



Direct and residual effect of herbicides on weed dynamics and productivity of soybean (*Glycine max*) -wheat (*Triticum aestivum*) cropping system

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Received: 6 May 2013; Revised accepted: 10 January 2014

ABSTRACT

A field experiment aimed to evaluate the bio-efficacy of new low dose herbicides applied in soybean and their residual effect on succeeding wheat was conducted during 2007-08 and 2008-09 at New Delhi. Results revealed that in soybean, post-emergence application of imazethapyr (100 g/ha) was more effective against *Trianthema portulacastrum*, *Commelina benghalensis*, *Digitaria sanguinalis* and *Dactyloctenium aegyptium* but pendimethalin (1500 g/ha) against *Dactyloctenium aegyptium*, *Digitaria sanguinalis* and *Trianthema portulacastrum*. Chlorimuron-ethyl provided effective control of broad-leaved weeds but failed to control grasses and sedges. Application of imazethapyr (100 g/ha) increased the seed yield of soybean by 66.49% over weedy check. Herbicidal application significantly suppressed the microbial population at 30 DAS which recovered at the harvest of soybean. The residual effect of chlorimuron-ethyl (6-12 g/ha) and imazethapyr (50-100 g/ha) applied in soybean resulted in significant reduction in population of all major weeds except *Avena ludoviciana* in wheat grown in rotation. No injury to wheat plant was observed due to residues of chlorimuron-ethyl (6-12 g/ha) and imazethapyr (50-100 g/ha) and other herbicides applied in soybean.

Key words : Chlorimuron, Imzethapyr, Microbial population, Quizalofop, Residual study, Soybean, Weed control efficiency, Wheat

Weed competition is one of the most important causes of yield reduction in soybean (*Glycine max*) and is estimated to be 20-77% depending on the weed species, their density and period of weed-crop competition (Kurchania *et al.* 2001). The effective control of weeds can help in improving the productivity of soybean. Chhokar *et al.* (1995) revealed that weed free maintenance up to 45 days after sowing (DAS) resulted in 96% increase in seed yield of soybean compared to uncontrolled weedy situations. The effective and economical weed control in soybean on large scale is not possible through hand weeding or use of mechanical tools because of time and labour intensiveness and difficulty due to intermittent rains. The herbicides like alachlor, fluchloralin and pendimethalin have been recommended for weed control in soybean and are being used by the farmers (Raskar and Bhoi 2002).

These herbicides have been quite effective on grasses and their continuous use has resulted in weed shift in some areas in favour of non-grassy weeds like *Cleome viscosa*,

Celosia argentea, *Trianthema monogyna* and *Commelina benghalensis*, which are highly competitive with soybean crop. Further, these herbicides proved ineffective against *Cyperus rotundus* and *C. benghalensis* (Sharma and Raghuvanshi 1999). This could be due to immobility of herbicides from leaves to the tubers of *C. rotundus*. Therefore, there is a need to have alternate herbicides which may provide wide range of weed control to avoid weed shift and also possible development of herbicide resistant weeds. The new herbicides namely; quizalofop-ethyl, imazethapyr and chlorimuron-ethyl have been developed to control wide range of weeds in broad-leaved crops including soybean. However, residues of some herbicides applied in preceeding crop may injure the succeeding crops. In general, the herbicides are not harmful when applied at recommended levels but reports are there which envisaged that herbicidal application has adverse effect on bacterial (Rajendran and Lourduraj 1999), fungal and actinomycetes population. Effective herbicides that do not injure rotational crops and microbes are required for successful adoption of soybean (*Glycine max*)–wheat (*Triticum aestivum*) cropping system. Information on the bio-efficacy of these herbicides against weeds in soybean and their carry over on weeds and yield of succeeding wheat is not available and thus the present study was undertaken.

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MATERIALS AND METHODS

Field trial was conducted during *kharif* and *rabi* seasons of 2007-2008 and 2008-2009 at Indian Agricultural Research Institute, New Delhi situated at 28.4°N latitude, 77.1°E longitude and at an elevation of 228.6 m above mean sea level to evaluate the bio-efficacy of different herbicides in soybean and their residual effect on succeeding wheat crop. The experimental soil was sandy loam (*Typic Ustochrepts*) with 61.5% sand, 12.1% silt and 26.4% clay, medium in fertility with 0.37% organic carbon and a pH of 7.6. The mean annual rainfall was 672 mm and more than 80% rain occurred during the monsoon season (July-September) with mean annual evaporation 850 mm. Soybean variety Pusa 9702 was sown on 21 July 2006 and 15 July 2007 in rows, 30 cm apart at 75 kg seed/ha. A uniform dose of 40:80:25 kg NPK/ha was applied as basal in soybean. A set of treatments consisting of pre-emergence application of pendimethalin (1 000 and 1 500 g/ha) and post-emergence application (at 20 DAS) of quizalofop-ethyl (50 and 75 g/ha), chlorimuron-ethyl (6,9 and 12 g/ha) and imazethapyr (50, 75 and 100 g/ha) along with two hand weedings and unweeded (weedy check) control was laid out in a randomized block design with three replications. Herbicides were applied at various doses and time as per treatment schedule (Table 1). Herbicides were sprayed using operating knapsack sprayer with spray solution of 500 liter for pendimethalin and 350 liter/ha for quizalofop-ethyl, chlorimuron-ethyl and imazethapyr fitted with flat-fan nozzle. Two hand weedings were carried out in soybean at 20 and 40 DAS. Weed intensity (total and species wise) was recorded at 60 DAS with the help of 0.25 m² quadrat thrown randomly at four places in each plot and the data were subjected to square root transformation before statistical analysis. Weed control efficiency was also calculated based on weed population recorded at 60 DAS using the following formula suggested by Umroi and Boi (1982). Data recorded for each parameters were pooled together considering the minor difference in the values for both years of experimentation. For studying the effect of herbicides on soil microbes in soybean field, the pooled soil samples were analyzed for enumeration of total population of bacteria, fungi and actinomycetes using dilution technique. Tenfold serial dilutions were made in sterile distilled water and suitable dilution were plated using streptomycin potato dextrose (PDA), nutrient agar (N-agar) and spread plate method for fungi, bacteria and actinomycetes, respectively (Pramer and Schmidt 1965). The plates were incubated at 30 + 10°C and observations for their numbers were recorded at 30 DAS and at harvest of soybean from the plots treated with the highest dose of all four herbicides accordingly. Data on crop dry matter, yield attributes and seed yield of soybean were taken at harvest. To study the residual effect of herbicides applied in soybean after its harvest on succeeding wheat crop, wheat was sown after slight disking the field without disturbing the original layout. Weedy check (unweeded) and

two hand weeded plots were also maintained in wheat crop also. Wheat variety PBW 343 was sown on 28 November in 2006-2007 and 24 November in 2007-2008 in rows 22.5 cm apart at 100 kg seed/ha. The crop received 100 kg N and 60 kg P₂O₅/ha. Data on total weed count and species-wise weed density were also recorded in wheat crop at 90 DAS by using 0.25 m² size quadrat from four places in each plot similarly as done in preceding crop. Weed population data were subjected to square root transformation before statistical analysis. Analysis of variance was performed on all data collected. Where the F test was significant (at 5% level of significance), the Least Significant Differences (LSD) was used to compare mean at P=0.05 due to variation.

RESULTS AND DISCUSSION

Soybean

Weed flora

The experimental field of soybean crop was infested mainly with *Dactyloctenium aegyptium* (13.19%), *Digitaria portulacastrum* (18.80%) among grasses and *Tarantula portulacastrum* (14.47%) and *Commelina benghalensis* (15.91%) among broad-leaved weeds and *Cyperus rotundus* (22.79%) among sedges (Table 1). Hand weeding twice at 20 and 40 DAS recorded the lowest total density of weeds. Post-emergence application of imazethapyr at 100 g/ha (20 DAS) caused the highest reduction in the total density of weeds which, however, was statistically on a par with quizalofop ethyl applied at 75 g/ha. This might be due to better efficacy of imazethapyr against all dominant weeds except *Cyperus rotundus*. Quizalofop ethyl, proved second best herbicide treatment in reducing the total weeds density. This might be due to better control of grassy weeds and sedges. Chlorimuron ethyl (9-12 g/ha) had effectively reduced the number of broad-leaved weeds but found ineffective against sedges and grassy weeds. Pre-emergence application of pendimethalin at 1 500 g/ha found quite effective against *D. aegyptium*, *D. sanguinalis* and *T. portulacastrum* but did not inhibit the growth of *Cyperus rotundus* and *Commelina benghalensis*. This might be due to the fact that the elimination of competition of grasses by this herbicide allowed the maximum vigour of non-grassy weeds. Poor efficacy of pendimethalin at 1.25 kg/ha against *C. rotundus* and *C. benghalensis* was also reported by Pandey *et al.* (1999) in maize at Almora.

Growth and yields of soybean

The growth of soybean in terms of dry matter accumulation and number of pods per plant was the highest with hand weeding twice (at 20 and 40 DAS) which, however were found at par with post-emergence application of imazethapyr at 100 g/ha at 20 DAS (Table 2). Amongst the herbicides, post-emergence application of imazethapyr at 100 g/ha resulted in maximum increase in dry matter accumulation and number of pods/plant by soybean at 80

Table 1 Direct and residual effect of herbicides applied in soybean on weed growth in soybean and in succeeding wheat crop (Mean of 2 years)

Treatments	Soybean (Direct)					Wheat (Residual)								
	Weed density* (No/m ²) at 60 DAS					Weed density* (No/m ²) at 90 DAS								
	D. aegyptium	Digitaria sanguinalis	Cyperus rotundus	Trianthema portulacastrum	Commelinacorymbosa	Phalaris minor	Avena ludoviciana	Rumex dentatus	Melilotus indica	Chenopodium album	Total weed population	Weed control efficiency	Total weed population	Weed control efficiency
Pendimethalin @1000 g/ha PE	4.56 (20.33)	4.60 (20.67)	6.66 (44.00)	3.88 (14.67)	5.33 (28.00)	11.47 (131.33)	4.45 (19.33)	3.43 (11.33)	5.90 (34.66)	5.01 (24.66)	6.37 (40.00)	11.42 (129.98)	20.71 (129.98)	28.75 (36.89)
Pendimethalin @1500 g/ha PE	4.22 (17.33)	3.76 (13.67)	6.61 (43.33)	3.75 (13.67)	5.07 (25.33)	10.82 (116.33)	4.33 (18.33)	3.53 (12.00)	5.85 (34.00)	4.67 (21.33)	6.38 (40.66)	11.20 (126.33)	23.51 (126.33)	36.89 (41.59)
Quizalofop @50 g/ha at 20DAS	4.48 (19.66)	3.84 (14.33)	2.41 (5.33)	5.07 (25.33)	4.98 (24.33)	10.36 (107.66)	4.95 (24.00)	3.22 (10.00)	5.81 (33.33)	5.33 (28.00)	6.40 (41.00)	11.71 (136.33)	16.60 (136.33)	41.59 (43.94)
Quizalofop @75 g/ha at 20DAS	4.67 (21.33)	4.22 (17.33)	3.02 (8.67)	5.17 (26.33)	5.04 (25.00)	10.18 (103.33)	4.77 (22.33)	3.29 (10.33)	5.87 (34.00)	5.04 (25.00)	6.38 (40.33)	11.96 (142.66)	17.35 (142.66)	43.94 (26.58)
Chlorimuron @6 g/ha at 20 DAS	5.51 (30.00)	5.89 (34.33)	6.69 (44.33)	3.71 (13.33)	3.13 (9.33)	11.65 (135.33)	4.22 (17.33)	2.96 (8.33)	4.94 (24.00)	3.75 (13.67)	3.57 (12.33)	9.02 (81.00)	54.66 (81.00)	26.58 (34.54)
Chlorimuron @9 g/ha at 20 DAS	5.21 (26.66)	5.84 (33.67)	6.58 (43.00)	2.41 (5.33)	2.41 (5.33)	11.00 (120.66)	4.18 (17.00)	3.13 (9.33)	4.97 (24.33)	3.72 (13.33)	3.53 (12.00)	9.17 (83.66)	53.17 (83.66)	34.54 (40.32)
Chlorimuron @12 g/ha at 20 DAS	4.94 (24.00)	5.74 (32.67)	6.61 (43.33)	1.95 (3.33)	1.95 (3.33)	10.51 (110.00)	3.76 (13.67)	2.90 (8.00)	4.84 (23.00)	3.57 (12.33)	3.61 (12.66)	8.76 (76.33)	57.27 (76.33)	40.32 (36.16)
Imazethapyr @50 g/ha at 20 DAS	4.67 (21.33)	3.70 (13.33)	6.38 (40.33)	4.81 (22.67)	3.63 (12.67)	10.87 (117.66)	3.93 (15.00)	3.06 (9.00)	4.87 (23.33)	3.53 (12.00)	3.67 (13.00)	8.97 (80.00)	55.22 (80.00)	36.16 (40.68)
Imazethapyr @75 g/ha at 20 DAS	4.45 (19.33)	3.83 (14.33)	6.63 (43.67)	4.26 (17.67)	3.07 (9.00)	10.48 (109.33)	3.89 (14.67)	2.89 (8.00)	4.77 (22.33)	3.58 (12.33)	3.57 (12.33)	8.80 (77.00)	56.90 (77.00)	40.68 (48.10)
Imazethapyr @100 g/ha at 20 DAS	3.89 (14.66)	3.75 (13.67)	6.66 (44.00)	3.63 (12.67)	2.86 (7.67)	9.80 (95.66)	4.01 (15.67)	2.91 (8.00)	4.73 (22.00)	3.62 (12.66)	3.56 (12.33)	8.82 (77.33)	56.71 (77.33)	48.10 (00.00)
Weedy check	4.97 (24.33)	5.92 (34.67)	6.51 (42.00)	5.20 (26.67)	5.45 (29.33)	13.6 (184.33)	4.57 (20.33)	3.33 (10.66)	6.01 (35.67)	5.04 (25.00)	6.38 (40.33)	12.66 (160.00)	00.00 (160.00)	00.00 (85.53)
Two hand weeding in both crops	1.95 (3.33)	2.26 (4.67)	3.02 (8.67)	1.77 (2.67)	2.19 (4.33)	5.2 (26.66)	1.46 (1.67)	1.85 (3.00)	1.95 (3.33)	2.11 (4.00)	2.19 (4.45)	4.45 (19.33)	90.30 (19.33)	85.53 (—)
SEM±	0.13	0.17	0.20	0.14	0.14	0.17	0.13	0.18	0.27	0.14	0.16	0.18	0.18	—
LSD (P=0.05)	0.38	0.50	0.58	0.41	0.42	0.51	0.37	0.54	0.67	0.42	0.23	0.54	0.54	—

PE, Pre-emergence; DAS, Days after sowing; *Date were subjected to square root transformation before statistical analysis . Figures in parentheses are original values.

Table 2 Direct effect of weed control measures on growth, yield attributes and productivity of soybean and their residual effect on the productivity of succeeding wheat crop (Mean of two years)

Treatment	Soybean						Wheat				
	Crop dry matter (g/plant)	Pods/plant	Seeds/pod	Seed index (g)	Seed yield (t/ha)	Stover yield (t/ha)	Plant height at maturity (cm)	Effective tillers (m ⁻¹)	No. of grains per ear head	Grain yield (t/ha)	Straw yield (t/ha)
Pendimethalin @1000 g/ha PE	11.8	39.6	2.0	12.5	1.50	2.72	91.3	54.6	34.3	3.55	5.35
Pendimethalin @1500 g/ha PE	13.4	42.6	2.3	12.5	1.62	2.87	92.0	57.6	35.0	3.59	5.78
Quizalofop @50 g/ha at 20 DAS	8.9	31.6	2.3	12.2	0.85	1.27	90.0	57.6	34.3	3.40	5.13
Quizalofop @75 g/ha at 20 DAS	9.6	34.6	2.3	12.4	0.89	1.47	90.3	57.5	34.6	3.50	5.46
Chlorimuron @ 6 g/ha at 20 DAS	12.3	43.3	2.0	12.2	1.35	2.13	91.0	75.0	38.6	4.28	6.72
Chlorimuron @ 9 g/ha at 20 DAS	13.8	44.6	2.0	12.6	1.60	2.83	91.6	75.6	39.0	4.31	7.10
Chlorimuron @ 12 g/ha at 20 DAS	14.2	46.3	2.3	12.8	1.78	3.00	91.3	76.0	39.6	4.41	7.19
Imazethapyr @50 g/ha at 20 DAS	12.0	45.3	2.0	12.4	1.50	2.77	91.6	75.3	39.3	4.29	7.67
Imazethapyr @75 g/ha at 20 DAS	14.0	45.0	2.0	12.7	1.76	2.90	92.0	76.0	39.6	4.28	7.16
Imazethapyr @100 g/ha at 20DAS	15.1	46.9	2.3	12.9	1.88	3.13	92.3	77.6	40.3	4.46	7.67
Weedy Check	6.4	26.3	2.0	11.4	0.63	1.05	94.6	51.6	32.3	3.10	5.23
Two hand weeding at 20and 40 DAS	16.6	50.0	2.6	13.1	2.00	3.55	94.0	79.6	41.3	4.67	7.91
SEm±	0.5	1.1	0.2	0.10	0.15	0.15	1.7	2.1	1.1	0.17	0.24
LSD (P=0.05)	1.4	3.2	NS	0.31	0.43	0.44	NS	6.2	3.1	0.52	0.71

PE, Pre-emergence; DAS, days after sowing;NS, non-significant

Table 3 Effect of herbicides on microbial population in soybean (Mean of two years)

Treatment	Microbial populations (days after spraying)					
	Bacteria (× 10 ⁵ /g soil)		Fungi (× 10 ³ /g soil)		Actinomycetes (× 10 ⁵ /g soil)	
	30 DAS	At harvest (90 DAS)	30 DAS	At harvest (90 DAS)	30 DAS	At harvest (90 DAS)
Pendimethalin @1500 g/ha PE	54.8	65.3	7.93	8.00	44.7	47.5
Quizalofop @75 g/ha at 20DAS	52.9	68.0	6.75	7.0	39.9	46.7
Chlorimuron @ 12 g/ha at 20 DAS	51.5	66.8	6.55	7.2	35.3	46.8
Imazethapyr @100 g/ha at 20DAS	53.2	68.0	6.95	7.5	40.1	46.9
Weedy check	84.2	70.7	9.75	8.50	54.0	50.0
Two hand weeding	78.9	66.3	8.37	8.00	51.1	47.0
SE m±	1.7	2.1	0.44	0.52	3.45	3.39
LSD (P=0.05)	5.5	NS	1.41	NS	10.99	NS

PE, Pre-emergence; DAS, days after sowing

DAS which however was found on a par with its lower dose (75 g/ha) and chlorimuron-ethyl application at 9-12 g/ha. Hand weeding twice produced significantly the highest seed index but was on a par with imazethapyr (100 g/ha) and chlorimuron-ethyl (12 g/ha). Consequently, herbicides, viz. imazethapyr (100 g/ha) and chlorimuron-ethyl (12 g/ha) produced seed yield on a par with hand weeding twice.

Effect of herbicides on soil microflora

Application of herbicides had significant impact on soil microflora. Population of bacteria, fungi and actinomycetes was significantly reduced due to herbicides application at 30 DAS as compared untreated plots (weedy check and hand

weeded plots) (Table 3). However, the population of all three microbes did not vary significantly due to herbicidal treatments at the harvest. This might be due to stimulation in the population of bacteria, fungi and actinomycetes probably owing to reduction in the adverse effect of herbicides with passage of time. These findings are in accordance with that of Rajendra and Lourduraj (1999).

Maximum microbial population in soybean rhizosphere was noticed in untreated plots whereas minimum was in plots treated with chlorimuron-ethyl (12 g/ha) followed by quizalofop-ethyl (75 g/ha) and imazethapyr (100 g/ha). The highest population of all three microbes in weedy check at both 30 DAS and at harvest might be due to the more

rhizosphere area in comparison to the plots having less weed population owing better weed control measures. Suppression of fungal, bacterial and actinomycetes population due to pre-emergence application of butachlor and post-emergence application of fenoxaprop-p-ethyl and ethoxysulfuron was also reported by Chowdhary *et al.* (2008).

Residual effect of herbicides on wheat

Weed flora

Chenopodium album (25%), *Rumex dentatus* (22.29%), *Melilotus indica* (15.63%) among broad-leaved weeds and *Phalaris minor* (12.71%) and *Avena ludoviciana* among grassy weeds constituted the major part of the weed flora occurred in the wheat sown in sequence after soybean (Table 1).

Residual effect of all herbicides applied in soybean resulted in significant reduction in the total weed density over weedy check. However, the highest and the lowest reduction in the total weed density was obtained in plots treated with chlorimuron-ethyl (12 g/ha) and quizalofop-ethyl (75 g/ha), respectively. Species-wise count of weeds revealed that the population of all weeds except *Avena ludoviciana*, was significantly reduced due to the carryover effect of chlorimuron-ethyl (9-12 g/ha) and imazethapyr (50-100 g/ha) (Table 1). This might be due to longer persistence of chlorimuron-ethyl and imazethapyr in soil (Krausz 1992, Taylor *et al.* 1992). But the residues of pendimethalin (1 000-1500 g/ha) and quizalofop-ethyl (50-75 g/ha) failed to reduce the population of the major weed species. Maximum weed control efficiency (52.29%) after handweeded plot (87.92%) was obtained in chlorimuron-ethyl (12 g/ha) treated plots closely followed by imazethapyr (100 g/ha) treated plots (51.88%). This can be attributed to the effective, long-term, broad-spectrum action of the residual activity of these herbicides against the *Phalaris minor* and the major broad-leaved weeds.

Grain yield

The carryover effect of imazethapyr (50-100 g/ha) and chlorimuron-ethyl (6-12 g/ha) applied in soybean significantly improved the yield attributing characters (effective tillers and number of grain per ear head), grain and straw yield of wheat sown in sequence after soybean (Table 2). However the residues of herbicides applied in soybean could not influence the height of wheat-plant.

Residual effect of imazethapyr (50-100 g/ha) and chlorimuron-ethyl (6-12 g/ha) provided an yield advantage of 27.57 – 30.49 and 27.57 – 29.71%, respectively over weedy check. This might be due to longer residual soil activity of these herbicide which inhibited the weed growth and led improvement in the yield attributing characters and finally resulted in significant increase in grain yield of wheat.

No injury to wheat crop was recorded with the application of chlorimuron-ethyl (20-140 g/ha) and imazethapyr (50-300 g/ha) applied in soybean (Krausz *et al.* 1992). Similarly, seed yield of wheat was not affected due to residues of chlorimuron-ethyl and imazethapyr applied in clusterbean (Punia *et al.* 2011).

It may be concluded that herbicides, viz. chlorimuron-ethyl (6-12 g/ha) and imazethapyr (50-100 g/ha) applied to soybean are safe and effective in soybean-wheat sequence.

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