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Sequential application of metribuzin on weed control, growth and yield of soybean (*Glycine max*)

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ABSTRACT

A field experiment was conducted for two years at New Delhi to evaluate sequential applications [pre-emergence followed by (*fb*) post-emergence] of metribuzin on weed control in soybean [*Glycine max* (L.) Merrill] . Results indicated that metribuzin at 0.5 kg/ha as pre-emergence resulted in more suppression of *Trianthema portulacastrum* L., *Cyperus rotundus* L. and grasses, and caused a significant reduction in total weed population and dry weight. Highest weed control efficiency (WCE) of 83.6% and 73.9%, respectively at 40 and 60 days after sowing (DAS) was resulted from this treatment followed by metribuzin 0.25 kg/ha pre-emergence *fb* 0.1 kg/ha at 20 DAS with volume rate of 200 l/ha. Metribuzin 0.25 kg/ha pre-emergence *fb* metribuzin (0.1 kg/ha, 200 l/ha, 20 DAS) was the next best combination resulting higher soybean yield through concurrent reduction in weed growth. Excluding weed-free check, the highest net returns (₹4,691/ha), net benefit:cost ratio (0.43) were obtained under metribuzin 0.5 kg/ha pre-emergence.

Key words **:** Soybean, Productivity, Weed control efficiency, Metribuzin, Pendimethalin

Heavy infestation of weeds comprising of grasses, broad-leaved weeds and sedges poses a big challenge for soybean production in India. Initial slow growth of soybean coupled with little lateral spread increases opportunity for weeds to easily occupy vacant spaces between rows and offer serious competition with soybean. Besides, good sunshine and intermittent rains during rainy season provides congenial environment for excessive growth of weeds. Besides nutrient removal, weeds inflict greater reduction in soybean yield when compared with other pests. The yield reduction is up to 67% depending on the spectrum of weeds, crop variety, season, soil type, rainfall and duration and time of weed competition (Gaikwad and Pawar, 2002).

Metribuzin is used mainly as pre-emergence, the dose of which varies across soils/ locations. Pre-emergence applications alone are not sufficient to contain repeated flushes of weeds during rainy season, which highly necessitates a post-emergence application following a pre-emergence one. Sequential application (pre-emergence followed by post-emergence) of metribuzin has hardly been studied on weed control in soybean in India or elsewhere. Dose, volume rate and time of application, particularly in case of post-emergence application of metribuzin, are also not optimized. Besides, in stead of using different herbicides in sequence, exploring a single herbicide for use as both pre-emergence and post-emergence will make monitoring of herbicide residues in soil easier and cost-effective. In view of these, the present investigation was undertaken to evaluate metribuzin alone and as sequential application in soybean.

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MATERIALS AND METHODS

A field experiment with 13 weed control treatments (Table 1) laid out in a randomized complete block design replicated thrice, was undertaken at the research farm of Indian Agricultural Research Institute, New Delhi during the rainy (*kharif*) seasons of 2006 and 2007 in soybean. Soil was sandy loam, pH 7.9, organic carbon 0.52%, and medium in available N (272.6 kg/ha), P (18.4 kg/ha) and K (191.6 kg/ha). All the recommended package and practices except weed control were followed for raising the soybean crop. Soybean cv ‘Pusa 20’ was sown on 7 July in 2006 and 10 July in 2007 with a seed rate 75 kg/ha in rows spaced at 40 cm. Soybean received four irrigations including a pre-sowing one. Population and dry weight of weeds were recorded at 40 and 60 days after sowing (DAS) and harvest of crop by placing a quadrat of 50 cm × 50 cm randomly from three places in each plot. Data on number and dry weight of weeds were subjected to square-root [$\sqrt{(x+0.5)}$] transformation before analysis of variance. Data on seed yield were recorded from the net plot, whereas yield attributes from 5 randomly selected plants at harvest. For economic evaluation of the system, prevailing market price was used for different outputs and inputs. The prices of soybean seed and stover were ₹10,200 and ₹500/t, respectively in 2006. The same were ₹10,500 and ₹600/t, respectively in 2007. The trend of results was similar during 2006 and 2007, and hence, data were subjected to pooled analysis for results and discussion.

RESULTS AND DISCUSSION

Effect on Weeds

Weed growth

Weed flora in the experimental field consisted of *Echinochloa colona* (L.) Link., *Trianthema portulacastrum* L., *Cyperus rotundus* L., *Digera arvensis* (L) Forsk., *Acrachne racemosa* Heyne ex Roem & Ohwi, *Dactyloctenium aegyptium* (L.) P. Beauv., and *Digitaria sanguinalis* (L.) Scop. *Cyperus rotundus* had higher population compared to *Trianthema portulacastrum* and grasses and was more dominant at 40 and 60 DAS (Tables 1 and 2). Large variability in weed flora of soybean across locations, and due to differential effects of weed control treatments across growth stages of crop are reported (Balyan and Malik, 2003; Singh *et al*., 2006). *Trianthema portulacastrum* was evenly distributed across all weed control treatments/plots (visual observations), and was the most dominant. But, pendimethalin, and metribuzin irrespective of dose, time and volume rate of application, were highly effective on this weed and caused a significant reduction in its population.

Both pre-emergence and pre-emergence followed by (*fb*) post-emergence applications of metribuzin showed a significant suppression of weeds at 40 DAS when compared with weedy check. At 40 DAS, among all the pre-emergence *fb* post-emergence metribuzin treatments, metribuzin 0.25 kg/ha pre-emergence *fb* 0.1 kg/ha with 400 litres/ha at 20 DAS resulted in the lowest population of *Trianthema portulacastrum* during both years. The rest of pre-emergence *fb* post-emergence applications brought about more or less similar suppression of this weed. Metribuzin 0.5 kg/ha pre significantly reduced the number of *Cyperus rotundus.* Pendimethalin 0.75 kg/ha pre controlled all grassy weeds at 40 DAS, whereas it was the lowest with metribuzin 0.5 kg/ha pre at 60 DAS. However, considering the overall effect on total weed population at 40 and 60 DAS, metribuzin 0.5 kg/ha pre caused a significant reduction in total weed population compared to the rest of treatments. The periodic emergence of these weeds and the relative efficacy of herbicides played a role.

Table 1. Populations of *Trianthema portulacastrum, Cyperus rotundus* and grasses at 40 and 60 days after sowing (DAS) of soybean (Pooled data of 2 years)

Treatment	*Trianthema portulacastrum* (No./m^2)		*Cyperus rotundus* (No./m^2)		Grasses (No./m^2)**		Total weed population (No./m^2)	
	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Weedy check	8.8 (77.1)	3.8 (14.0)	14.6 (213.2)	15.9 (254.2)	4.5 (26.0)	3.7 (13.2)	17.7 (316.4)	16.7 (281.6)
Weed - free check	0.7 (0)	0.7 (0)	0.7 (0)	0.7 (0)	0.7 (0)	0.7 (0)	0.7 (0)	0.7 (0)
Pendimethalin 0.75 g/ha Pre	0.7 (0)	0.7 (0)	11.9 (142.0)	11.1 (123.0)	0.7 (0)	3.4 (14.3)	11.9 (142)	11.7 (137.3)
Metribuzin (MTB) 0.5 kg/ha Pre	3.9 (20.0)	0.7 (0)	5.5 (30.0)	8.3 (69.3)	1.4 (2)	2.2 (4.3)	7.1 (52)	8.6 (73.6)
MTB 0.25 kg/ha Pre	4.8 (24.7)	2.9 (8.0)	12.4 (156.5)	11.85(140.0)	3.2 (10.3)	4.0 (16.3)	13.7 (187.2)	12.8 (164.3)
MTB (0.1 kg/ha, 200 l/ha, 20 DAS) Post*	4.6 (21.6)	2.5 (6.0)	8.15 (66.0)	10.5 (109.5)	2.8 (8.0)	3.3 (10.8)	9.8 (95.6)	11.2 (126.3)
MTB (0.1 kg/ha, 400 l/ha, 20 DAS) Post*	3.1 (9.7)	2.5 (6.0)	9.6 (92.0)	10.5 (109.6)	2.5 (6.0)	4.2 (18.3)	10.4 (107.7)	11.5 (134.0)
MTB (0.1 kg/ha, 200 l/ha, 30 DAS) Post*	4.7 (22.3)	2.5 (6.0)	9.0 (82.0)	11.0 (121.8)	4.1 (16.0)	4.4 (19.3)	10.9 (120.3)	12.1 (147.1)
MTB (0.1 kg/ha, 400 l/ha, 30 DAS) Post*	3.7 (14.6)	2.1 (4.0)	9.2 (85.0)	10.2 (104.5)	3.2 (10.0)	4.6 (20.5)	10.5 (109.7)	11.3 (129.0)
MTB (0.2 kg/ha, 200 l/ha, 20 DAS) Post*	5.1 (27.2)	2.5 (6.0)	11.2 (125.0)	10.8 (115.6)	3.7 (14.0)	3.8 (14.5)	12.9 (166.2)	11.7 (136.1)
MTB (0.2 kg/ha, 400 l/ha, 20 DAS) Post*	4.4 (21.8)	2.5 (6.0)	10.5 (112.0)	10.6 (112.9)	2.1 (4.0)	4.4 (19.9)	11.7 (137.8)	11.9 (141.1)
MTB (0.2 kg/ha, 200 l/ha, 30 DAS) Post*	5.2 (28.3)	2.9 (8.0)	10.9 (119.0)	10.4 (107.5)	4.1 (16.0)	3.6 (12.6)	12.8 (163.3)	11.2 (124.6)
MTB (0.2 kg/ha, 400 l/ha, 30 DAS) Post*	3.7 (14.5)	2.1 (4.0)	10.7 (108.8)	9.8 (95.2)	2.8 (8.0)	3.7 (13.4)	11.5 (131.3)	10.6 (112.6)
SEm ±	0.2	0.2	0.5	0.5	0.2	0.3	0.3	0.3
CD (P=0.05)	0.9	0.6	1.6	1.6	0.6	0.9	0.9	0.9

* In all the post-emergence applications of metribuzin, metribuzin 0.25 kg/ha was applied as pre-emergence;

** Grasses include *Aerachne racemosa* and *Dactyloctenium aegyptium*; Data were transformed through square-root ($\sqrt{(x+0.5)}$) method; Figures in the parentheses are original values.

Cyperus rotundus, not being controlled by these herbicide treatments except metribuzin 0.5 kg/ha pre, its population continued to increase till 60 DAS in most of these herbicide treatments. In contrast, these herbicide treatments including pendimethalin being highly effective on *Trianthema portulacastrum* the populations of this weed went on declining from 40 to 60 DAS (Table 1). Dry matter accumulation of total weeds, too, was the highest at 40 DAS and declined marginally at 60 DAS and further increased due to weed plant growth (Table 2). It did not differ between the pre-emergence *fb* post-emergence applications of metribuzin indicating these treatments were more or less comparable with each other and equally effective on total weed. These pre-emergence *fb* post-emergence metribuzin treatments caused significant reductions in total weed dry weight compared to weedy check at both 40 and 60 DAS. At 40 DAS, metribuzin 0.5 kg/ha pre caused a significant reduction in total weed dry weight indicated the higher weed control efficiency (WCE) compared to weedy check. Most of the weeds emerged with crop, and, therefore, pre-emergence applications of these herbicides could take care of these weeds based on their relative efficacy on these individual weed species. The *Cyperus rotundus* which remained uncontrolled by most of these treatments continued to exist in soybean. Lower dose of metribuzin in post-emergence applications could not cause a significant reduction in its population. But, higher 0.5 kg/ha of metribuzin at pre-emergence was able to control *Cyperus rotundus* moderately, and *Trianthema portulacastrum* and grasses almost completely. Higher tolerance and persistent nature of perennial *C. rotundus* might be responsible. Pendimethalin 0.75 kg/ha pre and metribuzin 0.5 kg/ha pre being effective against grassy weeds were able to reduce their population and dry weight (Jain *et al*., 1998). Kewat and Pandey (2001) reported that metribuzin at 0.5 and 0.75 kg/ha pre effectively controlled most of the dominant weeds, *viz*., *Trianthema portulacastrum, Echinochloa colona*, *Digitaria sanguinalis* and *Digera arvensis.*

Nutrient uptake

Weedy check resulted in the highest uptake of N, P and K by weeds during both the years (Table 4). The lowest N, P and K uptake by weeds was observed with metribuzin 0.5 kg/ha pre. However, all pre-emergence *fb* post-emergence treatments of metribuzin irrespective of dose, volume rate and time, proved equally effective in reducing the N, P and K removal by weeds. The results are in conformity with Idapuganti *et al.* (2006).

Effect on soybean

Soybean plant population, dry weight and plant height experienced a marked variation across weed control treatments (Table 5). Weed-free check resulted in the highest plant population; pendimethalin 0.75 kg/ha pre resulted in the highest dry matter accumulation; and weedy check recorded the greatest height of soybean plants. Higher plant height but lower plant population and dry weight in

Table 2. Total weed dry weight at 40, 60 days after sowing (DAS) and harvest, weed control efficiency (WCE) and nutrient removal by weeds across the treatments in soybean (Pooled data of 2 years)

Treatment	Total weed dry weight (g/m^2)			WCE (%)		Nutrient removal (kg/ha)		
	40 DAS	60 DAS	harvest	40 DAS	60 DAS	N	P	K
Weedy check	8.25 (67.65)	7.45 (55)	8.55 (72.81)	0	0	15.92	2.8	13.51
Weed - free check	0.7 (0)	0.7 (0)	0.7 (0)	100	100	0	0	0
Pendimethalin 0.75 g/ha Pre	4.10 (16.35)	3.95 (15.45)	4.75 (22.13)	55.1	51.2	4.83	0.69	4.16
Metribuzin (MTB) 0.5 kg/ha Pre	3.25 (10.35)	3.20 (9.7)	4.45 (19.33)	83.6	73.9	3.96	0.68	3.49
MTB 0.25 kg/ha Pre	4.70 (21.3)	4.70 (21.6)	5.55 (30.37)	40.6	41.7	6.48	1.26	5.72
MTB (0.1 kg/ha, 200 l/ha, 20 DAS) Post*	4.55 (20.45)	4.30 (18.05)	5.25 (27.13)	69.7	55.1	5.67	1.03	4.91
MTB (0.1 kg/ha, 400 l/ha, 20 DAS) Post*	4.50 (19.85)	4.35 (18.55)	5.15 (26.03)	65.9	52.4	5.65	0.91	4.84
MTB (0.1 kg/ha, 200 l/ha, 30 DAS) Post*	4.20 (17.55)	4.30 (18.45)	5.30 (27.84)	61.9	47.8	4.99	0.92	5.10
MTB (0.1 kg/ha, 400 l/ha, 30 DAS) Post*	4.25 (18)	4.25 (17.9)	4.90 (23.51)	65.3	54.2	5.12	0.94	4.37
MTB (0.2 kg/ha, 200 l/ha, 20 DAS) Post*	4.30 (18.55)	4.35 (18.15)	4.70 (21.60)	47.5	51.7	4.59	0.78	3.89
MTB (0.2 kg/ha, 400 l/ha, 20 DAS) Post*	4.55 (19.9)	4.35 (18.75)	5.10 (25.52)	56.4	49.9	5.55	0.85	4.64
MTB (0.2 kg/ha, 200 l/ha, 30 DAS) Post*	4.55 (20.05)	4.40 (19.05)	5.35 (28.19)	48.4	55.8	5.35	0.97	5.31
MTB (0.2 kg/ha, 400 l/ha, 30 DAS) Post*	4.65 (21.2)	4.55 (20)	5.15 (26.05)	58.5	60.0	5.43	1.05	4.77
SEm ±	0.1	0.1	0.3			0.3	0.1	0.3
CD (P=0.05)	0.4	0.4	0.8			1.0	0.4	0.9

*In all the post-emergence applications of metribuzin, metribuzin 0.25 kg/ha was applied as pre-emergence; ** Grasses include *Aerachne racemosa* and *Dactyloctenium aegyptium*; Data were transformed through square-root ($\sqrt{(x+0.5)}$) method; Figures in the parentheses are original values.

weedy check were mainly due to stiff competition from weeds for space as was evidenced by lanky tall plants with fewer branches. In contrast, higher plant population in weed-free check was mainly due to uninterrupted soybean plant growth with sufficient nutrients and moisture. Plant population and dry matter accumulation of soybean were highly improved due to herbicide treatments including the pre-emergence *fb* post-emergence metribuzin treatments, which clearly demonstrate lower weed competition in these treatments. Metribuzin pre-emergence *fb* post-emergence treatments, irrespective of dose, volume rate and times of applications, caused a more or less similar improvement on these growth parameters of soybean when compared with weedy check. This improvement was, however, lower than those in the pre-emergence applications of pendimethalin and metribuzin. This could be due to slight phytotoxicity to soybean plants for a short period after application of the post-emergence metribuzin. The results are in conformity with that of Chandrakar and Urkurkar (1993).

All herbicide treatments including metribuzin pre-emergence *fb* post-emergence applications resulted in greater number of pods/plant compared to weedy check. Weed-free check resulted in the highest number of pods/plant followed by metribuzin 0.5 kg/ha pre, metribuzin 0.25 kg/ha pre and pendimethalin 0.75 kg/ha pre. All these pre-emergence treatments, in this regard, were superior to pre-emergence *fb* post-emergence treatments of metribuzin. The pre-emergence *fb* post-emergence metribuzin treatments had intermediate effect, but superior to that of weedy check. Weed-free check again resulted in significantly greater number of seeds/pod than those in other treatments except pendimethalin 0.75 kg/ha. Weed-free check, metribuzin 0.5 kg/ha pre, metribuzin 0.25 kg/ha pre and pendimethalin 0.75 kg/ha pre resulted in significantly higher test weight of soybean than in others. The test weight was similar across the pre-emergence *fb* post-emergence metribuzin treatments.

All pre-emergence and pre-emergence *fb* post-emergence treatments resulted in significantly higher soybean seed yield compared to weedy check. Seed yields were the highest under weed-free check. Metribuzin 0.5 kg/ha pre-emergence gave seed yield comparable with it during first year, but slightly lower in second year. This treatment reduced weed, particularly *Cyperus rotundus* competition to a great extent and consequently had better growth and yield attributes. It establishes that under situations of abundance of *Cyperus rotundus* any herbicide, which controls *Cyperus rotundus* better, is likely to provide advantage on seed yield. It was achieved by metribuzin 0.5 kg/ha pre (Arregui *et al*., 2006). However, among the pre-emergence *fb* post-emergence treatments, metribuzin 0.1 kg/ha with 200 litres/ha of water applied at 20 DAS was found to be the best. It, on seed yield, was comparable with pendimethalin 0.75 kg/ha and metribuzin 0.5 kg/ha in both years and was slightly superior to metribuzin 0.25 kg/ha pre. Otherwise, all pre-emergence *fb* post-emergence treatments of metribuzin except metribuzin 0.2 kg/ha with 400 litres/ha at 30 DAS, were comparable with each other in this regard. Among these treatments, metribuzin 0.2 kg/ha

Table 3. Plant population, dry weight and plant height of soybean at 60 DAS and yield attributes and yield of soybean (Pooled data of 2 years)

Treatment	Plant population (No./m row)	Plant dry matter (g/m^2)	Plant height (cm)	Pods/ plant	Seeds/ pod	Test weight (g)	Seed yield (kg/ha)	Biological yield (kg/ha)
Weedy check	9.8	74.3	69.8	18.5	2.2	84.8	866	2127
Weed - free check	17.0	153.7	53.0	37.7	2.5	96.6	1463	3014
Pendimethalin 0.75 g/ha Pre	13.1	183.7	66.0	31.7	2.3	92.3	1183	3060
Metribuzin (MTB) 0.5 kg/ha Pre	13.5	145.8	62.7	32.2	2.3	91.75	1296	3788
MTB 0.25 kg/ha Pre	12.7	125.8	56.3	32.0	2.2	91.4	1188	3350
MTB (0.1 kg/ha, 200 l/ha, 20 DAS) Post*	13.1	103.7	51.0	26.2	2.2	87.0	1214	3273
MTB (0.1 kg/ha, 400 l/ha, 20 DAS) Post*	12.1	102.9	47.0	23.7	2.2	87.1	1081	3048
MTB (0.1 kg/ha, 200 l/ha, 30 DAS) Post*	12.8	101.6	51.1	25.0	2.1	85.8	1115	2944
MTB (0.1 kg/ha, 400 l/ha, 30 DAS) Post*	11.6	110.0	50.3	24.1	2.1	86.5	1096	3164
MTB (0.2 kg/ha, 200 l/ha, 20 DAS) Post*	11.8	96.2	50.6	25.9	2.2	87.1	1068	2829
MTB (0.2 kg/ha, 400 l/ha, 20 DAS) Post*	11.5	98.7	47.8	25.1	2.2	85.6	1005	3115
MTB (0.2 kg/ha, 200 l/ha, 30 DAS) Post*	12.5	110.3	49.3	23.9	2.2	86.3	1108	2844
MTB (0.2 kg/ha, 400 l/ha, 30 DAS) Post*	11.8	94.1	49.1	22.2	2.2	86.6	1016	2910
SEm ±	0.6	7.0	1.7	1.6	0.1	1.2	57.6	198
CD (P=0.05)	1.9	20.1	4.9	4.8	0.2	3.6	170.0	577

* In all the post-emergence applications of metribuzin, metribuzin 0.25 kg/ha was applied as pre-emergence; ** Grasses include *Aerachne racemosa* and *Dactyloctenium aegyptium*; Data were transformed through square-root ($\sqrt{(x+0.5)}$) method; Figures in the parentheses are original values

Table 4. Effect of weed control measures on economics of soybean

Treatment	Cost of cultivation (₹/ha)	Net returns (₹/ha)	Net B:C ratio
Weedy check	9271	862	0.09
Weed - free check	11851	4949	0.42
Pendimethalin 0.75 g/ha Pre	10111	3816	0.38
Metribuzin (MTB) 0.5 kg/ha Pre	10806	4691	0.43
MTB 0.25 kg/ha Pre	10146	3992	0.39
MTB (0.1 kg/ha, 200 l/ha, 20 DAS) Post*	10625	3740	0.35
MTB (0.1 kg/ha, 400 l/ha, 20 DAS) Post*	10625	2240	0.21
MTB (0.1 kg/ha, 200 l/ha, 30 DAS) Post*	10625	2534	0.24
MTB (0.1 kg/ha, 400 l/ha, 30 DAS) Post*	10625	2459	0.23
MTB (0.2 kg/ha, 200 l/ha, 20 DAS) Post*	10889	1721	0.16
MTB (0.2 kg/ha, 400 l/ha, 20 DAS) Post*	10889	1226	0.11
MTB (0.2 kg/ha, 200 l/ha, 30 DAS) Post*	10889	2143	0.20
MTB (0.2 kg/ha, 400 l/ha, 30 DAS) Post*	10889	1227	0.11

*In all the post-emergence applications of metribuzin, metribuzin 0.25 kg/ha was applied as pre-emergence

with 400 litres/ha at 30 DAS gave the lowest yield in first year.

Economics

Weed-free treatment had the highest cost of cultivation. Yet, because of the highest seed yield of soybean, it gave the highest net returns and net B:C ratio (Table 4). Metribuzin 0.5 kg/ha pre was the next costly treatment, mainly because of higher dose adopted. This treatment, however, brought higher net returns and net B:C ratio than in other treatments. The reason could be higher yield of soybean. Pendimethalin 0.75 kg/ha pre and metribuzin 0.25 kg/ha pre were intermediate, but more or less comparable with metribuzin 0.5 kg/ha pre in terms of net returns and net B:C ratio. Metribuzin 0.25 kg/ha pre-emergence *fb* 0.2 kg/ha post-emergence, irrespective of volume rates and times of application, incurred higher cost of cultivation than others. Singh *et al.* (2006) reported similar variation in net returns and net B:C ratio among treatments due to variation in yield and expenditure incurred by treatments.

On the basis of two years experimentation, it can be concluded that metribuzin at 0.5 kg/ha pre is more effective in controlling weeds including *Cyperus rotundus* and, thus, increased weed control efficiency. It caused a significant reduction in the uptake of N, P and K by weeds and increased seed yield of soybean considerably.

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