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Efficacy and phytotoxicity of herbicides mixture on weeds and *Bt.* cotton in loamy sand soils of middle Gujarat

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Abstract
To study the efficacy and phytotoxicity of herbicide mixture on weeds and *Bt.* cotton in loamy sand soils of middle Gujarat, a field trial was carried out at the farm of AICRP-Weed Management, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat during two consecutive *kharif* season of the year 2019 and 2020. Results revealed that pre-emergence application of pendimethalin (38.7% CS) 500 g/ha + oxyfluorfen 50 g/ha as (tank mix) *fb* post-emergence application of pyrithiobac-sodium 62.5 g/ha + quizalofop-ethyl 50 g/ha (tank mix), sequential application of oxyfluorfen 100 g/ha as PE *fb* glufosinate ammonium 375 g/ha directed spray as PoE and IC + HW at 20, 40 and 60 DAS recorded significantly lower weed dry weight (monocot and dicot weeds) at 30 DAS and at harvest. These three treatments achieved cent percent monocot and dicot weed control efficiency at 30 DAS and resulted in significantly higher comparable seed cotton yield. With regards to phytotoxicity of applied herbicides on crop, none of herbicide caused any injury except oxyfluorfen which showed slight necrosis and epinasty symptoms (10 to 20%) at initial stage on cotton which was recovered in due course of time, but early cotton phytotoxicity had no significant long-term effect on growth and yield of *Bt*. Cotton.

Keywords: Cotton, phytotoxicity, herbicide mixture, weed, seed cotton yield

Introduction
India remains the leading country in terms of area under cotton cultivation and raw cotton production in the world. Cotton plays an important role in textile industries and is a means of livelihood for millions of farmers and those concerned with its trade, processing, manufacturing and other allied industries. Gujarat, Maharashtra and Telangana are the major cotton growing states in India. Productivity of cotton in India is lower against world's average. There are several constraints for low productivity in cotton like competition from weeds, micronutrient deficiency (Boron and Zinc), boll shedding, leaf reddening, sucking pests and poor agronomic practices. Among these constraints, the most troublesome one is competition from weeds particularly during early stages of crop growth. Weeds are major obstacles in successful cultivation of cotton. Reduction in seed cotton yield under irrigated conditions is primarily due to nutrient depletion caused by weeds and may vary from 10-90 per cent. Due to shortage of labours and wages, farmers are severely facing problem of timely weed management in cotton and increased cost of production. Majority of herbicides available in the market are not broad-spectrum herbicides. Hence, we need to go for combination of herbicides or herbicide mixtures for broad spectrum weed control. In long duration crops like cotton, weeds flourish even after critical period of crop weed competition and it is difficult to achieve effective weed control with single application of herbicides. Hence, in order to control weeds for a longer period of crop growth, it needs to apply herbicides as a mixture or on sequential basis. But herbicides are chemical in nature, therefore, excessive and repeated use may pose residue problems and may have phytotoxicity to crop plants (Sondhia, 2014) [6]. Considering all these facts, the present investigation was carried out to study the efficacy and phytotoxicity of herbicide mixture on weeds and yield of *Bt.* Cotton.

Material and Methods
A field trail was carried out in loamy sand soil during two consecutive *kharif* season of the year 2019 and 2020 at the farm of AICRP - Weed Management, B. A. College of Agriculture, Anand Agricultural University, Anand. Bt. cotton variety 'GTHH 49' was sown with a spacing of 120 x 45 cm, fertilized with recommended dose of fertilizers and all package of practice for

cotton cultivation was followed. The experiment was laid out in a Randomized Block Design (RBD) with four replication and ten treatments *viz.,* pendimethalin 750 g/ha (38.7% CS) PPI *fb* glufosinate ammonium 375 g/ha PoE directed spray, oxyfluorfen 100 g/ha PE *fb* glufosinate ammonium 375 g/ha PoE directed spray, pendimethalin 750 g/ha (30% EC) PE *fb* glyphosate 2000 g/ha PoE directed spray, pendimethalin 750 g/ha (30% EC) PE *fb* paraquat 600 g/ha PoE directed spray, pendimethalin 1000 g/ha (30% EC) PE *fb* pyrithiobac-sodium 62.5 g/ha + quizalofop-ethyl 50 g/ha PoE (Tank mix), pendimethalin (38.7% CS) 500 g/ha + oxyfluorfen 50 g/ha PE (Tank mix) *fb* pyrithiobac-sodium 62.5 g/ha + quizalofop-ethyl 50 g/ha PoE (Tank mix), pendimethalin 1000 g/ha (38.7% CS) PE *fb* IC + HW at 40 DAS, pyrithiobac-sodium 62.5 g/ha PoE + quizalofop-ethyl 50 g/ha PoE (Tank mix) *fb* IC + HW at 50 DAS, IC + HW at 20, 40 and 60 DAS and weedy check. There was no any adverse effect of weather as well as pest disease incidence on crop was observed during the course of investigation. Pre plant incorporation (PPI) of herbicides in respective treatments was given one day before sowing. Pre-emergence (PE) application of herbicides were sprayed two days after sowing in respective treatments while post-emergence herbicides (PoE) were applied at 30 DAS. The spraying was done by using Knapsack sprayer fitted with flat-fan nozzle using 500 L of water/ha. Weeds associated with cotton crop in experimental area were recorded at 30, 60 DAS and at harvest from all the treatments. Observation was taken randomly from 0.25 m^2 quadrat from net plot area from each treatment and converted into m^2 area. The mean data are used for analysis purpose. Collected weed samples at 30, 60 DAS and at harvest were allowed to sun dry and then oven dried at 65±5 °C temperature till the constant weight was obtained. The data on weed density and weed dry weight was not distributed normally hence, the data were transformed by using the square root transformation $\sqrt{(X+1)}$ and then the transformed data were analyzed statistically. The visual phytotoxicity of herbicides was observed at 10 days after application of herbicides (DAHA). Phytotoxicity observations were recorded on vein clearing, necrosis, wilting, epinasty and hyponasty etc. on 0-10 scale and converted into per cent. Weed control efficiency (WCE) was calculated on the basis of formula suggested by Mani *et al.* (1973) [7]. Duncan's New Multiple Range Test (DNMRT) was employed for comparison of treatments mean and analyzed at a probability level of 5%.

Results and Discussion

Effect on weeds

Total fourteen weed species (monocot, dicot and sedges) were identified in the experimental area during the crop growth period. Among all the weed species observed in the experiment *Commelina benghalensis*, *Eleusine indica*, *Digitaria sanguinalis* and *Dactyloctenium aegyptium* as monocot, *Digera arvensis*, *Trianthema monogyna*, *Phyllanthus niruri* and *Euphorbia hirta* as dicot as well as *Cyperus rotundus* as sedge were found dominant weed flora in experimental plot.

Dry weight of weeds is the clear reflection of efficacy of applied treatments. All the weed control treatments caused significant reduction in production of weed dry weight as compared to weedy check (Table 1). At 30 DAS, nil dry weight of monocot and dicot weeds was observed with cent percent weed control efficiency were achieved under application of pendimethalin (38.7% CS) 500 g/ha + oxyfluorfen 50 g/ha PE (Tank mix) *fb* pyrithiobac-sodium 62.5 g/ha + quizalofop-ethyl 50 g/ha PoE (Tank mix), oxyfluorfen 100 g/ha PE *fb* glufosinate ammonium 375 g/ha PoE directed spray and IC + HW at 20, 40 and 60 DAS. This might be due to broad spectrum initial weed control provided by applied herbicide mixture (oxyflourfen + pendimethalin) having different mode of action, high potent action of oxyflourfen and mechanical practices, respectively under these treatments. The results are in accordance with the results of Patel *et al*. (2014) [4] with respect to mechanical weeding.

Infestation of *Commelina benghalensis* was observed foremost among the monocot weeds, while infestation of dicot weeds especially *Digera arvensis* was observed under pendimethalin treated plots as alone at various doses. Similar results were also noticed by group of scientists at Anand, Gujarat wherein, escape incidence of these weeds was observed after application of pendimethalin 750-1000 g/ha in cotton (Anonymous, 2021) [1]. Application of pre emergence and post-emergence herbicides alone were found to be less effective in reducing complex weed flora and their weed dry matter was also observed by Gnanavel and Babu (2008) [2] in their study.

Significantly lower weed dry weight of monocot and dicot weeds (16.90 and 14.73 g/m^2, respectively) at harvest were recorded under application of pendimethalin (38.7% CS) 500 g/ha + oxyfluorfen 50 g/ha PE (Tank mix) *fb* pyrithiobac-sodium 62.5 g/ha + quizalofop-ethyl 50 g/ha PoE (Tank mix) which was remained at par with treatment of oxyfluorfen 100 g/ha PE *fb* glufosinate ammonium 375 g/ha PoE directed spray and IC + HW at 20, 40 and 60 DAS. Significantly the highest monocot and dicot weed dry weight was recorded under weedy check might be due to the non-interruption for growth of weeds in the absence of weed management practices resulting in luxuriant growth of weeds.

The pre-emergence application oxyflurofen being broad spectrum herbicides might have effectively hindered the germination of weed seeds and reduced the weed dynamics of grasses, sedges and broad-leaved weeds meritoriously. Further, sequential application of pyrithiobac sodium as post-emergence controlled mostly of later germinated broad leaved weeds and application of quizalofop ethyl applied as mixture effectively controlled monocot weeds in cotton. In addition to that, Singh *et al.* (2004) [5] also concluded that glufosinate ammonium could also be used as directed spray for weed control in cotton as an alternate herbicide to glyphosate or paraquat in cotton.

Effect on crops

Results indicated that all the herbicidal treatment applied in cotton did not show any phytotoxicity symptoms in terms of vein clearing, necrosis, wilting or epinasty and hyponasty at 10 days after herbicide application (Table 1). Madhavi and Ramprakash (2015) [3] also reported nil phytotoxocity of herbicide mixture containing pyrithiobac sodium + quizalofop ethyl at 100-125 g/ha on cotton. Although, pre-emergence application oxyfluorfen 100 g/ha PE *fb* glufosinate ammonium 375 g/ha PoE directed spray and pendimethalin (38.7% CS) 500 g/ha + oxyfluorfen 50 g/ha PE (Tank mix) *fb* pyrithiobac-sodium 62.5 g/ha + quizalofop-ethyl 50 g/ha PoE (Tank mix) found slightly phytotoxic (20% and 10%, respectively) showing the necrosis and epinasty symptoms on the leaves at 10 days after herbicide application, but the

phytotoxicity symptoms were recovered at twenty five days after herbicide application. Hence, it could be concluded that oxyfluorfen being soil active, selective, broad spectrum herbicide of diphenyl ether group actively controlled the weeds very effectively but simultaneously showed slight initial toxicity to the cotton crop at tested dose in loamy sand soils of middle Gujarat and which is recovered in due course of time.

Significantly higher seed cotton yield (3243 kg/ha) under tank mix pre-emergence application of pendimethalin (38.7% CS) 500 g/ha + oxyfluorfen 50 g/ha *fb* pyrithiobac-sodium 62.5 g/ha + quizalofop-ethyl 50 g/ha PoE followed by pre-emergence application of oxyfluorfen 100 g/ha *fb* glufosinate ammonium 375 g/ha PoE directed spray (3032 kg/ha) and IC + HW at 20, 40 and 60 DAS (2973 kg/ha) which might be due to fact that effective broad spectrum weed control provided by the applied herbicide mixture at critical crop growth period which helps in reducing dry weight of weeds lead to direct increase in uptake of nutrient and thereby robust growth and development of cotton crop. Higher seed cotton yield under mechanical methods of weed control was also observed by Patel *et al*. (2014) [4].

Fig 1: Growth of cotton under pendimethalin (38.7% CS) 500 g/ha + oxyfluorfen 50 g/ha PE (Tank mix) *fb* pyrithiobac-sodium 62.5 g/ha + quizalofop-ethyl 50 g/ha PoE (Tank mix)

Table 1: Effect of different herbicides on Weed dry weight, WCE, Seed cotton yield and Phytotoxicity (Mean data of two years)

Treatments	Weed dry weight of weeds (g/m²) at 30 DAS		Weed control efficiency (%) at 30 DAS		Weed dry weight of weeds (g/m²) at harvest		Weed control efficiency (%) at harvest		Seed cotton yield (kg/ha)	Visual phytotoxicity (%)	
	Monocot weeds	Dicot weeds	Monocot weeds	Dicot weeds	Monocot weeds	Dicot weeds	Monocot weeds	Dicot weeds		at 10 DAHA	at 25 DAHA
T_1:Pendimethalin 750 g/ha (38.7% CS) PPI *fb* Glufosinate ammonium 375 g/ha PoE directed spray	2.13^{b} (3.63)	4.27^{b} (17.46)	93.56	70.35	7.51^{d} (56.72)	7.72^{c} (58.80)	78.29	66.82	2651^{b}	0	0
T_2:Oxyfluorfen 100 g/ha PE *fb* Glufosinate ammonium 375 g/ha PoE directed spray	1.00^{c} (0.00)	1.00^{c} (0.00)	100.00	100.00	4.51^{e} (19.68)	4.46^{e} (19.10)	92.47	89.22	3032^{a}	20	0
T_3:Pendimethalin 750 g/ha (30% EC) PE *fb* Glyphosate 2000 g/ha PoE directed spray	2.32^{b} (4.51)	4.56^{b} (20.09)	91.99	65.88	8.59^{c} (73.07)	8.08^{c} (64.81)	72.03	63.42	2610^{b}	0	0
T_4:Pendimethalin 750 g/ha (30% EC) PE *fb* Paraquat 600 g/ha PoE directed spray	2.43^{b} (5.00)	4.71^{b} (21.29)	91.12	63.84	10.64^{b} (112.70)	10.34^{b} (106.43)	56.87	39.93	2344^{b}	0	0
T_5:Pendimethalin 1000 g/ha (30% EC) PE *fb* Pyrithiobac-sodium 62.5 g/ha + Quizalofop-ethyl 50 g/ha PoE (Tank mix)	2.20^{b} (3.94)	4.34^{b} (18.07)	93.01	69.31	9.00^{c} (80.76)	7.82^{c} (60.74)	69.09	65.72	2545^{b}	0	0
T_6:Pendimethalin (38.7% CS) 500 g/ha + Oxyfluorfen 50 g/ha PE (Tank mix) *fb* Pyrithiobac-sodium 62.5 g/ha + Quizalofop-ethyl 50 g/ha PoE (Tank mix)	1.00^{c} (0.00)	1.00^{c} (0.00)	100.00	100.00	4.22^{e} (16.90)	3.95^{e} (14.73)	93.53	91.69	3243^{a}	10	0
T_7:Pendimethalin 1000 g/ha (38.7% CS) PE *fb* IC + HW at 40 DAS	2.13^{b} (3.63)	4.53^{b} (19.69)	93.56	66.56	9.29^{c} (85.32)	8.29^{c} (67.96)	67.35	61.65	2447^{b}	0	0
T_8:Pyrithiobac-sodium 62.5 g/ha PoE + Quizalofop-ethyl 50 g/ha PoE (Tank mix) (30-35 DAS) *fb* IC + HW at 50 DAS	7.41^{a} (54.18)	7.50^{a} (55.66)	3.82	5.47	8.61^{c} (73.66)	6.67^{d} (43.76)	71.81	75.30	1956^{c}	0	0
T_9:IC + HW at 20, 40 and 60 DAS	1.00^{c} (0.00)	1.00^{c} (0.00)	100.00	100.00	4.42^{e} (18.93)	4.28^{e} (17.55)	92.75	90.10	2973^{a}	0	0
T_{10}:Weedy Check	7.56^{a} (56.33)	7.70^{a} (58.88)	0.00	0.00	16.17^{a} (261.28)	13.28^{a} (177.19)	0.00	0.00	940^{d}	0	0
T — S Em +	0.12	0.16	-	-	0.24	0.26	-	-	96	-	-
T — CD (P=0.05)	Sig.	Sig.	-	-	Sig.	Sig.	-	-	Sig.	-	-
Y x T — S Em +	0.17	0.24	-	-	0.36	0.39	-	-	141	-	-
Y x T — CD (P=0.05)	NS	NS	-	-	NS	NS	-	-	NS	-	-
CV (%)	11.68	11.61	-	-	8.71	10.49	-	-	11.40	-	-

Note: All figures are subjected to transformed values to square root (√x+1). Figures in parentheses indicate original values. Mean followed by common letter (s) in column are not significant by DNMRT at 5% level of significance

Conclusion

It can be concluded that tank mix application of pendimethalin (38.7% CS) 500 g/ha + oxyfluorfen 50 g/ha as PE *fb* tank mix application of pyrithiobac-sodium 62.5 g/ha + quizalofop-ethyl 50 g/ha as PoE or sequential application of oxyfluorfen 100 g/ha as PE *fb* glufosinate ammonium 375 g/ha directed spray as PoE or interculturing and hand weeding at 20, 40 and 60 DAS is effective for managing complex weed flora and obtaining higher seed cotton yield.

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