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Effect of Herbicides on Soil Microflora and Dehydrogenase Activity in Transplanted *Bt* Cotton Based Intercropping System

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A B S T R A C T

The experiment was conducted to analyse the effect of herbicides on soil microflora and Dehydrogenase activity in transplanted *Bt* cotton based intercropping system during 2018-19 and 2019-20, at Agricultural Research Station, Malnoor, University of Agricultural Sciences, Raichur, Karnataka. The soil of the experimental field was medium deep black with clay loam texture, slightly high in pH (8.14), normal EC (0.35 dS m^{-1}), medium in OC (0.56 %), available nitrogen (344 kg ha^{-1}), phosphorus (29.21 kg ha^{-1}) and high in available potassium (355 kg ha^{-1}). The treatments consisted of four cropping systems in main plots and five weed control treatments in sub plots and were replicated thrice in a split plot design. The data indicated that pre emergence application of pendimethalin 38.7 CS @ 0.34 kg *a.i.* ha^{-1} or oxadiargyl @ 0.04 kg *a.i.* ha^{-1} reduced the microbial population (Bacteria, Fungi and Actinomycetes) and Dehydrogenase enzyme activity significantly over the treatments where no herbicides were applied (unweeded check, weed free, hand weeding). While the values were on par at 60 DAS and at harvest which indicated that the herbicide effect did not persist for longer time as the herbicides degraded in soil by microbes as the herbicides were used as the carbon source for multiplication. The seed cotton equivalent yield was higher when herbicides were used, indicating that no adverse effect of the herbicide.

Introduction

Cotton the "*white gold* or the *king of fibres*" is one of the most important commercial crop. Cotton is known for the fibre and oil from seed, which plays a prominent role in the national and international economy. The Initial slow growth and adoption of wider spacing offers ample scope for raising intercrops *viz.*, foxtail millet and little millet. Intercropping in transplanted *Bt* cotton an economical approach for higher unit productivity from same piece of land. In cropping systems, weeds often pose a major threat to crop yields, manual weeding is always not feasible because of increasing labour cost and also due to scarcity of human labour. Hence it is necessary to use herbicides to control weeds in intercropping system. Though it is well know that use of herbicides

controls weeds efficiently and it is more economical but on the other hand, they may have adverse effect on soil health and soil microflora. Hence, the present study was to investigate how agronomic practices and herbicide application in transplanted *Bt* cotton intercropped with foxtail millet and little millet would affect soil microbial population and Dehydrogenase activity.

Materials and Methods

The application of herbicides and its impact in intercropping systems on major soil microbial population and Dehydrogenase activity was studied at Agricultural Research Station, Malnoor, University of Agricultural Sciences, Raichur, during 2018-19 and 2019-20. The soils of the experimental field was medium deep black with clay loam texture, slightly high in pH (8.14), normal EC (0.35 dS m^{-1}), medium in OC (0.56 %), available nitrogen (344 kg ha^{-1}), phosphorus (29.21 kg ha^{-1}) and high in available potassium (355 kg ha^{-1}). The treatments consisted of four cropping systems {sole *Bt* cotton (90 cm x 60 cm), paired row planting of *Bt* cotton (120/60 cm x 60 cm), paired row *Bt* cotton + foxtail millet (2:3) and paired row *Bt* cotton + little millet (2:3)} in the main plots and five weed control treatments {unweeded check, weed free, hand weeding @ 20 DAS *fb* IC at 35 DAT, pendimethalin 38.7 CS @ 0.34 kg *a.i.* ha^{-1} as PE *fb* IC at 35 DAT and oxadiargyl @ 0.04 kg *a.i.* ha^{-1} as PE *fb* IC at 35 DAT} in sub plots replicated thrice in a split plot design. For the purpose of analyzing the microbial activity, the soil samples were collected from experimental plot at 30, 60 DAT and at harvest of crop from each plot. The enumeration of total Bacteria, Fungi and Actinomycetes was carried out at different interval by serial dilution and Agar plate count method (Pramer and Schmidt, 1964). Dehydrogenase activity in the soil sample by colorimetric determination of TPF produced from the TTC in soils by Assay method as described by Casida *et al.,* (1964) at a wave length of 485 nm. The results are expressed as µg of triphenyl formazan (TPF) formed per gram of soil per day. The data were analyzed statistically as per the procedure described by Gomez and Gomez (1984).

Results and Discussion

Soil Microbial population (Bacteria, Fungi and Actinomycetes)

In both the seasons the data indicated that cropping systems did not affect the microbial population, where as the weed management practices influenced the microbial population significantly. In general, load of microbial population reduced immediately after the application of herbicides and as the days to go it attained normal state. Among weed management practices, the pooled data at 30 DAT indicated that application of pendimethalin 38.7 CS @ 0.34 kg *a.i.* ha^{-1} as pre emergence recorded bacteria, fungi and actinomycetes population of 34.68 $\times 10^6$ CFU g^{-1} of soil, 22.02 $\times$ 10^3 CFU g^{-1} of soil and 17.12 $\times$ 10^4 CFU g^{-1} of soil, respectively and when oxadiargyl @ 0.04 kg *a.i.* ha^{-1} was applied as pre emergence it was 33.70 $\times$ 10^6 CFU g^{-1} of soil, 16.35 $\times$ 10^3 CFU g^{-1} of soil and 14.64 $\times$ 10^4 CFU g^{-1} of soil, respectively. All these values were significantly lesser over plots where no herbicide was applied *viz.*, unweeded check (76.48 $\times$ 10^6 CFU g^{-1} of soil, 32.16 $\times$ 10^3 CFU g^{-1} of soil and 45.92 $\times$ 10^4 CFU g^{-1} of soil, respectively), weed free check (74.79 $\times$ 10^6 CFU g^{-1} of soil, 31.47 $\times$ 10^3 CFU g^{-1} of soil and 45.15 **x** 10^4 CFU g^{-1} of soil, respectively) and hand weeding @ 20 DAT *fb* IC at 35 DAT (67.61 $\times$ 10^6 CFU g^{-1} of soil, 30.34 $\times$ 10^3 CFU g^{-1} of soil and 42.81 $\times$ 10^4 CFU g^{-1} of soil, respectively). The latter treatments were on par with each other (Table 1-3). However, the data was non significant at 60 days after transplanting and at harvest.

Table.1 Bacterial population (No. × 10^6 CFU g^{-1} of soil) at different growth stages as influenced by weed management practices in transplanted *Bt* cotton with minor millet intercropping system

Treatments	Bacterial population (No. × 10^6 CFU g^{-1} of soil)								
	30 DAT			60 DAT			At Harvest		
Cropping system	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Sole *Bt* cotton (90 cm x 60 cm)	56.70	54.14	55.42	77.40	76.13	76.77	54.47	54.09	54.28
Paired row planting of *Bt* cotton (120/60 cm x 60 cm)	57.80	54.58	56.19	76.13	74.67	75.40	54.00	53.83	53.92
Paired row *Bt* cotton + Foxtail millet (2:3)	63.04	56.90	59.97	81.13	77.53	79.33	58.70	56.24	57.47
Paired row *Bt* cotton + Little millet (2:3)	61.35	55.07	58.21	79.07	76.60	77.83	55.23	55.10	55.16
S. Em±	2.44	2.71	2.50	3.04	4.24	3.23	4.24	2.34	3.08
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed management practices									
Un weeded check	79.58	73.37	76.48	85.62	80.58	83.10	58.92	57.82	58.37
Weed free	78.81	70.76	74.79	83.75	79.92	81.83	57.00	56.99	57.00
Hand weeding @ 20 DAS *fb* IC at 35 DAT	71.38	63.83	67.61	77.70	74.08	75.89	55.24	56.28	55.76
Pendimethalin 38.7 CS @ 0.34 kg *a.i.* ha^{-1} as PE *fb* IC at 35 DAT	35.01	34.34	34.68	73.77	73.42	73.59	54.92	52.41	53.66
Oxadiargyl @ 0.04 kg *a.i* ha^{-1} as PE *fb* IC at 35 DAT	33.83	33.56	33.70	71.33	73.17	72.25	51.92	50.58	51.25
S. Em±	2.67	2.83	2.59	3.96	3.07	2.99	3.59	3.26	3.06
C.D. at 5%	7.69	8.15	7.47	NS	NS	NS	NS	NS	NS

Table.2 Fungal population (No. × 10^3 CFU g^{-1} of soil) at different growth stages as influenced by weed management practices in transplanted *Bt* cotton with minor millet intercropping system

Treatments	Fungal population (No. × 10^3 CFU g^{-1} of soil)								
	30 DAT			60 DAT			At Harvest		
Cropping system	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Sole *Bt* cotton (90 cm x 60 cm)	25.99	26.09	26.04	33.08	31.62	32.35	12.35	11.40	11.87
Paired row planting of *Bt* cotton (120/60 cm x 60 cm)	26.96	22.87	24.91	33.62	31.39	32.50	11.64	10.66	11.15
Paired row *Bt* cotton + Foxtail millet (2:3)	30.20	30.13	30.17	34.70	35.36	35.03	12.84	12.29	12.57
Paired row *Bt* cotton + Little millet (2:3)	25.84	23.67	24.75	33.67	32.31	32.99	11.80	11.58	11.69
S. Em±	2.11	1.95	1.84	2.97	2.34	2.39	0.59	0.48	0.34
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed management practices									
Un weeded check	32.73	31.58	32.16	38.70	36.70	37.70	12.92	12.19	12.55
Weed free	31.99	30.94	31.47	37.87	35.86	36.87	13.25	11.80	12.53
Hand weeding @ 20 DAS *fb* IC at 35 DAT	31.58	29.10	30.34	35.85	34.47	35.16	12.01	11.43	11.72
Pendimethalin 38.7 CS @ 0.34 kg *a.i.* ha^{-1} as PE *fb* IC at 35 DAT	23.07	20.98	22.02	28.48	28.48	28.48	11.53	11.18	11.36
Oxadiargyl @ 0.04 kg *a.i* ha^{-1} as PE *fb* IC at 35 DAT	16.86	15.85	16.35	27.93	27.83	27.88	11.08	10.81	10.94
S. Em±	2.09	1.66	1.64	3.43	2.73	2.88	0.67	0.68	0.50
C.D. at 5%	6.02	4.77	4.73	NS	NS	NS	NS	NS	NS

Table.3 Actinomycetes population (No. × 10^4 CFU g^{-1} of soil) at different growth stages as influenced by weed management practices in transplanted *Bt* cotton with minor millet intercropping system

Treatments	Actinomycetes population (No. × 10^4 CFU g^{-1} of soil)								
	30 DAT			60 DAT			At Harvest		
Cropping system	**2018**	**2019**	**Pooled**	**2018**	**2019**	**Pooled**	**2018**	**2019**	**Pooled**
Sole *Bt* cotton (90 cm x 60 cm)	32.67	29.75	31.21	43.07	41.75	42.41	8.53	9.66	9.10
Paired row planting of *Bt* cotton (120/60 cm x 60 cm)	35.11	30.23	32.67	43.43	41.16	42.30	8.13	9.78	8.96
Paired row *Bt* cotton + Foxtail millet (2:3)	36.51	33.32	34.91	45.15	43.40	44.28	8.73	10.15	9.44
Paired row *Bt* cotton + Little millet (2:3)	35.23	32.21	33.72	44.30	42.99	43.64	8.49	9.59	9.04
S. Em±	4.30	2.64	3.41	1.97	1.94	1.85	0.35	0.30	0.19
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed management practices									
Un weeded check	48.18	43.66	45.92	48.28	46.11	47.20	9.25	10.25	9.75
Weed free	47.60	42.70	45.15	47.08	46.00	46.54	8.58	10.16	9.37
Hand weeding @ 20 DAS *fb* IC at 35 DAT	45.06	40.55	42.81	43.48	42.61	43.05	8.33	9.83	9.08
Pendimethalin 38.7 CS @ 0.34 kg *a.i.* ha^{-1} as PE *fb* IC at 35 DAT	18.33	15.90	17.12	41.33	39.11	40.22	8.17	9.50	8.83
Oxadiargyl @ 0.04 kg *a.i* ha^{-1} as PE *fb* IC at 35 DAT	15.22	14.07	14.64	39.75	37.78	38.77	8.03	9.25	8.64
S. Em±	2.37	1.58	1.86	2.72	2.59	2.29	0.39	0.37	0.27
C.D. at 5%	6.82	4.54	5.36	NS	NS	NS	NS	NS	NS

Table.4 Soil Dehydrogenase (µg TPF formed g^{-1} soil day^{-1}) activity at different growth stages as influenced by weed management practices in transplanted *Bt* cotton with minor millet intercropping system

Treatments	Soil Dehydrogenase (µg TPF formed g^{-1} soil day^{-1}) activity								
	30 DAT			60 DAT			At Harvest		
Cropping system	**2018**	**2019**	**Pooled**	**2018**	**2019**	**Pooled**	**2018**	**2019**	**Pooled**
Sole *Bt* cotton (90 cm x 60 cm)	28.41	27.58	28.00	33.59	32.57	33.08	28.77	27.38	28.07
Paired row planting of *Bt* cotton (120/60 cm x 60 cm)	28.08	27.23	27.66	33.34	32.54	32.94	28.90	27.32	28.11
Paired row *Bt* cotton + Foxtail millet (2:3)	29.03	28.18	28.60	33.99	33.02	33.51	29.29	28.05	28.67
Paired row *Bt* cotton + Little millet (2:3)	28.54	27.63	28.09	33.62	32.63	33.13	29.11	27.44	28.27
S. Em±	0.74	0.65	0.69	0.70	0.60	0.65	0.60	0.47	0.52
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed management practices									
Un weeded check	30.33	29.31	29.82	34.78	33.61	34.19	29.93	28.27	29.10
Weed free	29.46	28.91	29.19	34.26	33.45	33.85	29.43	27.94	28.68
Hand weeding @ 20 DAS *fb* IC at 35 DAT	28.54	27.56	28.05	33.22	32.47	32.84	28.53	27.33	27.93
Pendimethalin 38.7 CS @ 0.34 kg *a.i.* ha^{-1} as PE *fb* IC at 35 DAT	27.15	26.35	26.75	33.14	32.03	32.59	28.59	27.22	27.90
Oxadiargyl @ 0.04 kg *a.i* ha^{-1} as PE *fb* IC at 35 DAT	27.10	26.14	26.62	32.78	31.89	32.34	28.62	26.98	27.80
S. Em±	0.66	0.79	0.72	0.75	0.78	0.76	0.72	0.72	0.71
C.D. at 5%	1.91	2.28	2.06	NS	NS	NS	NS	NS	NS

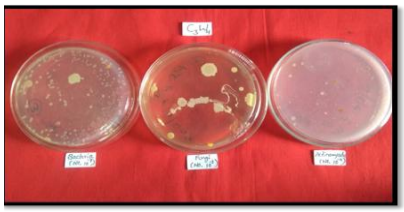
Table.5 Cotton equivalent yield influenced by weed management practices in transplanted *Bt* cotton with minor millet intercropping system

Treatments	Cotton equivalent yield (kg ha^{-1})		
	2018	2019	Pooled
Main plot			
Sole *Bt* cotton (90 cm x 60 cm) (C_1)	1771	1699	1735
Paired row planting of *Bt* cotton (120/60 cm x 60 cm) (C_2)	1730	1667	1699
Paired row *Bt* cotton + Foxtail millet (2:3) (C_3)	2508	2547	2528
Paired row *Bt* cotton + Little millet (2:3) (C_4)	2182	2200	2191
S. Em±	18	11	12
C.D. at 5%	53	33	36
Sub plot			
Un weeded check (W_1)	1073	980	1027
Weed free (W_2)	2528	2552	2540
Hand weeding @ 20 DAS *fb* IC at 35 DAT (W_3)	2342	2365	2353
Pendimethalin 38.7 CS @ 0.34 kg *a.i.* ha^{-1} as PE *fb* IC at 35 DAT (W_4)	2307	2352	2330
Oxadiargyl @ 0.04 kg *a.i* ha^{-1} as PE *fb* IC at 35 DAT (W_5)	1988	1894	1941
S. Em±	16	19	13
C.D. at 5%	47	56	38
Interaction			
C_1W_1	892	748	820
C_1W_2	2140	2120	2130
C_1W_3	2047	2037	2042
C_1W_4	2034	2032	2033
C_1W_5	1744	1559	1651
C_2W_1	782	709	745
C_2W_2	2091	2087	2089
C_2W_3	2037	2032	2034
C_2W_4	2034	2027	2031
C_2W_5	1708	1480	1594
C_3W_1	1323	1279	1301
C_3W_2	3009	3078	3044
C_3W_3	2887	2995	2941
C_3W_4	2873	2991	2932
C_3W_5	2445	2394	2419
C_4W_1	1296	1184	1240
C_4W_2	2873	2923	2898
C_4W_3	2398	2394	2396
C_4W_4	2288	2358	2323
C_4W_5	2055	2144	2099
S. Em±	27	28	21
C.D. at 5%	77	80	60

Plate.1 Bacteria, Fungi and Actinomycetes population of soil collected at 30 days after treatment incorporation

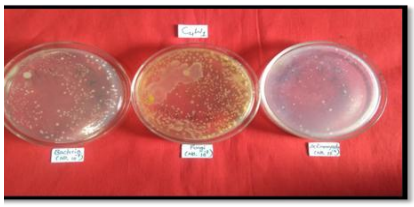
Soil collected from weed free treatment

Soil collected from hand weeding treatment



Soil collected from pendimethalin sprayed treatment

Soil collected from oxadiargyl sprayed treatment



il collected from un weeded check treatment

The trend remained same during both the years showing no pendimethalin and oxadiargyl herbicide residue present in the soil at toxic level indicating degradation of the herbicide in the soil. The results were confirmed with the findings of Kaur *et al.,* (2014) and Trimurthulu *et al.,* (2015).

Dehydrogenase enzyme activity (µg TPF formed g^{-1} soil day^{-1})

Dehydrogenase enzyme activity in soil is used as an indicator of soil biological (microbial) activity in soil because it is an intracellular enzyme in all living microbial cells (Quilchano and Maranon, 2002).

Dehydrogenase activity of soil did not differ significantly due to cropping systems at different growth stages of *Bt* cotton during both the years of experimentation.

Among weed management practices, the pooled data at 30 DAT indicated that application of pendimethalin 38.7 CS @ 0.34 kg *a.i.* ha^{-1} or oxadiargyl @ 0.04 kg *a.i.* ha^{-1} as pre emergence recorded Dehydrogenase activity of 26.75 µg TPF formed g^{-1} soil day^{-1} and 26.62 µg TPF formed g^{-1} soil day^{-1}, respectively. These values were significantly lower over Dehydrogenase activity recorded in unweeded check (29.82 µg TPF formed g^{-1} soil day^{-1}), weed free check (29.19 µg TPF formed g^{-1} soil day^{-1}) and hand weeding @ 20 DAT *fb* IC at 35 DAT (28.05 µg TPF formed g^{-1} soil day^{-1}). The latter treatments were on par with each other. The trend remained same during both the years. The data was non significant at 60 DAT and at harvest. This clearly indicated that though application of pendimethalin or oxadiargyl reduced the Dehydrogenase activity immediately after application but its effect did not persists longer in soil (Table 4).

Cotton equivalent yield

Cotton equivalent yield (CEY) varied significantly due to cropping systems with weed management practices. Among the cropping systems, in pooled data significantly higher CEY was recorded in paired row *Bt* cotton + foxtail millet (2:3) (2528 kg ha^{-1}) followed by paired row *Bt* cotton + little millet (2:3) (2191 kg ha^{-1}). This was followed by sole *Bt* cotton (1735 kg ha^{-1}) which inturn on par with paired row sole *Bt* cotton (1699 kg ha^{-1}). The results suggest that though the intercrops reduced the yield of cotton, the total productivity

would be high in intercropping system. There will be better utilization of other resources like light, nutrients and moisture. These results confirm the findings of Aladakatti *et al.,* (2011).

In pooled data, among weed management practices, weed free check recorded significantly higher seed cotton equivalent yield (2540 kg ha^{-1}) over rest of the treatments. This was followed by hand weeding @ 20 DAT *fb* IC at 35 DAT (2353 kg ha^{-1}) and pendimethalin 38.7 CS @ 0.34 kg *a.i.* ha^{-1} as PE *fb* IC at 35 DAT (2330 kg ha^{-1}) which were on par with each other but significantly higher over oxadiargyl @ 0.04 kg *a.i.* ha^{-1} as PE *fb* IC at 35 DAT (1941 kg ha^{-1}).

The significantly lower seed cotton equivalent yield was recorded in unweeded check (1027 kg ha^{-1}). The trend remains same during both the years. The increased seed cotton equivalent yield $hectare^{-1}$ might be due to better control of weeds during critical period of crop weed competition over unweeded check treatment that inturn improved the growth and yield parameters of *Bt* cotton and foxtail millet. The results were confirmed with the findings of Giri *et al.,* (2006). There was no suppression of yield due to herbicide application indicating no residual effect.

Further, in pooled data interaction between cropping systems and weed management practices, paired row *Bt* cotton + foxtail millet (2:3) coupled with weed free treatment (C_3W_2) recorded significantly higher CEY (3044 kg ha^{-1}) closely followed by paired row *Bt* cotton + foxtail millet (2:3) in combination with hand weeding @ 20 DAT *fb* IC at 35 DAT (2941 kg ha^{-1}), pendimethalin 38.7 CS @ 0.34 kg *a.i.* ha^{-1} as PE *fb* IC at 35 DAT (2932 kg ha^{-1}) and paired row *Bt* cotton + little millet with weed free treatment (2898 kg ha^{-1}) (Table 5). These treatments were on par with each other but significantly higher CEY over rest of the combinations. This clearly indicate that these herbicides can be used in these intercropping systems without any adverse effect of herbicide.

In conclusion the pre emergence application of pendimethalin 38.7 CS @ 0.34 kg *a.i.* ha^{-1} and oxadiargyl @ 0.04 kg *a.i.* ha^{-1} had temporarily reduction in number of soil Bacteria, Fungi, Actinomycetes and Dehydrogenase activity but later it was recovered showing no residual effect. The seed cotton equivalent yield was significantly higher in cultural and herbicide treated plots indicating these herbicides can be used for control of weeds.

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