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RESEARCH ARTICLE

Effects of Conservation Agricultural Practices on Soil Microbial Population and Yield of Cotton

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ABSTRACT

Field investigations were conducted to assess the effect of conservation agricultural practices on soil biological properties and yield of cotton during the kharif season of 2018 and 2019. The experiments were laid out in a split plot design with four main factors *viz.,* conventional tillage with irrigation schedule of 0.8 IW/CPE ratio (M_1), conventional tillage with irrigation schedule of 0.6 IW/CPE ratio (M_2), minimum tillage with irrigation schedule of 0.8 IW/CPE ratio (M_3) and minimum tillage with irrigation schedule of 0.6 IW/CPE ratio (M_4). Sub plot had six treatments of weed and nutrient management viz., crop residue mulch with 100% RDF (S_1), crop residue mulch with 75% RDF (S_2), pre-emergence application of pendimethalin fb one hand weeding with 100% RDF (S_3), pre-emergence application of pendimethalin fb one hand weeding with 75% RDF (S_4), mechanical weeding twice with 100% RDF (S_5) and mechanical weeding twice with 75% RDF (S_6). Total microbial populations viz., bacteria, fungal, and actinobacteria were higher in cotton rhizosphere soil with the minimum tillage of irrigation at 0.8 IW/CPE ratio (M_3) in the main plot treatments. Cotton rhizosphere soil with crop residue mulch with 100% RDF (S_1) recorded a higher microbial population and it was statistically similar with pre-emergence application of pendimethalin fb one hand weeding with 100% RDF (S_3) in the sub plot treatments. Among the treatment combination, minimum tillage with irrigation at 0.8 IW/CPE ratio (M_3) and crop residue mulch with 100% RDF (S_1) recorded a higher microbial population. Similarly, a higher seed yield of cotton was also recorded with minimum tillage and irrigating the crop at 0.8 IW/CPE ratio and pre-emergence application of pendimethalin fb one hand weeding along with application of 100% RDF (M_3S_3).

Keywords: *Conventional tillage; Conservation agriculture; Minimum tillage; Mulch*

INTRODUCTION

Conservation agriculture is a concept evolved to respond to the concerns of sustainability of agriculture (FAO, 2012). This is a resource-saving agricultural production system aims to achieve high and sustaining yields and also will be able to enhance and maintain natural resource base through compliance of interrelated principles and with other good production management practices of plant nutrition (Abrol and Sangar, 2006). Traditional agriculture is based on intensive tillage and through mechanization in farming and held responsible for soil erosion problems, surface and underground water pollution and more consumption of irrigation water (Wolff and Stein, 1998). Moreover, it is implicated in land resource degradation and low energy efficiency and also contributes to global warming (Boatman *et al*., 1999). Hence, the conservation agriculture is an effective alternative way to cultivate annual and perennial crop-based systems and with crop residue management to have a soil cover. This will precede way to increase the organic matter content in the surface soil horizons. Instantaneously, it also has the beneficial impacts on the global environment as compared to traditional agriculture (Derpsch *et al*., 2010).

Microorganisms are essential component of soil, directly related to plant growth and soil fertility. Soil microbes are the living portion of soil that plays a vital role in the function of ecosystems through their complex interactions with the environment (Joergensen and Wichern, 2018). These include

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organic matter decomposition and nutrient cycling, including carbon (C) and nitrogen (N) cycling and soil aggregate formation and maintenance (Joergensen and Wichern, 2018; Hewins *et al*., 2017). Furthermore, the size of the microbial population in agricultural soils can be affected by management practices.

India has a long history of agricultural activities, produces a vast amount of crop residues, which are generally discarded, resulting in significant accumulation and cause pollution. Direct incorporation of crop residues into agricultural land to conserve soil nutrients, soil moisture and organic carbon content can cause considerable crop management problems. However, a long-term field experiment has confirmed that adding crop residues to agricultural land leads to a large increase in soil carbon stocks in the short term but minimal increase in the long term due to natural decay. In this regard, the study was conducted to assess the impact of conservation agricultural practice on biological properties of rhizosphere soil and yield of seed cotton during *kharif* 2018 and 2019.

MATERIAL AND METHODS

The field experiments were conducted at Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai. The experimental field is located in the southern agro-climatic zone of Tamil Nadu at 9°54' N latitude and 78°54' E longitude and at an altitude of 147 m above the MSL. A mean annual rainfall of 848 mm was received in 46 rainy days. The soil of the experimental site is clay loam with available 203.2, 16.7,419.6 kg NPK ha^{-1}, pH (8.0), Ec (0.37 dS m^{-1}) and organic carbon 0.48 per cent. The initial soil microbial population of bacteria, fungi and actinobacteria was 98.9 cfu g^{-1}, 16.7 cfu g^{-1} and 82.6 cfu g^{-1}

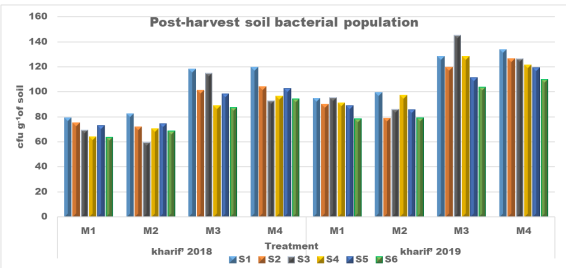

Figure 1. Effect of conservation agricultural practices on post-harvest soil bacterial population of cotton

The conventional tillage is comprised of one disc ploughing, two cultivator ploughing and one rotavator pass. Minimum tillage plots were prepared with the help of mulcher and one pass with disc harrow followed by one cultivator ploughing. The main and sub plots were formed with irrigation and drainage channels. The experiment was laid out in split-plot design with three replications. The main plot consisted of four treatments, conventional tillage with irrigation at 0.8 IW/CPE ratio (M_1), conventional tillage with irrigation at 0.6 IW/CPE ratio (M_2), minimum tillage with irrigation at 0.8 IW/CPE ratio (M_3), minimum tillage with irrigation at 0.6 IW/CPE ratio (M_4) and sub plot consisted of six treatments *viz.,* crop residue mulch with 100% RDF (S_1), crop residue mulch with 75% RDF (S_2) pre-emergence application of pendimethalin *fb* one hand weeding along with 100% RDF (S_3), pre-emergence application of pendimethalin *fb* one hand weeding along with 75% RDF (S_4), mechanical weeding twice with 100% RDF (S_5), mechanical weeding twice with 75% RDF (S_6). Cotton variety SVPR 4 was used in the study. Bacteria, fungal and actinobacteria populations were observed at pre and post-harvest sowing of seed cotton. These data were analyzed statistically by following Gomez and Gomez (2010).

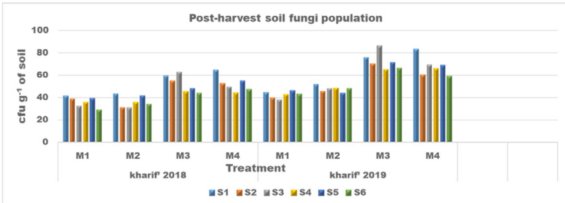

Figure 2. Effect of conservation agricultural practices on post-harvest soil fungal population of cotton

RESULTS AND DISCUSSION

Bacterial population

In the present study, the effect of different types of tillage, irrigation regimes, weed and nutrient management on the bacterial population of cotton rhizosphere soil was assessed and the results are given in Figure 1. Among the tillage practices and irrigation regimes, the total bacterial population was higher in minimum tillage practices with 0.6 IW/CPE ratio of irrigation (M_4) (101.7 × 10^6 cfu g^{-1} and 122.8 × 10^6 cfu g^{-1}) at post-harvest soil of cotton during the year 2018 and 2019 respectively. This result is at par with minimum tillage practices with irrigation at 0.8 IW/CPE ratio (M_3). Among the sub plot treatments, the total soil bacterial population at post-harvest soil of cotton was higher in crop residue mulch with 100 per cent RDF (S_1) during 2018 and 2019 (99.9 × 10^6 cfu g^{-1} and 114.0× 10^6 cfu g^{-1} respectively). This treatment was followed by pre-emergence application of pendimethalin *fb* one hand weeding along with application of 100 per cent RDF (S_3) during 2019. Among the treatment combinations soil the total bacterial population at post-harvest soil of cotton was higher (119.7×10^6 cfu g^{-1}) in minimum tillage practices with 0.6 IW/

CPE ratio irrigation with crop residue mulch with 100 per cent RDF (M_4S_1) during 2018, and it was followed by minimum tillage practices irrigation at 0.8 IW/CPE ratio with crop residue mulch along with application of 100 per cent RDF (M_3S_1) and minimum tillage with 0.8 IW/CPE ratio irrigation with pre-emergence application of pendimethalin *fb* one hand weeding along with application of 100 per cent RDF (M_3S_4). However, during 2019 bacterial population (145.2×10^6 cfu g^{-1}) was more in minimum tillage practices with irrigation at 0.8 IW/CPE ratio with pre-emergence application of pendimethalin *fb* one hand weeding along with application of 100 per cent RDF (M_3S_3).

Table 1. Effect of conservation agricultural practices on cost of cultivation, gross return, net return, benefit-cost ratio of cotton

Treatments	kharif' 2018				kharif' 2019			
	Cost of Cultivation (Rs ha^{-1})	Gross Return (Rs ha^{-1})	Net Return (Rs ha^{-1})	Benefit Cost Ratio	Cost of Cultivation (Rs ha^{-1})	Gross Return (Rs ha^{-1})	Net Return (Rs ha^{-1})	Benefit Cost Ratio
M_1S_1	41325	97146	55821	2.35	41325	99954	58629	2.42
M_1S_2	41325	74628	33303	1.81	41325	77004	35679	1.86
M_1S_3	46175	110106	63931	2.38	46175	113886	67711	2.47
M_1S_4	46175	90828	44653	1.97	46175	93690	47515	2.03
M_1S_5	43825	94284	50459	2.15	43825	97416	53591	2.22
M_1S_6	43825	91368	47543	2.08	43825	94122	50297	2.15
M_2S_1	40825	72792	31967	1.78	40825	75168	34343	1.84
M_2S_2	40825	62856	22031	1.54	40825	64854	24029	1.59
M_2S_3	45675	83700	38025	1.83	45675	86454	40779	1.89
M_2S_4	45675	73980	28305	1.62	45675	76302	30627	1.67
M_2S_5	43325	77112	33787	1.78	43325	79596	36271	1.84
M_2S_6	43325	76896	33571	1.77	43325	79164	35839	1.83
M_3S_1	39525	89208	49683	2.26	39525	91854	52329	2.32
M_3S_2	39525	87318	47793	2.21	39525	89802	50277	2.27
M_3S_3	44375	110916	66541	2.50	44375	114858	70483	2.59
M_3S_4	44375	96390	52015	2.17	44375	99522	55147	2.24
M_3S_5	42025	98010	55985	2.33	42025	101304	59279	2.41
M_3S_6	42025	93096	51071	2.22	42025	95904	53879	2.28
M_4S_1	39025	77922	38897	2.00	39025	80082	41057	2.05
M_4S_2	39025	85374	46349	2.19	39025	88128	49103	2.26
M_4S_3	43875	103950	60075	2.37	43875	107406	63531	2.45
M_4S_4	43875	92610	48735	2.11	43875	95472	51597	2.18
M_4S_5	41525	94176	52651	2.27	41525	97146	55621	2.34
M_4S_6	41525	82782	41257	1.99	41525	85158	43633	2.05

Fungal population

Results of the fungal population in cotton rhizosphere soil are given in Figure 2. Fungal population of soil was higher in minimum tillage practices with irrigation at 0.6 IW/CPE ratio (M_4). However, post-harvest soil of cotton recorded the higher fungal population in minimum tillage practices with irrigation at 0.8 IW/CPE ratio (M_3) during 2018 as well at 2019 (52.6×10^4 cfu g^{-1} and 72.5×10^4 cfu g^{-1}, respectively). Among the weed and nutrient management treatments, crop residue mulch with 100 per cent RDF (S_1) treatment showed a higher soil fungal population at post-harvest soil during both the years of field experimentation (52.5×10^4 cfu g^{-1} and 63.9×10^4 cfu g^{-1} in 2018 and 2019, respectively). This result did not significantly differ from pre-emergence application of pendimethalin *fb* one hand weeding along with application of 100 per cent RDF (S_3) during 2019 at post-harvest soil (60.5×10^4 cfu g^{-1}). Among treatment combination, minimum tillage practices with irrigation at 0.8 IW/CPE ratio with pre-emergence application of pendimethalin *fb* one hand weeding along with application of 100 per cent RDF (M_3S_3) recorded a higher fungal population at post harvest soil of cotton during 2019 (86.1 × 10^4 cfu g^{-1}) followed by minimum tillage with irrigation at 0.6 IW/CPE ratio and crop residue mulch along with application of 100 per cent RDF (M_4S_1). While in 2018 more fungal population was recorded in minimum tillage practices with irrigation at 0.6 IW/CPE ratio and crop residue mulch along with 100 per cent RDF (M_4S_1) (64.7 × 10^4 cfu g^{-1}). This treatment was followed by minimum tillage practices with irrigation at 0.8 IW/CPE and pre-emergence application of pendimethalin *fb* one hand weeding along with 100 per cent RDF (M_3S_3) (62.8 × 10^4 cfu g^{-1}). Conservation tillage can also influence soil suitability for the growth of crops (Hewins *et al*., 2017), promoting the formation of fungal hyphal networks, and leading to higher soil fungal population sizes (Gottshall *et al*., 2017).

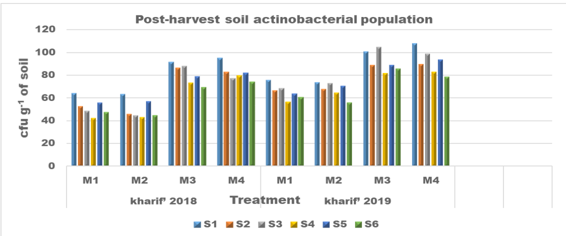

Figure 3. Effect of conservation agricultural practices on post-harvest soil actinobacterial population of cotton

Actinobacterial population

The results of the actinobacterial population are given in Figure 3. Among the main plot treatments, post-harvest soil (2018 and 2019) of cotton recorded higher (82.1 × 10^5 cfu g^{-1} and 92.0 × 10^5 cfu g^{-1}) actinobacterial population in minimum tillage practices with irrigation at 0.6 IW/CPE ratio (M_4) and was at par with minimum tillage practices with irrigating crop at 0.8 IW/CPE ratio (M_3). Among the different weed and nutrient management treatments, actinobacterial population was higher in crop residue mulch with 100 per cent RDF (S_1) during 2018 and 2019 with a value of 78.9 × 10^5 cfu g^{-1} and 89.9 × 10^5 cfu g^{-1}, respectively. This results did not statistically differ from the treatment of pre-emergence application of pendimethalin *fb* one hand weeding along with application of 100 per cent RDF (S_3) (86.6 × 10^5 cfu g^{-1}) during 2019. Among the treatment combination with respect of post-harvest soil of cotton, minimum tillage practices with irrigation at 0.6 IW/CPE ratio and crop residue mulch along with 100 per cent RDF (M_4S_1) treatment registered a higher actinobacterial population during 2018 and 2019 (95.4 × 10^5 cfu g^{-1} and 108.2 × 10^5 cfu g^{-1}, respectively). This was followed by minimum tillage practices with irrigation at 0.8 IW/CPE ratio and pre-emergence application of pendimethalin *fb* one hand weeding along with 100 per cent RDF (M_3S_3) during 2019. Similar to the present study, Li *et al*. (2020) reported an increase in soil bacteria, fungi, and actinobacteria counts in conservation tillage practices, which created favorable environmental conditions for microbial growth. Conservation tillage practices can influence the soil microclimate, the distribution and decomposition of crop residues, and the transformation of nutrients (Cheng *et al*., 2017); those factors, in turn, can alter soil microbial population size and diversity (Li *et al*., 2018). Minimum tillage causes less disturbance of the soil, creating a better environment for microbial growth, leading to increased C use efficiency and elevated activity levels of various extracellular enzymes (Sauvadet *et al*., 2018).

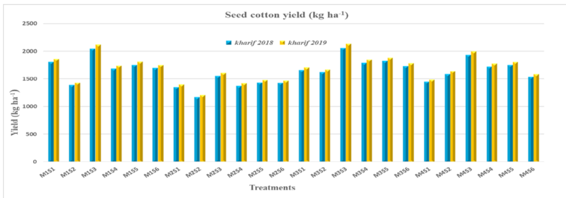

Figure 4. Effect of conservation agricultural practices on seed cotton yield (kg ha^{-1}) (kharif' 2018 and 2019)

Yield

Tillage is an important management practice involving physical manipulation of soil for crop establishment. Optimization of tillage practices leads to improvement in soil health. Soil health is a dynamic and complex system, and its functions are mainly mediated by agricultural management practices (Doran and Zeiss, 2000). In the current study, Figure 4 reveals that among the tillage practices and irrigation regimes, minimum tillage with irrigation at 0.8 IW/CPE ratio (M_3) recorded the highest seed cotton yield of 1774 and 1831 kg ha^{-1} during *kharif* 2018 and 2019, respectively. However, this treatment did not differ from the plots with conventional tillage and irrigation at 0.8 IW/CPE ratio (M_1). While conventional tillage combined with irrigation at 0.6 IW/CPE ratio (M_2) registered the lowest seed cotton yield of 1381 and 1425 kg ha^{-1} during *kharif* 2018 and 2019, respectively. Among weed and nutrient management practices, pre-emergence application of pendimethalin *fb* one hand weeding with 100 per cent RDF (S_3) recorded the highest seed cotton yield of 1892 and 1957 kg ha^{-1} during *kharif* 2018 and 2019, respectively. In addition, crop residue mulch with 75 per cent RDF (S_2) consistently recorded the lowest seed cotton yield (1436 and 1480 kg ha^{-1}). Among the treatment combination, minimum tillage with irrigation scheduling at 0.8 IW/CPE ratio combined with pre-emergence application of pendimethalin *fb* one hand weeding along with application of 100 per cent RDF registered the highest yield of 2054 and 2127 kg ha^{-1} during *kharif* 2018 and 2019 (M_3S_3), respectively. This treatment was at par with conventional tillage and irrigation at the 0.8 IW/CPE ratio combined with pre-emergence application of pendimethalin fb one hand weeding and 100 percent RDF (M_1S_3). The lowest seed cotton yield was observed with conventional tillage and irrigation at a 0.6 IW/CPE ratio along with crop residue mulch and 75 percent RDF (M_2S_2) with a seed cotton yield 1164 and 1201 kg ha^{-1} during *kharif* 2018 and 2019, respectively). Similar to the present study, Mutonga *et al.,* (2019) also reported a higher grain yield in wheat under conservation tillage than conventional agricultural practices by conserving more moisture.

Economics

Yield and cost of cultivation are the prime factors for determining the economic efficiency and viability of a crop. Higher crop productivity with minimum cost of cultivation resulted in higher net returns and B: C ratio.

Conservation agricultural practices showed variation with the cost of cultivation, net income and benefit cost ratio (Table 1). The cost of cultivation was less under minimum tillage practices and irrigating the crop at 0.8 IW/CPE ratio and pre-emergence application of pendimethalin *fb* one hand weeding along with application of 100 per cent RDF (M_3S_3) due to reduced labor requirement and machinery usage. While, conventional tillage practices increased the cost of cultivation.

During the *kharif* season in both the years *i.e.,* 2018 and 2019, higher gross return, net return and B:C ratio of 110916, 66541, 2.50, 114858, 70483 and 2.59, respectively, were observed with minimum tillage practices and irrigating the crop at 0.8 IW/CPE ratio and pre-emergence application of pendimethalin *fb* one hand weeding along with application of 100 per cent RDF (M_3S_3) followed by the treatment of conventional tillage and irrigation at 0.8 IW/CPE ratio and pre-emergence application of pendimethalin *fb* one hand weeding along with 100 per cent RDF (M_1S_3). Singh and Meena (2018) also stated that the higher B:C ratio was observed with conservation agriculture than conventional agriculture.

CONCLUSION

Based on the experimental results,, minimum tillage practices with irrigation at 0.8 IW/CPE ratio and pre-emergence application of pendimethalin fb hand weeding along with 100 per cent RDF recorded higher soil microbial population, seed cotton yield, gross return, net return and benefit-cost ratio. Hence, the above treatment can be recommended as the best conservation management practices for the farmers in the southern states of India.

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