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Evaluation of accord plus and Lanfida for control of *Chenopodium* spp. in wheat

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Abstract
(*Triticum aestivum* L.) is the world's most widely cultivated and leading staple food. But their production is continuously decreased due to infestation of grassy and broadleaf weeds. *Chenopodium album* is most dominant broadleaf weed of wheat and other *Rabi* crops. Which limit the production of *Rabi* crops. Therefore, there is need to know about the current status of herbicide resistance/poor efficacy of different herbicides against *C. album.* The present investigation was conducted during the *Rabi* season of 2017-18 in the screen house of Department of Agronomy Chaudhary Charan Singh Haryana Agricultural University, Hisar (Haryana). Pot experiment was conducted in completely randomized design, replicated thrice using different herbicides namely Accord Plus and Lanfida applied at three doses (0.5X, X and 2.0X) in the experiment as post-emergence. Untreated pots were maintained as control for comparison. The results in general indicated that *Chenopodium* populations have poor efficacy was observed with Lanfida; however application of Accord Plus recorded complete control. Higher value of plant height, chlorophyll fluorescence, fresh weight and dry weight and lower value of EC was observed in the herbicidal treatments showing poor efficacy against the test populations. Accord Plus post-emergence (POE) application of other herbicides has already been recommended and promoted for the management of *Chenopodium* populations.

Keywords: Chlorophyll fluorescence, herbicides, efficacy, post-emergence, *Chenopodium* spp., population

Introduction
Wheat *(Triticum aestivum* L.) is one of the most important food grain crop which is grown with an approximately area 221.3 mha with a production and productivity of, 726.9 mt and 3290 kg/ha respectively (FAO STAT, 2016). India, is the second largest producer of wheat in the world contributing about 99.8 mt of grain with the productivity of 3220 kg/ha from the area 30.6 mha (Anonymous, 2018) [1]. Haryana is the major wheat growing state of India with an area of about 2.53 mha with 11.7 mt production and 4.62 t/ha productivity (Anonymous, 2018a) [2]. In crop production, weeds infestation is one of the biotic factor limiting production and productivity. A yield reduction of 10-50% by weed is very common in wheat; complete loss of crop has also been reported under certain cases (Malik and Singh, 1995) [7].
In north India, 80-90% fields under rice-wheat rotations are covered by herbicides for weed control; however, resistant weeds so far evolved only in wheat. *Phalaris minor* has become the most troublesome wheat weed, significantly knocking its productivity. Continuous use of a single herbicide over the years has not only evolved resistance to isoproturon (PSII) in the nineties, but also cross- and multiple-resistance to diclofop, fenoxaprop, clodinafop, pinoxaden (ACCase), sulfosulfuron and premix of mesosulfuron + iodosulfuron (ALS inhibitors) mediated by enhanced metabolism and target site mutation (Singh *et al*., 2009, 2017) [9, 12].
Recently resistance too evolved in *Avena ludoviciana*, *Rumex dentatus*, *Chenopodium album* and *Polypogon monspeliensis* to several herbicides (Singh *et al*., 2017) [12]. Occurrence of herbicide resistance in *C. album* has been reported recently (Singh, 2016; Singh *et al*., 2017) [11, 12] in India. *C. album* has evolved resistance globally to 17 herbicides under different cropping system (Heap, 2019) [5].
C. album is a major broadleaf weed of *Rabi* season and is a serious problem of cotton/pearl millet-wheat rotation in Haryana (Singh *et al*., 1995) [7] as well as in other regions of the Indo-Gangetic plains of India. This besides reducing the yield, it also interferes with manual harvesting and reduce the quality of the produce. Complaints of poor efficacy of several herbicides against *C. album* and *C. murale* have been reported recently from the farmer fields of different locations of Haryana states.

Materials and Methods

Experimental sites: The experiment was conducted in the screen house, Department of Agronomy in Chaudhary Charan Singh Haryana Agricultural University, Hisar during *Rabi* season of 2017-18. The site is situated at 29º.10' North latitude, 75º46' East longitude and an altitude of 215.2 m above mean sea level.

Treatment details: Accord Plus and Lanfida was applied at three doses (0.5X, X and 2.0X) in pot experiment under Completely Randomized Design with three replications.

Planting material: Seeds of five populations of *Chenopodium* spp. were collected from different locations where farmers reported poor control with recommended herbicides, whereas seeds collected from Research farm, CCSHAU Hisar population were used as standard check for comparison.

Pot preparation: For filling the pots, soil was collected from Agronomy Research Farm which was not exposed to any herbicides application from the last two years. It was air-dried, crushed, well ground to pass through a sieve of 2 mm pore size and. Plastic pots (8cm diameter) were filled with 2 kg soil composing sand, field soil and vermi-compost (2:3:1).

Observations recorded: Plant height, chlorophyll fluorescence, mortality percentage, electrical conductivity, fresh weight and dry weight.

Statistical analysis

All the observations were statistically analyzed by using software OP STAT. Angular transformation also known as Arcsine transformation was used in per cent control data of weeds. Formula used for angular transformation was:

Arcsine transformation = ARSIN[SQRT (germination/100)] x90/1.571

Results

Lanfida (carfentrazone + metsulfuron) dose-response studies

Plant height

No significant differences were observed at spraying time in plant height of all the populations. Significant variations in plant height of *Chenopodium* populations were observed at 2 and 4 WAT with the application of Lanfida (Table 1). When data were averaged over treatments, significantly higher plant height (cm) was recorded in Siswal 2 (14.9-17.5) *fb* Saharwa (13.9-16.8), Siswal 1 (14.0-16.7), Charkhi Dadri (14.5-16.2), H.A.U. 2 (14.7-16.1) and H.A.U. 1(13.9-16.0) populations, respectively at 2 and 4 WAT. Half dose of Lanfida resulted in 7.5% and % higher plant height over recommended dose, whereas double dose resulted in 9.0% and 4.4% lower plant height than the recommended dose, respectively at 2 and 4 WAT, over all the population. Interaction between populations and Lanfida rates was non-significant at 2 and 4 WAT.

Chlorophyll fluorescence

Table 2 presents the data on chlorophyll fluorescence of *Chenopodium* populations as affected by the application of Lanfida at 1, 2 and 7 DAT. When data were averaged over Lanfida doses, significantly lower chlorophyll fluorescence (Fv/Fm) was observed in H.A.U. 1 (0.760-0.756-0.603) *fb* H.A.U. 2 (0.768-0.761-0.662), Charkhi Dadri (0.777-0.769-0.657), Siswal 1 (0.781-0.769-0.660), Saharwa (0.772-0.780-0.680) and Siswal 2 (0.791-0.774-0.747) populations, respectively at 1, 2 and 7 DAT. Mean chlorophyll fluorescence in Siswal 1 population was found statistically similar with H.A.U. 2 population at 7 DAT. Half dose of Lanfida resulted in 2.7%, 3.3% and 9.5% higher chlorophyll fluorescence over the recommended dose, whereas double dose resulted in 2.1%, 2.6% and 7.7% lower chlorophyll fluorescence over the recommended dose, respectively at 1, 2 and 7 DAT.

Per cent control

Per cent control of *Chenopodium* populations significantly varied with application of Lanfida at 1, 2 and 4 WAT (Table 3). Significantly higher mortality (%) was observed in H.A.U. 1(28.4-38.8-52.6) *fb* H.A.U. 2 (24.6-35.4-52.3), Charkhi Dadri (24.3-33.7-47.1), Siswal 1(26.4-33.7-45.5), Saharwa (27.9-33.7-45.5) and Siswal 2 (21.0-29.4-34.7) populations, respectively at 1, 2 and 4 WAT. Mean per cent mortality of Siswal 1 or Saharwa and H.A.U. 1 or H.A.U. 2 populations was found statistically similar at 4 WAT. Half dose of Lanfida resulted in 11.5-10.2-13.9% lower mortality over the recommended dose, whereas double dose resulted in 12.4-10.6-16.3% higher mortality than the recommended dose, respectively at 1, 2 and 4 WAT.

Electrical conductivity (EC)

Significant effect was observed on the EC of *Chenopodium* populations, before and after boiling at 1 WAT (Table 4). Significantly lower EC (ds/m) was observed in H.A.U. 1 (0.123-0.202) *fb* H.A.U. 2 (0.119-0.198), Charkhi Dadri (0.111-0.192), Siswal 1 (0.108-0.189), Saharwa (0.098-0.188) and Siswal 2 populations (0.068-0.147), respectively before and after boiling at 1 WAT (mean data over herbicide doses). Statistically similar EC was observed in Siswal 1 and Saharwa populations after boiling and also observed significant interaction. Half dose of Lanfida resulted in 17-22% lower EC over recommended dose, whereas double dose resulted in 16-37% higher EC than the recommended dose, respectively before and after boiling at 1WAT.

Fresh and dry weight

Data on fresh and dry weight of *Chenopodium* populations recorded at harvest with the application of Lanfida had significant variations (Table 5). When data were averaged over LANFIDA doses, significantly lowest fresh weight and dry weight (g/pot) was recorded in H.A.U. 1(7.4-3.2) *fb* H.A.U. 2 (7.4-3.6), Charkhi Dadri (8.9-4.2), Siswal 1 (8.4-4.3), Saharwa (9.2-4.6) and Siswal 2 populations (12.8-6.2), at harvesting. Mean dry weight in H.A.U. 1 population was found statistically similar with H.A.U. 2 and Siswal 1 was similar with Charkhi Dadri population. Half dose of Lanfida resulted in 35% and 51.0% higher fresh and dry weight, respectively over recommended dose, whereas double dose resulted in 38.5% and 46% lower fresh and dry weight, respectively than the recommended dose at harvesting, among all the populations.

Accord Plus (fenoxaprop + metribuzin) dose-response studies

Plant height

No significant differences were observed in plant height of *Chenopodium* populations at spraying time, 2 and 4 WAT with the application of Accord Plus (Table 6). When data were averaged over Accord Plus doses, significantly higher

plant height (cm) was recorded in Siswal 2 population (13.4-14.5) which was found statistically similar with other populations, respectively at 2 and 4 WAT. Accord Plus at 275 and 550 g/ha resulted in statistically similar plant height among all the population at 2 and 4 WAT. Half dose of Accord Plus resulted in 9.8% and 11.2% higher plant height over recommended dose, whereas double dose resulted in 4.7% and 8.9% lower plant height than recommended dose, respectively at 2 and 4 WAT, among all the populations. Interaction between populations and Accord Plus was observed non-significant at 2 and 4 WAT.

Chlorophyll fluorescence

Table 7 presents the data on chlorophyll fluorescence of *Chenopodium* populations as affected by the application of Accord Plus at 1, 2 and 7 DAT. When data were averaged over treatments, significantly higher chlorophyll fluorescence (Fv/Fm) was observed in Saharwa population (0.385-0.379-0.379), *fb* Siswal 2 (0.408-0.385-0.346), Siswal 1 (0.332-0.328-0.325), Charkhi Dadri (0.374-0.354-0.354), H.A.U. 2 (0.363-0.355-0.355) and H.A.U. 1 populations (0.326-0.319-0.319), also Charkhi Dadri population was statistically similar with H.A.U. 2 population but significantly different with other populations, respectively at 1, 2 and 7 DAT. Half dose of Accord Plus resulted in 50% and 59% higher chlorophyll fluorescence over recommended dose, whereas double dose resulted in 64% and 35% lower chlorophyll fluorescence than recommended dose, respectively at 1 and 2 DAT, among all the populations. Interaction between populations and Accord Plus was observed non-significant at 1 DAT.

Per cent control

Significant variations in per cent controls of *Chenopodium* populations were observed with the application of Accord Plus at 1, 2 and 4 WAT (Table 8). Though differences among populations were non-significant at 1, 2 and 4 WAT, respectively (mean data over herbicide doses). Half dose of Accord Plus resulted in lower mortality over recommended dose, but statistically similar, whereas double dose resulted in higher mortality than recommended dose at 1, 2 and 4 WAT, respectively.

Electrical conductivity (EC)

Accord Plus had significant effect on the EC of *Chenopodium* populations before and after boiling at 1 WAT (Table 9). Significantly lower EC (ds/m) was observed in Charkhi Dadri (0.118-0.168) *fb* Saharwa (0.114-0.170),H.A.U. 2 (0.116-0.173), H.A.U. 1 (0.114-0.178), Siswal 2 (0.125-0.183) and Siswal 1 populations (0.114-0.192), respectively before and after boiling at 1 WAT (mean data over treatments). Half dose of Accord Plus resulted in 16.4-17.1% lower EC over recommended dose, whereas double dose resulted in 26-40% higher EC than recommended dose, respectively at before and after boiling at 1 WAT.

Fresh and dry weight

Significant variations in fresh and dry weight of *Chenopodium* populations were observed at harvest with the application of Accord Plus at different rates (Table 10). When data were averaged over treatments fresh and dry weight of *Chenopodium* populations recorded was non-significant (g/pot) among all the population at harvesting, though it was slightly higher in Saharwa population. Half dose of Accord Plus resulted in 35% and 50% higher fresh and dry weight, respectively over recommended dose, whereas double dose resulted in 21% lower fresh but no difference was observed in dry weight, respectively than recommended dose at harvesting, among all the populations.

Table 1: Plant height of *Chenopodium* populations as influenced by Lanfida (metsulfuron + carfentrazone) at spraying, 2 and 4 WAT

Populations	Plant height (cm)														
	Spraying					2 WAT					4 WAT				
	Lanfida (g/ha)														
	0	12.5	25	50	Mean	0	12.5	25	50	Mean	0	12.5	25	50	Mean
Siswal 1	12.3	12.7	12.0	11.7	12.2	16.7	14.0	13.0	12.3	14.0	21.7	16.3	14.7	14.0	16.7
Siswal 2	12.0	11.7	11.7	11.8	11.8	17.7	15.0	14.0	13.0	14.9	22.0	17.7	15.3	15.0	17.5
Saharwa	11.7	11.7	11.8	11.7	11.7	16.7	14.2	12.7	12.3	13.9	22.7	15.7	14.7	14.3	16.8
H.A.U. 1	12.0	11.7	11.7	11.7	11.7	16.3	14.0	13.0	12.3	13.9	22.3	15.0	13.8	12.8	16.0
Charkhi Dadri	12.7	12.0	11.7	12.3	12.2	17.0	14.7	13.7	12.7	14.5	21.7	15.3	14.3	13.7	16.2
H.A.U. 2	12.0	11.4	11.7	11.3	11.6	18.3	14.3	13.7	12.7	14.7	22.0	15.0	14.0	13.3	16.1
Mean	12.1	11.8	11.7	11.7		17.1	14.4	13.3	12.6		22.1	15.8	14.5	13.9	
CD (P=0.05)															
Population	0.4					0.6					0.7				
Lanfida	NS					0.5					0.5				
Population x Lanfida	NS					NS					NS				

WAT, weeks after treatment.

Table 2: Chlorophyll fluorescence (Fv/Fm) of *Chenopodium* populations as influenced by Lanfida (metsulfuron + carfentrazone) at 1, 2 and 7 DAT

Populations	Chlorophyll fluorescence (Fv/Fm)														
	1 DAT					2 DAT					7 DAT				
	Lanfida (g/ha)														
	0	12.5	25	50	Mean	0	12.5	25	50	Mean	0	12.5	25	50	Mean
Siswal 1	0.846	0.776	0.759	0.745	0.781	0.850	0.773	0.738	0.716	0.769	0.868	0.680	0.570	0.523	0.660
Siswal 2	0.872	0.780	0.763	0.749	0.791	0.838	0.769	0.754	0.734	0.774	0.889	0.740	0.703	0.657	0.747
Saharwa	0.869	0.762	0.737	0.719	0.772	0.911	0.764	0.732	0.712	0.780	0.911	0.687	0.592	0.530	0.680
H.A.U. 1	0.836	0.752	0.732	0.720	0.760	0.837	0.749	0.724	0.715	0.756	0.836	0.577	0.520	0.480	0.603
Charkhi Dadri	0.852	0.765	0.757	0.733	0.777	0.852	0.755	0.747	0.720	0.769	0.853	0.627	0.600	0.550	0.657
H.A.U. 2	0.852	0.766	0.734	0.722	0.768	0.852	0.755	0.727	0.711	0.761	0.853	0.622	0.600	0.573	0.662
Mean	0.854	0.767	0.747	0.731		0.857	0.761	0.737	0.718		0.868	0.655	0.598	0.552	

CD (P=0.05)			
Population	0.010	0.009	0.011
Lanfida	0.008	0.008	0.009
Population x Lanfida	NS	0.019	0.022

DAT, days after treatment.

Table 3: Per cent control of *Chenopodium* populations as influenced by Lanfida (metsulfuron + carfentrazone) at 1, 2 and 4 WAT

Populations	Mortality (%)														
	1 WAT					2 WAT					4 WAT				
	Lanfida (g/ha)														
	0	12.5	25	50	Mean	0	12.5	25	50	Mean	0	12.5	25	50	Mean
Siswal 1	0 (0)	31.1 (26.7)	35.2 (33.3)	39.2 (40.0)	26.4 (25.0)	0 (0)	39.2 (40.0)	44.0 (48.3)	51.8 (61.7)	33.7 (37.5)	0 (0)	52.7 (63.3)	61.7 (76.7)	67.4 (85.0)	45.5 (56.2)
Siswal 2	0 (0)	24.0 (16.7)	27.7 (21.7)	32.1 (28.3)	21.0 (16.7)	0 (0)	34.2 (31.7)	39.2 (40.0)	44.0 (48.3)	29.4 (30.0)	0 (0)	42.1 (45.0)	45.9 (51.7)	50.8 (60.0)	34.7 (39.2)
Saharwa	0 (0)	32.1 (28.3)	37.2 (36.7)	42.1 (45.0)	27.9 (27.5)	0 (0)	42.1 (45.0)	44.0 (48.3)	48.8 (56.7)	33.7 (37.5)	0 (0)	49.8 (58.3)	58.9 (73.3)	73.4 (91.7)	45.5 (55.8)
H.A.U. 1	0 (0)	34.2 (31.7)	38.2 (38.3)	41.1 (43.3)	28.4 (28.3)	0 (0)	48.8 (56.7)	51.7 (61.7)	54.7 (66.7)	38.8 (46.2)	0 (0)	60.0 (75.0)	69.2 (86.7)	81.2 (96.6)	52.6 (64.6)
Charkhi Dadri	0 (0)	28.8 (23.3)	32.1 (28.3)	36.3 (35.0)	24.3 (21.7)	0 (0)	38.2 (38.3)	46.0 (51.7)	50.8 (60.0)	33.7 (37.5)	0 (0)	57.7 (63.3)	62.3 (78.3)	73.4 (91.7)	47.1 (58.3)
H.A.U. 2	0 (0)	28.8 (23.3)	32.1 (28.3)	37.2 (36.7)	24.6 (22.1)	0 (0)	44.0 (48.3)	46.9 (53.3)	50.8 (60.0)	35.4 (40.4)	0 (0)	59.0 (73.3)	69.2 (86.7)	81.2 (96.7)	52.3 (64.2)
Mean	0 (0)	29.9 (25.0)	33.8 (31.1)	38.0 (38.0)		0 (0)	41.1 (43.3)	45.3 (50.6)	50.1 (58.9)		0 (0)	52.7 (63.1)	61.2 (75.6)	71.2 (86.9)	
CD (P=0.05)															
Population	1.3 (2.0)					1.4 (2.4)					3.4 (4.0)				
Lanfida	1.1 (1.7)					1.2 (2.0)					2.8 (3.3)				
Population x Lanfida	2.6 (4.1)					2.8 (4.8)					6.8 (8.0)				

Original figures in parenthesis were subjected to angular transformation. WAT, weeks after treatment.

Table 4: EC of *Chenopodium* populations before and after boiling as influenced by Lanfida (metsulfuron + carfentrazone) at 1 WAT

Populations	EC (ds/m)									
	Before boiling					After boiling				
	Lanfida (g/ha)									
	0	12.5	25	50	Mean	0	12.5	25	50	Mean
Siswal 1	0.015	0.123	0.133	0.160	0.108	0.023	0.187	0.230	0.317	0.189
Siswal 2	0.017	0.057	0.090	0.110	0.068	0.030	0.163	0.187	0.207	0.147
Saharwa	0.013	0.097	0.130	0.153	0.098	0.023	0.180	0.227	0.320	0.188
H.A.U. 1	0.017	0.133	0.153	0.187	0.123	0.027	0.207	0.237	0.337	0.202
Charkhi Dadri	0.017	0.123	0.137	0.167	0.111	0.027	0.187	0.227	0.327	0.192
H.A.U. 2	0.013	0.127	0.150	0.187	0.119	0.027	0.200	0.237	0.327	0.198
Mean	0.015	0.110	0.132	0.161		0.026	0.187	0.224	0.306	
CD (P=0.05)										
Population	0.007					0.010				
Lanfida	0.005					0.008				
Population x Lanfida	0.013					0.020				

EC, electrical conductivity; WAT, weeks after treatment.

Table 5: Fresh and dry weight of *Chenopodium* populations as influenced by Lanfida (metsulfuron + carfentrazone) at harvesting

Populations	Weight (g/pot)									
	Fresh Weight					Dry weight				
	Lanfida (g/ha)									
	0	12.5	25	50	Mean	0	12.5	25	50	Mean
Siswal 1	20.0	7.3	5.3	1.1	8.4	10.0	3.2	2.3	1.5	4.3
Siswal 2	20.0	11.7	10.7	9.0	12.8	10.0	5.5	5.0	4.4	6.2
Saharwa	19.7	8.3	6.7	2.2	9.2	10.3	4.2	3.0	0.9	4.6
H.A.U. 1	19.7	6.0	3.2	1.0	7.4	9.9	2.7	1.4	0.3	3.6
Charkhi Dadri	20.7	7.5	5.3	2.2	8.9	10.0	3.7	2.3	0.8	4.2
H.A.U. 2	20.0	5.3	3.2	1.2	7.4	10.0	2.7	1.3	0.3	3.6
Mean	20.0	7.7	5.7	2.8		10.0	3.6	2.6	1.4	
CD (P=0.05)										
Population	0.7					0.3				
Lanfida	0.6					0.3				
Population x Lanfida	1.5					0.7				

Table 6: Plant height of *Chenopodium* populations as influenced by Accord Plus (fenoxaprop + metribuzin) at spraying, 2 and 4 WAT

Populations	Plant height (cm)														
	Spraying					2 WAT					4 WAT				
	ACD (g/ha)														
	0	137.5	275	550	Mean	0	137.5	275	550	Mean	0	137.5	275	550	Mean
Siswal 1	12.3	11.7	11.8	11.7	11.9	16.7	11.7	11.8	11.7	12.9	21.7	11.7	11.8	11.7	14.2
Siswal 2	12.0	12.3	11.7	11.8	11.9	17.7	12.3	11.7	11.8	13.4	22.0	12.3	11.7	11.8	14.5
Saharwa	11.7	11.7	12.0	11.7	11.7	16.7	11.7	12.0	11.7	13.0	22.7	11.7	12.0	11.7	14.5
H.A.U. 1	12.0	12.3	11.7	12.0	12.0	16.3	12.3	11.7	12.0	13.1	22.3	12.3	11.7	12.0	14.6
Charkhi Dadri	12.7	12.3	12.0	11.7	12.2	17.0	12.3	12.0	11.7	13.2	21.7	12.3	12.0	11.7	14.4
H.A.U. 2	12.0	12.3	11.7	12.0	12.0	18.3	12.3	11.7	12.0	13.6	22.0	12.3	11.7	12.0	14.5
Mean	12.1	12.1	11.8	11.8		17.1	12.1	11.8	11.8		22.9	12.1	11.8	11.8	
CD (P=0.05)															
Population	NS					NS					NS				
ACD	NS					0.5					0.6				
Population x ACD	NS					NS					NS				

ACD; Accord Plus, WAT; weeks after treatment.

Table 7: Chlorophyll fluorescence (Fv/Fm) of *Chenopodium* populations as influenced by Accord Plus (fenoxaprop + metribuzin) at 1, 2 and 7 DAT

Populations	Chlorophyll fluorescence (Fv/Fm)														
	1 DAT					2 DAT					7 DAT				
	ACD (g/ha)														
	0	137.5	275	550	Mean	0	137.5	275	550	Mean	0	137.5	275	550	Mean
Siswal 1	0.846	0.212	0.150	0.120	0.332	0.850	0.203	0.145	0.115	0.328	0.868	0.187	0.137	0.107	0.325
Siswal 2	0.872	0.317	0.262	0.180	0.408	0.838	0.310	0.230	0.163	0.385	0.889	0.230	0.163	0.100	0.346
Saharwa	0.869	0.298	0.218	0.156	0.385	0.911	0.247	0.210	0.148	0.379	0.911	0.247	0.210	0.148	0.379
H.A.U. 1	0.836	0.219	0.136	0.114	0.326	0.837	0.207	0.125	0.107	0.319	0.837	0.207	0.125	0.107	0.319
Charkhi Dadri	0.852	0.290	0.205	0.148	0.374	0.852	0.264	0.172	0.128	0.354	0.852	0.264	0.172	0.128	0.354
H.A.U. 2	0.852	0.241	0.230	0.128	0.363	0.852	0.227	0.220	0.121	0.355	0.852	0.227	0.220	0.121	0.355
Mean	0.854	0.263	0.200	0.141		0.857	0.243	0.184	0.130		0.868	0.227	0.171	0.118	
CD (P=0.05)															
Population	0.024					0.014					0.014				
ACD	0.020					0.011					0.012				
Population x ACD	NS					0.027					0.029				

ACD, Accord Plus; DAT, days after treatment.

Table 8: Per cent control of *Chenopodium* populations as influenced by Accord Plus (fenoxaprop + metribuzin) at 1, 2 and 4 WAT

Populations	Mortality (%)														
	1 WAT					2 WAT					4 WAT				
	ACD (g/ha)														
	0	**137.5**	**275**	**550**	**Mean**	**0**	**137.5**	**275**	**550**	**Mean**	**0**	**137.5**	**275**	**550**	**Mean**
Siswal 1	0 (0)	73.3 (88.3)	76.0 (91.7)	79.3 (94.9)	57.2 (68)	0 (0)	81.2 (96.7)	81.2 (96.7)	85.3 (98.3)	61.9 (72.9)	0 (0)	81.2 (96.7)	89.4 (99.9)	89.4 (99.9)	64.9 (74.2)
Siswal 2	0 (0)	89.4 (99.9)	89.4 (99.9)	89.4 (99.9)	67.0 (75.0)	0 (0)	89.4 (99.9)	89.4 (99.9)	89.4 (99.9)	67.0 (75.0)	0 (0)	89.4 (99.9)	89.4 (99.9)	89.4 (99.9)	67.0 (75.0)
Saharwa	0 (0)	89.4 (99.9)	89.4 (99.9)	89.4 (99.9)	67.0 (75.0)	0 (0)	89.4 (99.9)	89.4 (99.9)	89.4 (99.9)	67.0 (75.0)	0 (0)	89.4 (99.9)	89.4 (99.9)	89.4 (99.9)	67.0 (75.0)
H.A.U. 1	0 (0)	89.4 (99.9)	89.4 (99.9)	89.4 (99.9)	67.0 (75.0)	0 (0)	89.4 (99.9)	89.4 (99.9)	89.4 (99.9)	67.0 (75.0)	0 (0)	89.4 (99.9)	89.4 (99.9)	89.4 (99.9)	67.0 (75.0)
Charkhi Dadri	0 (0)	89.4 (99.9)	89.4 (99.9)	89.4 (99.9)	67.0 (75.0)	0 (0)	89.4 (99.9)	89.4 (99.9)	89.4 (99.9)	67.0 (75.0)	0 (0)	89.4 (99.9)	89.4 (99.9)	89.4 (99.9)	67.0 (75.0)
H.A.U. 2	0 (0)	89.4 (99.9)	89.4 (99.9)	89.4 (99.9)	67.0 (75.0)	0 (0)	89.4 (99.9)	89.4 (99.9)	89.4 (99.9)	67.0 (75.0)	0 (0)	89.4 (99.9)	89.4 (99.9)	89.4 (99.9)	67.0 (75.0)
Mean	0 (0)	86.7 (98.0)	87.2 (98.6)	87.7 (99.2)		0 (0)	88.0 (99.9)	88.0 (99.9)	88.7 (99.9)		0 (0)	88.0 (98.0)	89.4 (99.9)	89.4 (99.9)	
CD (P=0.05)															
Population	3.4 (2.3)					2.1 (.8)					1.2 (.5)				
ACD	2.8 (1.9)					1.7 (.7)					0.9 (.4)				
Population x ACD	NS (NS)					NS (NS)					2.4 (1.0)				

Original figures in parenthesis were subjected to angular transformation. ACD, Accord Plus; WAT, weeks after treatment.

Table 9: EC of *Chenopodium* populations before and after boiling as influenced by Accord Plus (fenoxaprop + metribuzin) at 1 WAT

Populations	EC (ds/m)									
	Before boiling					After boiling				
	ACD (g/ha)									
	0	137.5	275	550	Mean	0	137.5	275	550	Mean
Siswal 1	0.015	0.117	0.143	0.180	0.114	0.023	0.200	0.243	0.300	0.192
Siswal 2	0.017	0.127	0.147	0.210	0.125	0.030	0.180	0.233	0.287	0.183
Saharwa	0.013	0.120	0.147	0.177	0.114	0.023	0.167	0.190	0.300	0.170
H.A.U. 1	0.017	0.117	0.137	0.187	0.114	0.027	0.170	0.213	0.300	0.178
Charkhi Dadri	0.017	0.127	0.150	0.180	0.118	0.027	0.163	0.193	0.287	0.168
H.A.U. 2	0.013	0.127	0.150	0.173	0.116	0.027	0.170	0.193	0.300	0.173
Mean	0.015	0.122	0.146	0.184		0.026	0.175	0.211	0.296	
CD (P=0.05)										
Population	0.007					0.011				
ACD	0.006					0.009				
Population x ACD	0.014					0.022				

EC, electrical conductivity; ACD, Accord Plus; WAT, weeks after treatment.

Table 10: Fresh and dry weight of *Chenopodium* populations as influenced by Accord Plus (fenoxaprop + metribuzin) at harvesting

Populations	Weight (g/pot)									
	Fresh Weight					Dry weight				
	ACD (g/ha)									
	0	137.5	275	550	Mean	0	137.5	275	550	Mean
Siswal 1	20.0	2.2	1.5	1.5	6.3	10.0	0.2	0.2	0.2	2.7
Siswal 2	20.0	2.7	2.0	1.7	6.6	10.0	0.3	0.2	0.2	2.7
Saharwa	19.7	3.0	2.0	1.0	6.4	10.3	0.3	0.2	0.2	2.8
H.A.U. 1	19.7	0.5	0.5	0.3	5.2	9.9	0.3	0.2	0.2	2.6
Charkhi Dadri	20.7	3.0	2.0	1.0	6.7	10.0	0.3	0.2	0.2	2.7
H.A.U. 2	20.0	1.5	1.0	1.0	5.9	10.0	0.3	0.2	0.2	2.7
Mean	20.0	2.2	1.5	1.1		10.0	0.3	0.2	0.2	
CD (P=0.05)										
Population	0.6					NS				
ACD	0.5					0.2				
Population x ACD	NS					NS				

ACD, Accord Plus.

Discussion

Metsulfuron + carfentrazone RM (Lanfida) dose-response studies

Siswal 1, Siswal 2 and Saharwa populations were moderately resistant whereas, Charkhi Dadri, H.A.U. 1 and H.A.U. 2 were susceptible to the application of LANFIDA at 1, 2 and 4 WAT. It provided 76, 51 and 73% mortality in Siswal 2, Saharwa and Siswal 1 populations, respectively at recommended dose. At the double dose, LANFIDA provided 85-100% visual control in all the population at 4 WAT. These results corroborate with the findings of Singh *et al*. (2011, 2017) [10, 12]. Singh *et al*. (2017) [12] studied herbicide efficacy and found that metsulfuron + carfentrazone (LANFIDA) was effective against *R. dentatus* and *C. album* compared to metsulfuron, mesosulfuron + iodosulfuron and sulfosulfuron + metsulfuron. Similarly, Singh *et al*. (2011) [10] reported that metsulfuron + carfentrazone at (50 g/ha + 0.2% surfactant) *fb* metsulfuron + carfentrazone at 25 and 30 g/ha + 0.2% surfactant were most effective against all the broad leaf weeds and reduced the population of weeds by 97-99% and also the dry weight of weeds reduced by 98-99% than other application of herbicides against the broadleaf weeds. Paswan *et al.*, (2012) [6] also reported that metsulfuron + carfentrazone at (50 g/ha + 0.2% surfactant) *fb* metsulfuron + carfentrazone at 25 and 30 g/ha + 0.2% surfactant were most effective against all the broad leaf weeds. More number of tillers/m row, dry weight/m row, yield attributes and highest yield of crop was observed with application of metsulfuron + carfentrazone at (50 g/ha + 0.2% surfactant) *fb* metsulfuron + carfentrazone at 25 and 30 g/ha + 0.2%, surfactant.

Accord Plus dose-response studies

Chenopodium populations were highly susceptible to Accord Plus and provided 100% visual mortality even at half of the recommended dose at 4 WAT. Low values of chlorophyll fluorescence, fresh and dry weight were recorded in all populations with the application of Accord Plus due to inhibition PSII. These results corroborate the findings of Walia *et al.* (2011) [13] on different rates of mixture of fenoxaprop + metribuzin application at 275 and 330 g/ha provided effective control of *Phalaris minor* and broadleaf weeds and lower dry matter accumulation. Similarly, Bhullar *et al*. (2012) [3] reported that among different herbicides, post-emergence application of fenoxaprop + metribuzin at 275 g/ha registered complete control of all the narrow and broad-leaved weeds. Singh *et al.* (2017) [12] also proved the efficacy of fenoxaprop + metribuzin against *C. album* compared to metsulfuron, mesosulfuron + iodosulfuron and sulfosulfuron + metsulfuron. Tank mixture of metribuzin + clodinafop at 45 + 140 g/ha and fenoxaprop + metribuzin at 90 + 140 g/ha reduced the total dry weight of weeds (Singh *et al*., 2005) [8].

Summary and Conclusion

- Highest % emergence of *Chenopodium* was reported in Siswal 2 *fb* Siswal 1, Saharwa, H.A.U. 1, Charkhi Dadri, and H.A.U.2 populations. This finding implies that good control as to arrest the seed formation would reduce the carry over weed infestation in the next season and could be used as a tool in resistance management in this weed.

- Lanfida recorded 50-75% control of Siswal 2, Saharwa and Siswal 1 populations and 80-85% control of H.A.U. 1, Charkhi Dadri, and H.A.U.2 populations.
- Accord Plus recorded 90-100% control at all doses of all the populations. *Chenopodium* spp. was found highly sensitive to Accord Plus when applied as post-emergence. This herbicide provided complete control in all populations even at half of the recommended dose of herbicide. The present study suggests that post-emergence intervention with Accord Plus could resolve the problem of resistant *Chenopodium.*

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