	68	66
T_{2}- PE Flumioxazine 50% SC 100 g a.i. /ha	6.63(42.0)	3.33(9.33)	4.93(22.3)	5.27(25.8)	2.65(5.05)	3.26(8.61)	79	72	70
T_{3}- PE Flumioxazine 50% SC 112.5 g a.i. /ha	5.25(25.7)	3.19(8.33)	4.42(17.7)	4.50(18.3)	2.60(4.57)	2.79(5.81)	84	80	78
T_{4}- PE Flumioxazine 50% SC 125 g a.i. /ha	4.40(17.3)	3.21(8.33)	3.96(13.7)	4.19(16.0)	2.47(4.09)	2.76(5.62)	88	84	82
T_{5}- PE Flumioxazine 50% SC 150 g a.i. /ha	3.87(13.0)	3.10(7.67)	3.60(11.0)	3.50(10.3)	2.47(4.09)	2.69(5.24)	92	86	84
T_{6}- PE Flumioxazine 50% SC 250 g a.i. /ha	3.56(10.7)	2.82(6.00)	2.94(6.67)	3.03(7.16)	2.31(3.17)	2.43(3.93)	94	89	88
T_{7}- PE Pendimethalin 30% EC 1.0 kg a.i. /ha	3.78(12.3)	3.27(8.67)	5.31(26.3)	4.77(20.9)	2.47(4.09)	3.60(10.0)	81	75	74
T_{8}- PE Oxyflourfen 23.5% EC 125 g a.i. /ha	6.23(37.0)	3.16(8.33)	6.04(34.7)	5.13(24.4)	2.82(5.96)	4.12(15.0)	75	68	66
T_{9}- EPOE Chlorimuron ethyl 25% WP 9 g a.i. /ha	9.62(90.7)	3.90(13.3)	4.43(17.7)	5.92(33.1)	3.13(7.83)	3.79(12.4)	63	62	60
T_{10}- Hand weeding on 25 & 45 DAS	5.68(30.3)	2.65(5.00)	5.85(32.3)	4.56(18.8)	2.99(6.96)	3.50(10.3)	1	75	76
T_{11}- Unweeded check	14.9(221)	3.86(13.0)	11.9(140)	9.80(94.1)	2.99(6.92)	6.43(40.4)	-	-	-
LSD (0.05%)	**0.71**	**0.51**	**0.59**	**0.66**	**0.52**	**0.33**	**-**	**-**	**-**

Table 3. Effect of treatments on growth parameter, yield attributes, yield and economics of soybean

Treatments	Growth parameter at 45 DAS			Yield Attributes			Yield and Economics		
	Plant height(cm)	LAI	DMP (kg/ha)	Number of pods per plant	Number of seeds per pod	100 seed weight (g)	Grain yield (kg/ha)	Net return (₹)	B:C ratio
T_{1}- PE Flumioxazine 50% SC 75 g a.i. /ha	60.1	1.77	1207	81.6	3.3	11.2	1624	22811	1.88
T_{2}- PE Flumioxazine 50% SC 100 g a.i. /ha	62.9	1.87	1236	83.7	3.5	11.3	1754	26680	2.03
T_{3}- PE Flumioxazine 50% SC 112.5 g a.i. /ha	65.4	2.11	1315	85.9	3.7	12.1	1897	30947	2.19
T_{4}- PE Flumioxazine 50% SC 125 g a.i. /ha	61.6	1.98	1125	79.3	3.3	10.3	1429	19381	1.75
T_{5}- PE Flumioxazine 50% SC 150 g a.i. /ha	60.6	1.87	1131	76.3	3.0	10.5	1400	15985	1.61
T_{6}- PE Flumioxazine 50% SC 250 g a.i. /ha	56.0	1.68	1107	63.9	2.9	10.3	1321	13464	1.51
T_{7}- PE Pendimethalin 30% EC 1.0 kg a.i. /ha	64.0	1.91	1208	84.3	3.6	11.6	1880	29144	2.07
T_{8}- PE Oxyflourfen 23.5% EC 125 g a.i. /ha	63.7	1.73	1180	77.2	3.5	11.0	1602	21329	1.80
T_{9}- EPOE Chlorimuron ethyl 25% WP 9 g a.i. /ha	62.6	1.55	1100	76.3	3.3	10.9	1451	17308	1.66
T_{10}- Hand weeding on 25 & 45 DAS	63.9	1.88	1185	81.3	3.5	11.1	1813	17411	1.47
T_{11}- Unweeded check	49.3	1.27	837	52.7	2.9	10.0	981	4931	1.20
LSD (0.05%)	**2.01**	**0.17**	**0.59**	**5.75**	**NS**	**0.85**	**261**	**-**	**-**

Table 4. Residual effect of treatments on succeeding crops

Treatments	Sunflower			Pearl millet		
	Germination At 10 DAS (%)	Plant Height at 30 DAS (cm)	DMP at 30 DAS (kg/ha)	Germination at 10 DAS (%)	Plant Height (cm)	DMP at 30 DAS (kg/ha)
T_1- PE Flumioxazine 50% SC 75 g a.i. /ha	69.7	23.2	83	92.3	82.0	154
T_2- PE Flumioxazine 50% SC 100 g a.i. /ha	66.7	25.9	98	89.2	81.6	170
T_3- PE Flumioxazine 50% SC 112.5 g a.i. /ha	65.6	23.8	108	85.1	80.3	136
T_4- PE Flumioxazine 50% SC 125 g a.i. /ha	63.1	22.5	98	83.1	79.2	131
T_5- PE Flumioxazine 50% SC 150 g a.i. /ha	62.6	21.1	98	82.1	78.8	158
T_6- PE Flumioxazine 50% SC 250 g a.i. /ha	62.5	22.8	93	82.4	79.7	133
T_7- PE Pendimethalin 30% EC 1.0 kg a.i. /ha	67.7	25.3	86	87.7	82.3	157
T_8- PE Oxyflourfen 23.5% EC 125 g a.i. /ha	66.7	23.7	102	83.6	81.0	153
T_9- EPOE Chlorimuron ethyl 25% WP 9 g a.i. /ha	66.2	22.8	103	82.6	80.7	163
T_{10}- Hand weeding on 25 & 45 DAS	70.8	24.5	98	95.9	81.6	131
T_{11}- Unweeded check	67.2	21.6	99	84.6	79.4	160
LSD(P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

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