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Effect of herbicides on soil microflora and enzymatic activity in high density planting cotton in vertisol of Northern Karnataka

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Abstract
The experiment was conducted for two consecutive years 2017-18 and 2018-19 to study to study the efficiency of new formulation of pre-emergence herbicide clomazone 50 EC on growth and development of HDPS cotton with better weed management in a cost effective manner. Clomazone 50 EC was tried in three different doses, *viz*. 250, 500 and 750 g *a.i.* ha^{-1} concentrations and was compared with pendimethalin 680 g *a.i.* ha^{-1}, post-emergence herbicides such as, pyrithiobac sodium 10 EC and quizalofop ethyl 5 EC @, cultural; method like one HW at 25 DAS and IC at 50 and 75 DAS, weed free check, unweeded control and other integrated methods. The data indicated that pre emergence application of pendimethalin 38.7 CS @ 680 g *a.i.* ha^{-1} and clomazone 50 EC @ 250 g *a.i.* ha^{-1} as PE with one HW at 25 DAS and IC at 50 DAS (30.6 and 29.6) were on par with each other and recorded significantly lower soil dehydrogenase activity over reduced the microbial population (Bacteria, Fungi and Actinomycetes) and dehydrogenase and phosphatase activity significantly over the treatments where no herbicides was applied (one HW at 25 DAS and IC at 50 DAS, weed free check and unweeded control were on par with each other (33.8, 33.7 and 32.2). While the values were on par at 100 DAS and at harvest which indicated that the herbicide effect 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 no adverse effect of the herbicide.

Keywords: Pendimethalin, clomazone, bacteria, fungi, actinomycetes, dehydrogenase and phosphatase enzyme activity

Introduction
Cotton (*Gossypium* sp.) is popularly known as "the white gold or the king of fibre crops" is an important commercial fibre crop grown under diverse agro-climatic conditions around the world. It provides fibre, a raw material for textile industry along with cotton seed and quality animal feed and biomass in the form of cotton stalks and plays a vital role in economy of the country. In the world, cotton is cultivated in 70 countries with a total coverage area of 31.8 million ha. In India, cotton is grown over an area of about 124.44 lakh ha with a total production of 370 lakh bales. India ranks fifth in area and third in production of cotton after USA and China. The productivity of cotton is 505.46 kg per ha which is much lower than the world average of 621 kg per ha. Among the cotton growing states, Karnataka ranks eighth with an area (5.46 lakh ha) and seventh in production with 18.0 lakh bales of lint with an average productivity of 560.44 kg of lint per ha (Anon., 2018) [1]. India has unique place among the cotton growing countries of the world are cultivated commercially in the country.
The high density planting system (HDPS) is now being conceived as an alternate production system having a potential for improving productivity and profitability, increasing efficiency, reducing input costs and minimizing risks associated with India's cotton production system. Of many problems faced by the cotton growers, the most troublesome one is the control of weeds particularly during early stages of crop growth. Weed infestation in cotton has been reported to offer severe competition and causing yield reduction to an extent 50 to 85 per cent (Venugopalan *et al*., 2009) [9]. Thus, if proper weed control measures are followed, there would be greater availability of nutrients and moisture for the benefit of crop (Jalis and Shah, 1982) [4]. Cotton with minimal weed competition during the initial phase *i.e*., three to five weeks would yield better (Mohamed Ali and Bhanumurthy, 1985). Hence, the present study was to investigate how there is need for selection of new molecules of pre-emergence would affect soil microbial population, dehydrogenase and phosphatase activity.

Material and Methods

Experiment was conducted for two consecutive years 2017-18 and 2018-19 at Department of Agronomy, College of Agriculture, UAS, Raichur. The experiment was laid out in Randomized Completely Block Design with three replications. The soil of the experimental site was medium black with clay loam texture. The pre sowing composite soil samples collected from the experimental fields were analysed for physico-chemical characteristics. The treatments were allotted at random in each replication. The weed management practices evaluated in the present study consisted of chemical weed control (application of pre-emergence, Pre-emergence application on next day after sowing and post-emergence herbicides were applied 10 days after sowing), Hand weeding was done at 25 DAS and Intercultivation was done at 50 and 75 DAS as per the treatment schedule and Unweeded control. The weed management practices tested include: Pendimethalin 38.7 CS @ 680 g *a.i.* ha^{-1} as PE followed by (*fb*) HW at 25 DAS and IC at 50 and 75 DAS, Clomazone 50 EC @ 250, 500 and 750 g *a.i.* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS, Clomazone 50 EC @ 250, 500 and 750 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} at 25 DAS as PoE, Clomazone 50 EC @ 250, 500 and 750 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5 EC @ 37.5 g *a.i.* ha^{-1} at 25 DAS as PoE, Pendimethalin 38.7 CS @ 680 g *a.i.* ha^{-1} as PE fb pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5 EC @ 37.5 g *a.i.* ha^{-1} at 25DAS as POE, One HW at 25 DAS and IC at 50 and 75 DAS, weed free check and unweeded control. Cotton (*Gossypium hirsutum* L.) variety Suraj was raised during both the seasons of 20017-18 and 2018-19.

For the purpose of analyzing the microbial activity, the soil samples were collected from experimental plot at 30, 60, 90, 120 DAS 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) [6]. 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) [2] 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) [3].

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.

At 30 days after sowing, one hand weeding at 25 DAS (31.6 cfu × 10^6 g^{-1}), weed free check (30.8 cfu × 10^6 g^{-1}) and unweeded control (31.5 cfu ×10^6 g^{-1}, respectively) were on par with each other and recorded significantly higher over rest of the treatments. Application of pre-emergence herbicides reduced the bacterial population over non application of herbicides. Application clomazone 50 EC @ 250 g *a.i.* ha^{-1} as PE (21.6) and pendimethalin 38.7 CS @ 680 g *a.i* ha^{-1} (20.4) recorded higher bacterial population over other higher concentrations.

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 ×10^6 CFU g^{-1} of soil, 22.02 × 10^3 CFU g^{-1} of soil and 17.12 × 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 × 10^6 CFU g^{-1} of soil, 16.35 × 10^3 CFU g^{-1} of soil and 14.64 × 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 × 10^6 CFU g^{-1} of soil, 32.16 × 10^3 CFU g^{-1} of soil and 45.92 × 10^4 CFU g^{-1} of soil, respectively), weed free check (74.79 × 10^6 CFU g^{-1} of soil, 31.47 × 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 × 10^6 CFU g^{-1} of soil, 30.34 × 10^3 CFU g^{-1} of soil and 42.81 × 10^4 CFU g^{-1} of soil, respectively). The latter treatments were on par with each other (Table 1, 2 and 3). However, the data was non significant at 60 days after transplanting and at harvest. 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) [5] and Trimurthulu *et al.* (2015) [8].

Table 1: Bacterial population (×10^6 cfu/ml) at different growth stages of HDPS cotton as influenced by different chemical weed management practices

Treatment	2017-18							2018-19							Pooled						
	Before	25 DAS	50 DAS	75 DAS	100 DAS	125 DAS	At harvest	Before	25 DAS	50 DAS	75 DAS	100 DAS	125 DAS	At harvest	Before	25 DAS	50 DAS	75 DAS	100 DAS	125 DAS	At harvest
T_1	31.5	22.0	25.8	30.0	30.9	32.0	29.0	29.9	21.2	25.0	28.2	29.7	31.6	28.4	30.7	21.6	25.4	29.1	30.3	31.8	28.7
T_2	30.6	21.8	24.8	28.2	30.5	30.3	28.9	28.6	19.0	23.8	25.8	28.9	29.5	27.9	29.6	20.4	24.3	27.0	29.7	29.9	28.4
T_3	29.9	19.4	23.6	27.8	29.4	31.0	28.0	31.9	18.8	22.4	25.8	27.0	29.0	26.4	30.9	19.1	23.0	26.8	28.2	30.0	27.2
T_4	28.0	18.9	23.1	25.5	27.4	28.0	27.1	31.2	17.9	22.5	23.5	26.6	27.8	26.5	29.6	18.4	22.8	24.5	27.0	27.9	26.8
T_5	31.2	22.8	21.2	25.0	29.8	30.2	29.0	26.4	22.0	20.2	23.0	29.2	29.4	28.2	28.8	22.4	20.7	24.0	29.5	29.8	28.6
T_6	30.5	22.4	19.3	24.6	29.3	29.8	28.8	28.5	20.6	17.1	22.6	28.7	28.6	27.2	29.5	21.5	18.2	23.6	29.0	29.2	28.0
T_7	31.5	19.4	18.3	22.2	26.5	28.4	26.2	30.9	18.8	14.3	20.2	25.5	26.4	24.4	31.2	19.1	16.3	21.2	26.0	27.4	25.3
T_8	31.4	20.8	19.8	22.5	28.9	30.2	28.0	29.4	21.4	18.6	21.7	27.9	29.6	27.0	30.4	21.1	19.2	22.1	28.4	29.9	27.5
T_9	31.5	21.0	19.3	22.8	28.2	29.3	27.5	28.5	20.4	18.7	20.4	27.0	28.1	25.5	30.0	20.7	19.0	21.6	27.6	28.7	26.5
T_{10}	31.2	18.6	16.0	22.5	27.2	28.0	26.0	32.0	17.8	15.4	20.1	25.2	26.8	25.0	31.6	18.2	15.7	21.3	26.2	27.4	25.5

T_{11}	31.2	20.5	18.7	23.5	26.7	27.2	25.2	30.0	18.5	19.1	21.5	24.7	26.6	24.8	30.6	19.5	18.9	22.5	25.7	26.9	25.0
T_{12}	29.8	32.8	33.6	34.6	35.0	35.9	34.2	32.2	31.8	29.6	30.6	31.0	34.5	35.2	31.0	31.6	32.3	32.6	33.0	35.2	34.7
T_{13}	30.8	32.4	33.8	35.9	36.0	37.9	35.8	30.0	31.6	27.8	31.9	35.6	37.5	37.2	30.4	30.8	32.0	33.9	35.8	37.7	36.5
T_{14}	31.5	33.0	34.5	35.3	36.2	38.7	36.4	29.5	32.4	28.5	33.3	36.6	38.1	38.2	30.5	31.5	32.7	34.3	36.4	38.4	37.3
S.Em±	1.2	0.3	0.3	0.4	0.4	1.3	0.6	1.6	0.3	0.3	0.3	0.3	0.8	0.8	1.1	0.3	0.3	0.3	0.4	1.0	0.5
C.D. at 5%	NS	0.9	0.8	1.3	1.3	3.8	1.6	NS	0.7	0.8	0.9	0.1	2.4	2.3	NS	0.9	0.8	1.0	1.1	3.0	1.5

T_1 to T_{14}: Treatment **DAS-Days after sowing**

T_1: Pendimethalin 38.7 CS @ 680 g *a.i* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS

T_2: Clomazone 50 EC @ 250 g *a.i* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS

T_3: Clomazone 50 EC @ 500 g *a.i.* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS

T_4: Clomazone 50 EC @ 750 g *a.i.* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS

T_5: Clomazone 50 EC @ 250 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10EC 75 g *a.i.* ha^{-1} at 25 DAS as PoE

T_6: Clomazone 50 EC @ 500 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10EC 75 g *a.i.* ha^{-1} at 25 DAS as PoE

T_7 Clomazone 50 EC @ 750 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10EC 75 g *a.i.* ha^{-1} at 25 DAS as PoE

T_8: Clomazone 50 EC @ 250 g *a.i.*/ha as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5 EC @ 37.5 g *a.i.* ha^{-1} at 25 DAS as PoE.

T_9: Clomazone 50 EC @ 500 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5 EC @ 37.5 g *a.i.* ha^{-1} at 25 DAS as PoE.

T_{10}: Clomazone 50 EC @ 750 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5EC @ 37.5 g *a.i.* ha^{-1} at 25 DAS as PoE.

T_{11}: Pendimethalin 38.7 CS @ 680 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5 EC @ 37.5 g *a.i.* ha^{-1} at 25DAS as PoE

T_{12}: One HW at 25 DAS and IC at 50 and 75 DAS

T_{13}: Weed free check

T_{14} Unweeded control

Table 2: Fungal population (×10^{3}cfu/ml) at different growth stages of HDPS cotton as influenced by different chemical weed management practices

Treatment	2017-18							2018-19							Pooled						
	Before	25 DAS	50 DAS	75 DAS	100 DAS	125 DAS	At harvest	Before	25 DAS	50 DAS	75 DAS	100 DAS	125 DAS	At harvest	Before	25 DAS	50 DAS	75 DAS	100 DAS	125 DAS	At harvest
T_1	12.7	11.6	12.6	14.8	15.2	17.0	13.1	12.7	11.6	12.6	14.8	15.2	17.0	13.1	12.4	11.2	12.50	14.7	14.4	16.9	12.9
T_2	13.2	11.8	13.3	15.8	16.0	17.2	13.3	13.2	11.8	13.3	15.8	16.0	17.2	13.3	12.8	11.6	12.90	15.4	15.6	17.0	13.2
T_3	12.5	11.6	12.8	14.2	15.5	16.9	13.2	12.5	11.6	12.8	14.2	15.5	16.9	13.2	12.3	11.9	12.50	13.2	15.4	16.8	13.0
T_4	13.5	11.6	12.5	13.2	14.0	15.0	12.4	13.5	11.6	12.5	13.2	14.0	15.0	12.4	13.5	11.8	12.00	12.8	13.4	14.8	12.2
T_5	14.5	11.6	11.9	14.5	15.4	15.9	13.9	14.5	11.6	11.9	14.5	15.4	15.9	13.9	14.1	12.0	10.60	14.4	15.2	15.6	13.8
T_6	14.2	11.5	10.4	13.6	15.2	16.8	14.6	14.2	11.5	10.4	13.6	15.2	16.8	14.6	13.5	11.8	10.30	13.3	15.0	16.6	14.3
T_7	13.8	10.9	10.0	12.5	14.5	15.0	13.4	13.8	10.9	10.0	12.5	14.5	15.0	13.4	13.3	10.8	9.80	12.0	14.4	14.6	13.0
T_8	13.2	10.5	9.5	12.3	14.3	15.6	13.7	13.2	10.5	9.5	12.3	14.3	15.6	13.7	13.0	9.8	9.20	12.2	14.2	15.5	13.5
T_9	12.5	11.3	10.2	12.0	14.4	15.0	14.0	12.5	11.3	10.2	12.0	14.4	15.0	14.0	12.2	10.2	10.00	11.6	14.0	14.7	13.9
T_{10}	12.6	10.0	9.6	11.7	14.0	14.4	13.0	12.6	10.0	9.6	11.7	14.0	14.4	13.0	12.4	9.9	9.40	11.3	13.8	14.2	12.7
T_{11}	13.1	12.2	10.6	12.0	13.6	14.9	13.8	13.1	12.2	10.6	12.0	13.6	14.9	13.8	12.9	10.2	10.40	11.8	13.5	14.7	13.5
T_{12}	12.8	15.0	16.3	16.8	17.2	18.6	15.8	12.8	15.0	16.3	16.8	17.2	18.6	15.8	12.7	14.8	16.4	16.1	16.9	18.3	15.2
T_{13}	13.8	15.5	16.8	18.1	18.9	20.9	18.5	13.8	15.5	16.8	18.1	18.9	20.9	18.5	13.3	15.4	16.5	17.6	18.6	20.4	18.2
T_{14}	13.9	15.8	17.0	17.8	19.5	21.8	19.3	13.9	15.8	17.0	17.8	19.5	21.8	19.3	13.6	15.6	16.8	17.2	19.3	21.2	19.0
S.Em±	0.5	0.2	0.2	0.2	0.3	0.3	0.6	0.5	0.1	0.2	0.2	0.2	0.3	0.6	0.5	0.2	0.2	0.2	0.3	0.3	0.6
C.D. at 5%	NS	0.5	0.5	0.6	0.9	0.9	1.9	NS	0.4	0.5	0.5	0.7	0.8	1.7	NS	0.4	0.5	0.6	0.8	0.8	1.8

T_1 to T_{14}: Treatment **DAS-Days after sowing**

T_1: Pendimethalin 38.7 CS @ 680 g *a.i* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS

T_2: Clomazone 50 EC @ 250 g *a.i* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS

T_3: Clomazone 50 EC @ 500 g *a.i.* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS

T_4: Clomazone 50 EC @ 750 g *a.i.* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS

T_5: Clomazone 50 EC @ 250 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10EC 75 g *a.i.* ha^{-1} at 25 DAS as PoE

T_6: Clomazone 50 EC @ 500 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10EC 75 g *a.i.* ha^{-1} at 25 DAS as PoE

T_7 Clomazone 50 EC @ 750 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10EC 75 g *a.i.* ha^{-1} at 25 DAS as PoE

T_8: Clomazone 50 EC @ 250 g *a.i.*/ha as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5 EC @ 37.5 g *a.i.* ha^{-1} at 25 DAS as PoE.

T_9: Clomazone 50 EC @ 500 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5 EC @ 37.5 g *a.i.* ha^{-1} at 25 DAS as PoE.

T_{10}: Clomazone 50 EC @ 750 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5EC @ 37.5 g *a.i.* ha^{-1} at 25 DAS as PoE.

T_{11}: Pendimethalin 38.7 CS @ 680 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5 EC @ 37.5 g *a.i.* ha^{-1} at 25DAS as PoE

T_{12}: One HW at 25 DAS and IC at 50 and 75 DAS

T_{13}: Weed free check

T_{14} Unweeded control

Table 3: Actinomycetes population (×10^4 cfu/ml) at different growth stages of HDPS cotton as influenced by different chemical weed management practices

Treatment	2017-18							2018-19							Pooled						
	Before	25 DAS	50 DAS	75 DAS	100 DAS	125 DAS	At harvest	Before	25 DAS	50 DAS	75 DAS	100 DAS	125 DAS	At harvest	Before	25 DAS	50 DAS	75 DAS	100 DAS	125 DAS	At harvest
T_1	16.6	14.1	14.3	15.6	16.2	16.5	14.8	16.2	13.5	14.1	15.0	15.8	16.3	14.2	16.4	13.8	14.2	15.3	16.0	16.4	14.5
T_2	16.9	13.6	14.1	16.6	16.8	18.1	15.6	16.5	13.0	13.7	16.0	16.2	17.1	15.0	16.7	13.3	13.9	16.3	16.5	17.6	15.3
T_3	17.2	13.5	13.9	16.4	16.4	17.2	16.2	16.4	12.7	13.7	16.6	16.0	16.6	15.6	16.8	13.1	13.8	16.5	16.2	16.9	15.9
T_4	17.8	12.6	12.5	15.0	14.8	15.6	13.8	17.4	11.6	12.1	14.6	14.0	14.4	13.4	17.6	12.1	12.3	14.8	14.4	15.0	13.6
T_5	18.3	14.2	13.4	15.3	16.1	16.6	15.7	18.1	13.6	13.0	14.9	15.7	15.4	14.9	18.2	13.9	13.2	15.1	15.9	16.0	15.3
T_6	18.4	13.9	13.1	15.0	15.7	16.2	15.2	17.8	13.5	12.9	14.6	15.3	15.6	14.8	18.1	13.7	13.0	14.8	15.5	15.9	15.0
T_7	17.9	12.5	11.9	13.8	14.3	15.0	13.6	17.5	12.3	11.3	13.4	13.7	14.4	12.8	17.7	12.4	11.6	13.6	14.0	14.7	13.2
T_8	18.3	13.2	12.9	14.3	15.4	16.4	15.8	18.1	14.0	12.5	13.7	15.2	15.4	15.0	18.2	13.6	12.7	14.0	15.3	15.9	15.4
T_9	18.0	13.3	12.6	14.9	15.5	16.0	15.4	16.8	13.3	12.2	14.7	15.1	15.4	14.8	17.4	13.3	12.4	14.8	15.3	15.7	15.1
T_{10}	17.4	12.8	11.8	14.0	14.3	15.2	13.6	16.6	12.6	11.2	13.4	13.9	14.4	13.0	17.0	12.7	11.5	13.7	14.1	14.8	13.3
T_{11}	17.0	12.6	12.2	14.0	14.8	15.4	14.8	16.4	12.2	11.8	13.6	14.4	14.4	14.0	16.7	12.4	12.0	13.8	14.6	14.9	14.4
T_{12}	17.8	19.6	20.4	19.1	19.6	20.1	18.4	17.2	19.0	19.8	18.5	19.0	19.5	17.8	17.5	19.3	20.1	18.8	19.3	19.8	18.1
T_{13}	17.4	19.8	20.8	21.5	20.7	22.0	19.6	16.6	19.0	19.8	19.5	20.3	21.2	18.8	17.0	19.4	20.3	20.5	20.5	21.6	19.2
T_{14}	16.9	20.2	20.9	21.2	22.1	22.8	21.0	16.3	19.4	19.9	20.6	21.5	21.8	20.4	16.6	19.8	20.4	20.9	21.8	22.3	20.7
S.Em±	0.7	0.2	0.2	0.2	0.3	0.6	0.6	0.6	0.5	0.2	0.2	0.2	0.5	0.5	0.7	0.2	0.2	0.2	0.2	0.6	0.5
C.D. at 5%	NS	0.7	0.6	0.6	0.7	1.8	1.6	NS	3.6	0.5	0.5	0.6	1.5	1.4	NS	0.6	0.5	0.6	0.7	1.7	1.5

T_1 to T_{14}: Treatment **DAS-Days after sowing**

T_1: Pendimethalin 38.7 CS @ 680 g *a.i* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS

T_2: Clomazone 50 EC @ 250 g *a.i* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS

T_3: Clomazone 50 EC @ 500 g *a.i.* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS

T_4: Clomazone 50 EC @ 750 g *a.i.* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS

T_5: Clomazone 50 EC @ 250 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10EC 75 g *a.i.* ha^{-1} at 25 DAS as PoE

T_6: Clomazone 50 EC @ 500 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10EC 75 g *a.i.* ha^{-1} at 25 DAS as PoE

T_7 Clomazone 50 EC @ 750 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10EC 75 g *a.i.* ha^{-1} at 25 DAS as PoE

T_8: Clomazone 50 EC @ 250 g *a.i.*/ha as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5 EC @ 37.5 g *a.i.* ha^{-1} at 25 DAS as PoE.

T_9: Clomazone 50 EC @ 500 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5 EC @ 37.5 g *a.i.* ha^{-1} at 25 DAS as PoE.

T_{10}: Clomazone 50 EC @ 750 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5EC @ 37.5 g *a.i.* ha^{-1} at 25 DAS as PoE.

T_{11}: Pendimethalin 38.7 CS @ 680 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5 EC @ 37.5 g *a.i.* ha^{-1} at 25DAS as PoE

T_{12}: One HW at 25 DAS and IC at 50 and 75 DAS

T_{13}: Weed free check

T_{14} Unweeded control

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

Dehydrogenase and phosphatase enzyme activity in soil is used as an indicator of biological (microbial) activity in soil because it is an intracellular enzyme in all living microbial cells (Quilchano and Maranon, 2002) [7].

Dehydrogenase and phosphatase 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 50 DAS indicated that, one HW at 25 DAS and IC at 50 DAS, weed free check and unweeded control were on par with each other (33.8, 33.7 and 32.2) and recorded significantly higher soil dehydrogenase activity over rest of the treatments. With respect to application of herbicides, pendimethalin 38.7 CS @ 680 g *a.i.* ha^{-1} and clomazone 50 EC @ 250 g *a.i.* ha^{-1} as PE with one HW at 25 DAS and IC at 50 DAS (30.6 and 29.6) were on par with each other and recorded significantly lower soil dehydrogenase activity over the above treatments. Increase in clomazone from 250 g *a.i.* ha^{-1} to 750 g *a.i.* ha^{-1} with or without pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5 EC @ 37.5 g *a.i.* ha^{-1} decreased the soil dehydrogenase activity. Similar trend was noticed at 100 DAS and at harvest (Table 4).

At 50 DAS, the pooled data revealed that, phosphatase activity was found significantly higher in one HW at 25 DAS and IC at 50 DAS (T_{12}: 33.7) and unweeded control (T_{14}: 31.1) over rest of the treatments. Application of pre emergence and post emergence herbicides showed reduction in soil phosphatase activity. The application of lower concentration of herbicide *viz*, clomazone 50 EC @ 250 g *a.i.* ha^{-1} as PE and pendimethalin 38.7 CS @ 680 g *a.i.* ha^{-1} with one HW at 25 DAS and IC at 50 DAS or application of lower concentration of herbicide *viz*, clomazone 50 EC @ 250 g *a.i.* ha^{-1} as PE with post emergence application of pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} or combined post emergence application of pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5 EC @ 37.5 g *a.i.* ha^{-1} recorded higher soil phosphatase activity compared to higher concentration of clomazone 50 EC @ 500 or 750 g *a.i.* ha^{-1}. Similar trend was noticed at 100 DAS and at harvest (Table 5).

This clearly indicated that though application of chemicals reduced the dehydrogenase and phosphatase activity immediately after application but its effect did not persists longer in soil

Table 4: Soil dehydrogenase (µg TPF formed g^{-1} soil d^{-1}) activity at different growth stages of HDPS cotton as influenced by different chemical weed management practices

Treatment	2017-18			2018-19			Pooled		
	50DAS	100 DAS	At harvest	50 DAS	100 DAS	At harvest	50 DAS	100 DAS	At harvest
T_1	31.6	35.2	30.4	29.6	33.2	28.3	30.6	34.2	29.3
T_2	30.6	34.8	28.9	28.5	32.8	26.9	29.6	33.8	27.9
T_3	30.5	33.6	27.5	27.8	32.6	26.6	29.2	33.1	27.0
T_4	28.7	29.8	27.5	25.6	27.6	26.5	27.1	28.7	27.0
T_5	28.3	30.6	26.5	24.3	28.6	24.5	26.3	29.6	25.5
T_6	27.3	28.5	25.5	25.1	25.5	24.6	26.2	27.0	25.0
T_7	26.8	26.7	24.6	24.8	24.7	22.7	25.8	25.7	23.7
T_8	25.8	28.9	25.9	24.4	26.9	24.0	25.1	27.9	24.9
T_9	32.0	31.4	28.1	30.2	28.8	26.7	31.1	30.1	27.4
T_{10}	27.9	29.9	27.5	25.9	27.9	25.6	26.9	28.9	26.5
T_{11}	27.3	31.4	27.2	27.1	29.4	25.2	27.2	30.4	26.2
T_{12}	34.3	37.8	34.8	33.3	35.8	28.8	33.8	36.8	31.8
T_{13}	34.0	38.3	32.4	33.3	36.3	28.0	33.7	37.3	30.2
T_{14}	33.8	36.9	32.5	30.7	34.9	28.7	32.2	35.9	30.6
S.Em±	0.5	1.1	0.5	1.0	0.5	0.9	0.6	0.7	0.6
C.D. at 5%	1.3	3.0	1.3	2.8	1.5	2.7	1.7	1.9	1.7

T_1 to T_{14}: Treatment **DAS-Days after sowing**

T_1: Pendimethalin 38.7 CS @ 680 g *a.i* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS

T_2: Clomazone 50 EC @ 250 g *a.i* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS

T_3: Clomazone 50 EC @ 500 g *a.i.* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS

T_4: Clomazone 50 EC @ 750 g *a.i.* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS

T_5: Clomazone 50 EC @ 250 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10EC 75 g *a.i.* ha^{-1} at 25 DAS as PoE

T_6: Clomazone 50 EC @ 500 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10EC 75 g *a.i.* ha^{-1} at 25 DAS as PoE

T_7 Clomazone 50 EC @ 750 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10EC 75 g *a.i.* ha^{-1} at 25 DAS as PoE

T_8: Clomazone 50 EC @ 250 g *a.i.*/ha as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5 EC @ 37.5 g *a.i.* ha^{-1} at 25 DAS as PoE.

T_9: Clomazone 50 EC @ 500 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5 EC @ 37.5 g *a.i.* ha^{-1} at 25 DAS as PoE.

T_{10}: Clomazone 50 EC @ 750 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5EC @ 37.5 g *a.i.* ha^{-1} at 25 DAS as PoE.

T_{11}: Pendimethalin 38.7 CS @ 680 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5 EC @ 37.5 g *a.i.* ha^{-1} at 25DAS as PoE

T_{12}: One HW at 25 DAS and IC at 50 and 75 DAS

T_{13}: Weed free check

T_{14} Unweeded control

Table 5: Phosphatase activities (µg PNP formed g^{-1} soil d^{-1}) at different growth stages of HDPS cotton as influenced by different chemical weed management

Treatment	2017-18			2018-19			Pooled		
	50DAS	100 DAS	At harvest	50 DAS	100 DAS	At harvest	50 DAS	100 DAS	At harvest
T_1	32.4	33.9	28.3	31.4	33.1	26.4	31.9	33.5	27.3
T_2	30.8	33.4	27.9	29.6	32.2	26.0	30.2	32.8	26.9
T_3	29.4	32.6	27.8	28.1	32.2	25.9	28.8	32.4	26.9
T_4	27.3	29.0	26.2	26.5	27.0	20.3	26.9	28.0	23.2
T_5	29.6	33.9	27.9	29.0	33.3	25.9	29.3	33.6	26.9
T_6	28.6	33.4	28.6	28.1	32.4	25.8	28.4	32.9	27.2
T_7	28.5	29.0	25.3	27.0	28.2	21.3	27.8	28.6	23.3
T_8	28.9	33.5	27.3	28.3	32.9	25.0	28.6	33.2	26.1
T_9	32.0	34.6	28.3	31.4	33.4	26.8	31.7	34.0	27.5
T_{10}	28.6	29.4	24.5	27.6	28.6	22.4	28.1	29.0	23.4
T_{11}	29.8	34.2	27.4	28.4	33.4	24.9	29.1	33.8	26.2
T_{12}	34.0	38.6	31.2	33.4	37.4	28.5	33.7	38.0	29.8
T_{13}	30.1	37.9	30.4	29.2	35.1	28.4	29.6	36.5	29.4
T_{14}	31.4	39.4	32.4	30.8	38.4	28.4	31.1	38.9	30.4
S.Em±	1.0	0.6	0.8	1.1	0.9	1.2	1.0	0.6	1.0
C.D. at 5%	2.8	1.8	2.4	3.1	2.6	3.7	3.0	1.8	2.3

T_1 to T_{14}: Treatment **DAS-Days after sowing**

T_1: Pendimethalin 38.7 CS @ 680 g *a.i* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS

T_2: Clomazone 50 EC @ 250 g *a.i* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS

T_3: Clomazone 50 EC @ 500 g *a.i.* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS

T_4: Clomazone 50 EC @ 750 g *a.i.* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS

T_5: Clomazone 50 EC @ 250 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10EC 75 g *a.i.* ha^{-1} at 25 DAS as PoE

T_6: Clomazone 50 EC @ 500 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10EC 75 g *a.i.* ha^{-1} at 25 DAS as PoE

T_7 Clomazone 50 EC @ 750 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10EC 75 g *a.i.* ha^{-1} at 25 DAS as PoE

T_8: Clomazone 50 EC @ 250 g *a.i.*/ha as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5 EC @ 37.5 g *a.i.* ha^{-1} at 25 DAS as PoE.

T_9: Clomazone 50 EC @ 500 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5 EC @ 37.5 g *a.i.* ha^{-1} at 25 DAS as PoE.

T_{10}: Clomazone 50 EC @ 750 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5EC @ 37.5 g *a.i.* ha^{-1} at 25 DAS as PoE.

T_{11}: Pendimethalin 38.7 CS @ 680 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5 EC @ 37.5 g *a.i.* ha^{-1} at 25DAS as PoE

T_{12}: One HW at 25 DAS and IC at 50 and 75 DAS

T_{13}: Weed free check

T_{14} Unweeded control

Seed cotton yield

Increase in concentration of clomazone from 250 g *a.i.* ha^{-1} to 500 g *a.i.* ha^{-1} or 750 g *a.i.* ha^{-1} did not increase the seed cotton yield, indicating clomazone @ 250 g *a.i.* ha^{-1} was optimum. These treatments were on par with weed free check (T_{13}:1517 kg ha^{-1}) but significantly superior over unweeded control (T_{14}: 862 kg ha^{-1}) and HW at 25 DAS and IC at 50 and 75 DAS (T_{12}: 1148 kg ha^{-1}). These treatments were increased yield with the tune of T_{13}: 43.2%, T_1: 35.9% and T_2: 35.8 over unweeded control (Table 6). The variation in seed cotton yield may be attributed to be positive association between yield and yield contributing characters like sympodial branches, number of bolls plant^{-1}, mean boll weight and dry matter production. The improvement in growth and yield component in these treatments was due to reduced weed growth and weed dry weight. Better growth of cotton plants in these treatments might be due least competition with weeds for moisture, nutrients, space *etc.* Shahzad *et al.*, (2012) reported that, hand weeding and herbicidal treatments reduced the weed infestation, resulted in higher seed cotton yield over weedy plots. This was due to heavy infestation of weeds and poor yield components such as lower number of bolls plant^{-1}, less number of sympodial branches, lower seed index under unweeded control.

Table 6: Seed cotton yield of HDPS cotton as influenced by different chemical weed management practices

Treatment		Seed cotton yield (kg ha^{-1})		
		2017	2018	Pooled
T_1	Pendimethalin 38.7 CS @ 680 g *a.i* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS	1367	1326	1346
T_2	Clomazone 50 EC @ 250 g *a.i* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS	1387	1304	1345
T_3	Clomazone 50 EC @ 500 g *a.i.* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS	1477	1410	1444
T_4	Clomazone 50 EC @ 750 g *a.i.* ha^{-1} as PE *fb* HW at 25 DAS and IC at 50 and 75 DAS	1370	1183	1277
T_5	Clomazone 50 EC @ 250 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10EC 75 g *a.i.* ha^{-1} at 25 DAS as PoE	1407	1246	1326
T_6	Clomazone 50 EC @ 500 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10EC 75 g *a.i.* ha^{-1} at 25 DAS as PoE	1417	1267	1342
T_7	Clomazone 50 EC @ 750 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10EC 75 g *a.i.* ha^{-1} at 25 DAS as PoE	1361	1243	1302
T_8	Clomazone 50 EC @ 250 g *a.i.*/ha as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5 EC @ 37.5 g *a.i.* ha^{-1} at 25 DAS as PoE.	1296	1219	1258
T_9	Clomazone 50 EC @ 500 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5 EC @ 37.5 g *a.i.* ha^{-1} at 25 DAS as PoE.	1407	1267	1337
T_{10}	Clomazone 50 EC @ 750 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5EC @ 37.5 g *a.i.* ha^{-1} at 25 DAS as PoE.	1283	1173	1228
T_{11}	Pendimethalin 38.7 CS @ 680 g *a.i.* ha^{-1} as PE *fb* pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} + quizolofop ethyl 5 EC @ 37.5 g *a.i.* ha^{-1} at 25DAS as PoE	1300	1230	1265
T_{12}	One HW at 25 DAS and IC at 50 and 75 DAS	1159	1137	1148
T_{13}	Weed free check	1603	1431	1517
T_{14}	Unweeded control	859	865	862
S.Em±		124	84	85
C.D. at 5%		360	243	246

Conclusion

Pre emergence application of pendimethalin 38.7 CS @ 680 g *a.i.* ha^{-1} and clomazone 50 EC @ 250 g *a.i.* ha^{-1} had temporary reduction in number of soil bacteria, fungi, actinomycetes, dehydrogenase and phosphatase activity but later it was recovered showing no residual effect. The seed cotton yield was significantly higher in pre-emergence application of clomazone 50 EC @ 250 g *a.i.* ha^{-1} fb HW at 25 DAS and IC at 50 and 75 DAS is ideal for better weed control efficiency is good integrated weed control practice. Under scarcity of labours or unfavourable condition like continuous rainfall to employ labour to weed at later stages, sequential application of clomazone 50 EC @ 250 g *a.i.* ha^{-1} fb post emergence application pyrithiobac sodium 10 EC @ 75 g *a.i.* ha^{-1} at 25 DAS controlled the weeds effectively and increased seed cotton yields of high density planting system.

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