Short communication

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Residual effects of soybean herbicides on the succeeding winter crops

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Pendimethalin is a dinitroaniline herbicide used for selective control of annual grasses and few small seeded broad-leaved weeds in several crops. It is absorbed by the roots and leaves, and inhibits cell division and cell elongation (BCPC and RSC,1994). Quizalofop-p-ethyl is a widely used selective, post-emergence aryloxyphenoxypropionate herbicide and is used to control annual and perennial grass weeds in soybean and other broad-leaved crops. It inhibits the acetyl CoA carboxylase enzyme, necessary for lipid synthesis in the plants. The imidazolinone herbicides (imazethapyr and imazamox) inhibit acetolactate synthase (ALS), a key enzyme in the biosynthesis of branched-chain amino acids valine, leucine, and isoleucine. Once in the phloem and translocated to the site of action, the imidazolinones inhibit ALS, causing death of meristematic cells resulting in plant death (Masson and Webster 2001). They are applied either pre- or post-emergence as selective herbicides for broad-spectrum control of broad-leaf weeds and grasses in soybean and several other leguminous crops (Barkani *et al.* 2005). Wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), spinach (*Spinacia oleracea*), pea (*Pisum sativum*), raya (*Brassica juncea*), canola (*Brassica napus*) and sugarbeet (*Beta vulgaris*) are the important succeeding crops, grown after soybean in Punjab and neighbouring states of Haryana and Rajasthan. The crops have differential sensitivity to different herbicides. Sugar beet showed the highest sensitivity to imazamox followed by spinach, oilseed rape, fennel, cauliûower and lettuce that were damaged by imazamox while wheat, sunûower, grain sorghum and maize were far less sensitive to imazamox residues (Pannacci *et al.* 2006). Hence, studies on the residual effects of herbicide on the succeeding crops are important, before it is finally recommended for field applications to the farmers.

Chemical methods and plant bioassays are most frequently used for the assessment of herbicide residues in soil. Plant bioassays are simple and inexpensive and measure a phytotoxic portion of soil residual herbicide, which typically varies with soil type and plant species. There are fewer published details on use of field bioassay for measuring the residual effects of pendimethalin, quizalofop, imazethapyr and imazamox on wheat, barley, spinach, pea, raya, canola and sugarbeet. In the present study, the residual effects of pendimethalin, quizalofop, premix of imazethapyr + imazamox, applied to soybean, on the succeeding winter crops were determined through field bioassay during winter 2013-14 at Ludhiana, India. The soil was loamy sand, low in organic carbon and available nitrogen and medium in available phosphorus and available potassium. The soil pH (7.6) and electrical conductivity (0.2/dsm) values were within the normal range. Soybean variety '*SL 744'* was seeded on June 8, 2013. The crop was supplied with fifteen weed control treatments *viz*. pendimethalin at 450 g/ha as pre-emergence alone and followed by one hoeing at 40 days after sowing, premix of imazethapyr + imazamox at 60 and 70 g/ha each at 3 and 4 weeks after sowing (WAS), quizalofop at 37.5 and 50.0 g/ha at 3 WAS, pendimethalin at 450 g/ha *fb* premix of imazethapyr + imazamox at 60 and 70 g/ha at 4 WAS/ quizalofop at 37.5 and 50.0 g/ha at 4 WAS, pre-mix of imazethapyr + imazamox at 60 and 70 g/ha at 3 WAS *fb* quizalofop at 37.5 g/ha at 6 WAS and unsprayed check, laid out in a randomized complete block design with four replications.

After the harvest of soybean in mid-November 2013, the field was prepared by giving light cultivation followed by planking, without disturbing the original layout. Two rows of each of the succeeding winter season crops *viz*. wheat (cv. '*HD 2967'*), barley (cv. '*PL 807'*, spinach (cv. '*PB Green*'), pea (cv. '*PB 89'*), raya (cv. '*RLM 619'*), canola (gobh-isarson) (cv. '*GSC 6*') and sugarbeet (cv. '*Shubra'*) were sown in each plot, in rows spaced at 20 cm on 25 November 2013.These crops were raised as per package of practices recommended by PAU Ludhiana. The data on seedling emergence, plant height and dry matter

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Table 1. Residual effects of herbicides on plant height (cm) of succeeding crops at 40 days after sowing

Treatment	Wheat	Barley	Spinach	Pea	Raya	Canola	Sugarbeet
Pendimethalin 450 g/ha	11.3	13.7	5.9	10.9	12.8	9.1	5.2
Pendimethalin 450 g/ha *fb* hoeing at 40 DAS	10.1	11.4	4.9	12.4	10.9	7.8	4.3
Imazethapyr + imazamox 60 g/ha at 3 WAS	11.7	13.9	5.0	11.1	12.7	7.3	4.6
Imazethapyr + imazamox 60 g/ha at 4 WAS	13.0	12.5	5.9	11.7	13.5	8.8	5.1
Imazethapyr + imazamox 70 g/ha at 3 WAS	12.1	13.0	5.3	12.6	11.5	7.5	4.5
Imazethapyr + imazamox 70 g/ha at 4 WAS	12.5	14.4	5.4	13.6	12.7	9.0	5.3
Pendimethalin 450 g/ha *fb*imazethapyr + imazamox 60 g/ha at 4 WAS	12.0	13.0	4.9	10.9	12.7	7.3	4.9
Pendimethalin 450 g/ha fbimazethapyr + imazamox 70 g/ha at 4 WAS	12.5	12.7	5.4	13.1	11.7	7.1	4.2
Quizalofop 37.5 g/ha at 3 WAS	12.3	12.8	4.9	13.0	12.7	7.2	4.6
Quizalofop 50.0 g/ha at 3 WAS	12.1	11.7	5.6	11.3	13.1	8.8	5.3
Pendimethalin 450 g/ha *fb*quizalofop 37.5 g/ha at 4 WAS	11.8	13.3	5.7	10.0	12.1	7.3	4.5
Pendimethalin 450 g/ha *fb*quizalofop 50.0 g/ha at 4 WAS	12.1	14.6	5.3	11.5	13.5	7.9	5.1
Imazethapyr + imazamox 60 g/ha at 3 WAS *fb*quizalofop 37.5 g/ha at 6 WAS	11.6	14.3	5.5	13.1	12.2	9.3	4.5
Imazethapyr + imazamox 70 g/ha at 3 WAS *fb*quizalofop 37.5 g/ha at 6 WAS	12.6	13.4	4.6	13.5	13.2	7.5	5.0
Unsprayed check	11.5	13.3	5.1	12.1	11.9	7.3	5.1
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS

Table 2. Residual effects of herbicides on dry matter accumulation (g/m^2) of succeeding crops at 40 days after sowing

Treatment	Wheat	Barley	Spinach	Pea	Raya	Canola	Sugarbeet
Pendimethalin 450 g/ha	48.5	60.6	15.8	10.9	55.2	22.0	4.3
Pendimethalin 450 g/ha *fb* hoeing at 40 DAS	45.1	50.6	13.0	10.7	49.8	22.8	4.0
Imazethapyr + imazamox 60 g/ha at 3 WAS	52.3	54.8	14.9	11.3	53.8	24.8	3.9
Imazethapyr + imazamox 60 g/ha at 4 WAS	49.1	50.6	13.5	9.9	52.4	22.8	4.5
Imazethapyr + imazamox 70 g/ha at 3 WAS	54.9	55.8	13.8	12.2	53.7	26.0	3.7
Imazethapyr + imazamox 70 g/ha at 4 WAS	51.1	56.3	15.9	10.4	51.8	25.9	3.9
Pendimethalin 450 g/ha *fb* imazethapyr + imazamox 60 g/ha at 4 WAS	49.1	52.1	12.9	10.6	54.2	24.0	3.9
Pendimethalin 450 g/ha *fb* imazethapyr + imazamox 70 g/ha at 4 WAS	47.7	59.1	13.0	9.6	53.0	26.2	3.6
Quizalofop 37.5 g/ha at 3 WAS	51.7	53.3	13.4	12.2	53.0	26.0	3.6
Quizalofop 50.0 g/ha at 3 WAS	44.5	51.4	13.0	11.4	52.7	23.2	4.7
Pendimethalin 450 g/ha *fb*quizalofop 37.5 g/ha at 4 WAS	50.4	55.4	13.2	11.3	49.5	24.6	4.2
Pendimethalin 450 g/ha *fb* quizalofop 50.0 g/ha at 4 WAS	57.6	58.0	13.2	11.8	53.8	23.9	4.5
Imazethapyr + imazamox 60 g/ha at 3 WAS *fb* quizalofop 37.5 g/ha at 6 WAS	55.7	55.7	15.0	10.0	51.1	24.2	4.3
Imazethapyr + imazamox 70 g/ha at 3 WAS *fb* quizalofop 37.5 g/ha at 6 WAS	51.0	57.0	15.5	10.9	53.8	24.3	5.0
Unsprayed check	51.0	55.7	13.4	12.5	54.1	25.0	5.0
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS

accumulation by succeeding crops were recorded at 40 days after sowing. All the data were analyzed using the SAS Proc GLM (SAS 9.1). Differences between the treatments were determined using Fisher's protected LSD (P=0.05).

The results indicated that the herbicides applied to soybean did not show any significant effect on seedling emergence (data not shown), plant height and dry matter accumulation of all the succeeding crops,*viz.* wheat, barley, spinach, pea, raya, canola and sugarbeet (Table 1 and 2), indicating the safety of all the three herbicides, used alone or in sequence, for all the succeeding crops grown in rotation with soybean. The residual effects of herbicides depend upon soil texture, soil reaction, organic matter content and climatic conditions of a

place. A long time gap between application of herbicides and crop harvest, microbial degradation, and precipitation cause the degradation and leaching down of the herbicide (Idapuganti *et al.* 2005). Pendimethalin at 1.0 and 1.5 kg/ha remained biologically active up to 25 to 26 days in sandy loam soil; 75% pendimethalin was lost in 45 days (Kewat 1998). At pH 7, the half-life for imazamox was 10 days and for imazethapyr was 112 days (Aichele and Penner 2005). In moist sand, 52% of imazethapyr was degraded within 48 hour of exposure to UV light (Curran *et al.* 1992). In the present study, there was long time gap of 124 to 168 days between the applications of different herbicides to soybean to sowing of succeeding crop,which seemed to be sufficient for degradation of the herbicides.The results indicated that all the above herbicides at the doses tested, used for weed control in soybean, are safe for raising of wheat, barley, spinach, pea, raya, canola and sugarbeet, in rotation with soybean.

SUMMARY

The residual effects of pendimethalin, quizalofop, imazethapyr and imazamox, applied to soybean crop, on the succeeding winter season crops, *viz*. wheat, barley, spinach, pea, raya, canola and sugarbeet were determined through field bioassay at Ludhiana in 2013-14. Soybean was supplied with fifteen weed control treatments, *viz*. pendimethalin at 450 g/ha as pre-emergence alone and followed by (*fb*) hoeing, imazethapyr + imazamox at 60 and 70 g/ha each at 3 and 4 weeks after sowing (WAS), quizalofop 37.5 and 50.0 g/ha at 3 WAS, pendimethalin 450 g/ha *fb* imazethapyr + imazamox 60 and 70 g/ha at 4 WAS/quizalofop at 37.5 and 50.0 g/ha at 4 WAS, imazethapyr + imazamox 60 and 70 g/ha at 3 WAS *fb* quizalofop 37.5 g/ha at 6 WAS and unsprayed check. The emergence, plant height and dry matter accumulation of all the succeeding crops were similar among herbicidal and unsprayed plots indicating that all the herbicides are safe for raising of these winter crops in rotation with soybean.

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