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Response of the Succeeding Soybean Crop as affected by the residue effect of herbicides applied in Wheat in Kymore Plateau and Satpura Hill Zone of Madhya Pradesh

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A B S T R A C T

A field experiment was conducted during *Rabi* season of 2016-17 and 2018-19 at the Research Farm, Department of Agronomy, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.). The investigation was aimed to study the present status of response of the succeeding soybean crop as by the residue effect of herbicides applied in wheat in kymore plateau and satpura hill zone Jabalpur district of Madhya Pradesh. Residual effect of twelve herbicides on the succeeding soybean crop. Results of two years study revealed that emergence %, plant population, phytotoxic effect and branches plant^{-1} of succeeding soybean crop was not affected by any of the herbicides residue applied in wheat. Yield attributes *viz.*, number of pods plant^{-1}, number of seeds pod^{-1}, seed index, seed yield, Stover yield and harvest index of the succeeding soybean crop were also not influenced by herbicide residue effect. Therefore, residual effect study claimed that use of the tested herbicides in wheat is safe for succeeding soybean crop.

Introduction

Wheat is one of the important cereals contributing approximately 30-35 % to total food grain basket of the country. In India wheat crop is infested by more than 90 weed species which cause 20 to 40% yield losses as they compete with crop for available growth resources like nutrients, water, light and space etc. at same level (Rao, 2000). If weeds are not controlled during critical period of crop growth, may cause up to 66% reduction in wheat yield (Angiras *et al.*, 2008). Wheat crop is found very sensitive to early weed competition. It is being a *Rabi* season crop is infested with many grasses and broad leaf weeds. Wheat crop suffers a lot from a number of weeds such as *Avena ludoviciana*,

Phalaris minor, *Medicago hispida*, *Chenopodium album*, *Vicia sativa and Lathyrus aphaca* Jain *et al.*, (2007).

Therefore, major emphasis on control should be given during this period. Hand weeding is a traditional and effective method of weed control, but unavailability of labour during peak period of demand and hindrance of crop for manual weeding due to unpredictable continuous rains in the growing period make weed management in wheat a challenging task while mechanical means generally leads to root injury (Lal *et al.*, 2016).

Under such situations weed management through the herbicide application remains the only viable option. As a consequence of herbicide use, the presence of residues in field crop may cause damage to succeeding crop.

Herbicides residues also remain on the soil surface due to the adsorption process which may potentially affect quality and yield of the next crop cultivated on the same field. Stable herbicides may be taken up by plants, which results in unwanted terminal residues (Barnes and Lavy (1991); Battaglin *et al.*, 2000).

If herbicides apply in wheat crop at the recommended dose and have residual effect on the succeeding soybean crop, it is expected to have a penalty of yield of the crop that will be grown next to wheat. Therefore, the study was initiated with an aim to investigate the residual effects of herbicides applied wheat and their impact on succeeding soybean crops through bioassay technique.

Materials and Methods

A field experiment was conducted during two consecutive *Rabi* seasons of year 2016-17 and 2017-18 at Research Farm, Department of Agronomy, JNKVV Jabalpur, Madhya Pradesh. Twelve herbicide treatments comprised of post emergence with and without surfactant at different doses *viz.*,T_1Halauxifen – methyl 6.95% + Pyroxsulam 25% WG + Surfactant (14.38 *a.i.* g ha^{-1}), T_2Halauxifen – methyl 6.95% + Pyroxsulam 25% WG + Surfactant (19.17 *a.i.* g $ha^{-1)}$, T_3Halauxifen – methyl 6.95% + Pyroxsulam 25% WG + Surfactant (23.96 *a.i.* g ha^{-1}), T_4Halauxifen – methyl 6.95% + Pyroxsulam 25% WG (14.38 *a.i.* g ha^{-1}), T_5Halauxifen – methyl 6.95% + Pyroxsulam 25% WG (14.38 *a.i.* g ha^{-1}), T_6Halauxifen – methyl 6.95% + Pyroxsulam 25% WG (14.38 *a.i.* g ha^{-1}), and alone application of T_7Pyrosulam 4.5% + surfactant (18.75),T_8Halauxifen-methyl 10.42% + Surfactant (5.21), T_9Sulfosulfuron + Metsulfuron – methyl + Surfactant (32 *a.i.* g ha^{-1}), T_{10}Halauxifen – methyl 6.95% + Pyroxsulam 25% WG + Surfactant (47.93 *a.i.* g ha^{-1}), T_{11} (hand weeding twice (30 & 60 Days after sowing) and weedy check (control). The experiment was laid out in Randomized Block Design and replicated thrice.

The soil of the experimental area was clay, neutral in reaction (pH 7.16), medium in organic carbon content (0.54 %), normal in electrical conductivity (0.29 dS/m), medium in available N (260.12 kg ha^{-1}) and P (12.25 kg ha^{-1}) and high in available K (295.10 kg ha^{-1}).

Herbicides were applied as post emergence *i.e.* 35 DAS with the help of hand-operated Knapsack sprayer, fitted with flat fan nozzle with 300 litter ha^{-1} water. First hand weeding was done at 30 days after sowing (DAS) and second at 60 DAS in hand weeding treatment. A package and practices were adopted as recommended by JNKVV, Jabalpur. After harvest of wheat, micro-plots of 5.00 m x 3.15 meter were prepared within the unit plot of wheat through required number of spading and other earth works.

Seven shallow lines were made within each of the micro-plot by a wooden stick to accommodate soybean. 30 kg^{-1} sown for soybean crop by manually in line at 25 June 2017 and 24 June 2018 respectively. Plots were manually kept weed-free during the crop growing season to discover only the residual effect of herbicides on the tested succeeding crop.

Results and Discussion

Emergence (%)

The data give in Table 1 show that persistence effect of different herbicides applied in wheat crop was found non-significant on emergence (%) of succeeding soybean crop during both the years. The results clearly show that there was no any persistence effect of different herbicides on succeeding soybean crop. There was no any statistically difference between treatments.

Plant population

The results on residual effect of different weed management practices employed in wheat crop on plant population at initial stage (at 15 DAS) and at harvest of succeeding soybean crop, are presented in Table 2.

The results reveal that carry over effect of different herbicides applied in wheat crop was found non-significant on plant population of succeeding soybean crop recorded at 15 DAS and at harvest after harvesting of wheat in the same plots during both the years.

The results clearly indicate that there was no any residual phytotoxic effect in the soil after harvesting of wheat crop for succeeding crop. There were no any statistically difference between treatments but mathematically changes were recorded under different herbicidal treatments.

At 15 DAS highest plant population was recorded when (T_4) Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant applied at lowest dose 14.38 g *a.i.* ha^{-1} (17.8) followed by T_3 (17.7), T_7 (17.7) and T_{11} (17.7).

At harvest highest plant population was recorded when Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant applied at lowest dose 14.38 g *a.i.* ha^{-1} (17.2) and same plant population was recorded under T_8 (17.2).

Phytotoxic symptoms on succeeding soybean crop plant at 15, 30 and 45 DAS

The data related to residual effect of phytotoxicity of soybean crop applied herbicides on wheat crop are presented in Table 2. The herbicide toxicity on soybean crop stand and growth was to be recorded at15, 30 and 45 DAS.

During both the years of evaluation by visual scoring the herbicide toxicity on soybean crop stand and growth recorded and rated from 0 to 10 scaling (Rao, 2000).

During 2016-17 visual survey indicated slight stunting, some plant stand loss, injury and discoloration observe in soybean crop plot when treated with Halauxifen – methyl 6.95% + Pyroxsulam 25% 23.96 g *a.i.* ha^{-1} without surfactant at 15 DAS, Halauxifen – methyl 6.95 % Pyroxsulam 25% 47.93 g *a.i.* ha^{-1} at 15 and 30 DAS during both the year of experiment. However, these phytotoxic effects were recovering in later stages and did not show any significant effect on final yield of soybean crop.

Branches $plant^{-1}$

The results on residual effect of different weed management practices employed in wheat crop on branches $plant^{-1}$ of succeeding soybean crop at 30, 60, 90 DAS and at harvest, are presented in Table 3.

The results revealed that carry over effect of different herbicides applied in wheat crop was found non-significant on branches $plant^{-1}$ of succeeding soybean crop recorded at 30, 60, 90 DAS and at harvest after harvesting of wheat crop in the same plots during both the years.

The results clearly indicate that there was no any residual phytotoxic effect in the soil after harvesting of wheat crop on succeeding soybean crop. There were no any statistically difference between treatments but mathematically changes were recorded under different herbicidal treatments.

Yield attributing characters

The data on persistence effect of different herbicides applied in wheat crop on yield attributing characters *viz*. pods plant^{-1}, seed pod^{-1} and seed index of succeeding soybean crop was recorded at harvest are presented in Table 4.

Number of pods plant^{-1}, Number of seed pod^{-1} and Seed index (%)

The data indicated that persistence effect of different herbicides applied in wheat crop was found non-significant on pods plant^{-1} of succeeding soybean crop at harvest during both the years. The results clearly show that there was no any persistence effect of different herbicides on succeeding soybean crop. There were no any statistically difference between treatments but numerically changes were recorded under different herbicidal treatments. Highest pods plan^{-1} was recorded under application of T_7 Pyroxsulam 4.5% with surfactant 18.75 g *a.i.* ha^{-1} (46.2 pods plan^{-1}) and lowest pods plant^{-1} was recorded under T_{12} weedy check (44.0 pods plan^{-1}).

Highest seed plan^{-1} was recorded under application of T_{12} weedy check (2.4 seed pod^{-1}) and lowest seed plant^{-1} was recorded under T_{10}Halauxifen – methyl 6.96 % Pyroxsulam 25% with surfactant at highest dose 47.95 (1.8 seed pod^{-1}).

Highest seed index was recorded under different treatments *viz*. T_4, T_7 and T_{11} (9.8, 9.8, 9.8 g, respectively) and lowest seed index was recorded under T_{10}Halauxifen – methyl 6.96 % Pyroxsulam 25% with surfactant at highest dose 47.95 (9.4 g). The results clearly indicate that there was no any residual phytotoxic effect in the soil after harvesting of wheat crop for succeeding crop.

Table.1 Effect of different herbicidal treatments on emergence (%) of succeeding soybean crop

Treatment		Dose (g *a.i.* ha^{-1})	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	85	86	85.50
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	87	86	86.50
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	85	88	86.50
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	86	85	85.50
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	87	88	87.50
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	86	86	86.00
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	86	87	86.50
T_8	Halauxifen-methyl 10.42% **with surfactant**	05.21	85	86	85.50
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32.00	85	86	85.50
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	89	87	88.00
T_{11}	Hand weeding twice	30 & 60 DAS	85	86	85.50
T_{12}	Control (weedy check)	-	87	87	87.00

Table.2 Effect of different herbicidal treatments on plant population of succeeding soybean crop (Two year mean)

Treatment		Dose (g*a.i.* ha^{-1})	15 DAS			At harvest		
			2016-17	2017-18	Mean	2016-17	2017-18	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	17.2	17.5	17.3	16.8	16.5	16.7
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	17.3	17.2	17.3	17.0	16.8	16.9
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	17.5	17.7	17.6	17.2	16.9	17.1
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	17.8	17.8	17.8	17.1	17.2	17.2
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	17.6	17.6	17.6	16.9	16.9	16.9
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	16.5	16.8	16.7	16.1	15.9	16.0
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	17.4	17.7	17.5	16.7	16.7	16.7
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	18.0	17.3	17.7	17.3	17.0	17.2
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	18.0	17.3	17.6	17.5	16.9	17.2
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	16.8	17.2	17.0	16.3	17.0	16.7
T_{11}	Hand weeding twice	30 & 60 DAS	18.0	17.4	17.7	17.4	16.9	17.1
T_{12}	Control (weedy check)		16.5	17.6	17.0	16.9	16.9	16.9
SEm±			**2.42**	**0.40**	**0.30**	**0.35**	**0.39**	**0.23**
CD (P=0.05)			**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Yield

The data on persistence effect of different herbicides applied in wheat crop on seed yield kg ha^{-1}, straw yield kg ha^{-1} and harvest index of succeeding soybean crop was recorded are presented in Table 5.

Seed yield (kg ha^{-1}), Straw Yield (kg ha^{-1}) and harvest index (%)

The data show that persistence effect of different herbicides applied in wheat crop was found non-significant on seed yield and straw yield of succeeding soybean crop after harvest during both the years.

The results clearly show that there was no any persistence effect of different herbicides on succeeding soybean crop. There were no any statistically difference between treatments but numerically changes were recorded under different herbicidal treatments.

Highest seed yield kg ha^{-1} was recorded under T_8Halauxifen-methyl 10.42% with surfactant alone application at 5.21 g *a.i.* ha^{-1} (1889 kg ha^{-1}) and lowest yield was recorded under T_5Halauxifen – methyl 6.95% + Pyroxsulam 25% without surfactant at highest dose 47.95 g *a.i.* ha^{-1} (1730 kg ha^{-1}).

Table.3 Residual effect of herbicides on visual phytotoxicity on succeeding soybean crop (Two year mean)

Treatment		Dose (g*a.i.* ha^{-1})	15 DAS	30 DAS	45 DAS
			Mean	Mean	Mean
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	0	0	0
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	0	0	0
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	0	0	0
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	0	0	0
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	0	0	0
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	1	0	0
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	0	0	0
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	0	0	0
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	0	0	0
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	2	3	2
T_{11}	Hand weeding twice	30 & 60 DAS	0	0	0
T_{12}	Control (weedy check)		0	0	0

The results clearly indicate that there was no any residual phytotoxic effect in the soil after harvesting of wheat crop for succeeding crop.

Highest harvest index was recorded under T_{10}Halauxifen – methyl 6.96 % Pyroxsulam 25% with surfactant at highest dose 47.95 (35 %) and lowest harvest index was recorded under T_3Halauxifen – methyl 6.95% + Pyroxsulam 25% with surfactant at higher dose 23.96 g *a.i.* ha^{-1} (31 %).

Herbicide persistence in the soil is an important consideration for recommending it to the farmers as it is related to length of the time that the herbicides remain active, and climatic and edaphic factors. These factors strongly interact with one another and make an antagonistic or synergistic effect. In the present study, the possible carry over effect of the herbicides used was studied by sowing succeeding soybean crop consecutive two years.

The study clearly demonstrated that twelve applied in wheat crop at their recommended dose did not affect germination of the succeeding soybean crop. These results also found by Carvalho *et al.,* (2015); Singh and Ali (2004); Walia *et al.,* (2006) and Walia *et al.,* (2007).

Table.4 Effect of different herbicidal treatments on branches $plant^{-1}$ of succeeding soybean crop (Two year mean)

Treatment		Dose (g*a.i.* ha^{-1})	30 DAS	60 DAS	90 DAS	At harvest
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	2.3	2.6	3.4	3.4
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	2.5	2.6	3.4	3.4
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	2.6	2.7	3.4	3.4
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	2.8	2.7	3.4	3.4
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	2.4	2.8	3.5	3.5
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	2.4	2.5	3.4	3.4
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	2.6	2.7	3.5	3.5
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	2.3	2.6	3.5	3.5
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	2.3	2.6	3.5	3.5
T_{10}	Halauxifen – methyl 6.96 % Pyroxsulam 25% **with surfactant**	47.93	2.5	2.7	3.5	3.5
T_{11}	Hand weeding twice	30 & 60 DAS	2.5	2.6	3.6	3.6
T_{12}	Control (weedy check)	-	2.6	2.5	3.5	3.5
SEm±			0.22	0.16	0.08	0.08
CD (P=0.05)			NS	NS	NS	NS

Table.5 Effect of different herbicidal treatments on yield attributes of succeeding soybean crop(Two year mean)

Treatment		Dose (g*a.i.* ha^{-1})	Pods $plant^{-1}$	Seed pod^{-1}	Seed index (g)
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	45.4	2.0	9.5
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	44.1	2.0	9.5
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	44.2	2.1	9.6
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	45.7	2.3	9.8
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	42.4	2.2	9.7
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	43.3	2.1	9.6
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	46.2	2.2	9.8
T_8	Halauxifen-methyl 10.42% **with surfactant**	5.21	43.7	2.3	9.6
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32	44.5	2.0	9.7
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	45.7	1.8	9.4
T_{11}	Hand weeding twice	30 & 60 DAS	41.8	2.1	9.8
T_{12}	Control (weedy check)	-	44.0	2.4	9.5
SEm±			0.22	1.46	0.17
CD (P=0.05)			NS	NS	NS

Table.6 Effect of different herbicidal treatments on seed, straw yield and harvest index of succeeding soybean crop (Two year mean)

Treatment		Dose (g*a.i.* ha^{-1})	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
T_1	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	14.38	1830	3717	33
T_2	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	19.17	1811	3689	33
T_3	Halauxifen – methyl 6.95% + Pyroxsulam 25% **with surfactant**	23.96	1821	3985	31
T_4	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	14.38	1861	3874	32
T_5	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	19.17	1730	3826	31
T_6	Halauxifen – methyl 6.95% + Pyroxsulam 25% **without surfactant**	23.96	1844	3607	34
T_7	Pyroxsulam 4.5% **with surfactant**	18.75	1878	3719	34
T_8	Halauxifen-methyl 10.42% **with surfactant**	05.21	1889	3791	33
T_9	Sulfosulfuron + Metsulfuron – methyl 80 **with surfactant**	32.00	1882	3867	33
T_{10}	Halauxifen – methyl 6.95 % Pyroxsulam 25% **with surfactant**	47.93	1860	3481	35
T_{11}	Hand weeding twice	30 & 60 DAS	1878	3874	33
T_{12}	Control (weedy check)	-	1848	3826	33
SEm±			0.22	59.24	144.46
CD (P=0.05)			NS	NS	NS

In conclusion, results obtained from this investigation indicates no persistency of herbicides applied in the previous soybean crop, even though some phytotoxicity effect was noticed in soybean crop at higher dose of Halauxifen – methyl 6.96 % Pyroxsulam 25% with surfactant at highest dose 47.95 and the seedlings recovered within days. Therefore, based our result it could be concluded that there was no residue possibility of the Halauxifen – methyl 6.96 % Pyroxsulam 25% with and without surfactant for succeeding soybean crop.

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