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Effects of tillage practices and sources of nutrients on soil microbial population and grain yield of finger millet (*Eleusine coracana* L.)

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Abstract
A field experiment on ‘Effect of Tillage Practices and Sources of nutrients on soil Microbial population and Grain yield of finger millet (*Eleusine coracana* L.)’ conducted at Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai during 2018-19 and 2019-20. The experiment laid out in a split-plot design with replicated thrice. The experiment consisted of three main plot treatments *viz*., Conventional tillage (T_1), Minimum tillage (T_2), and Plough sole tillage (T_3) and subplot has six treatments with different sources of nutrients *viz*., Farm Yard Manure + biofertilizer (O_1), Vermicompost + biofertilizer, (O_2), Goat manure + biofertilizer (O_3), Poultry manure + biofertilizer (O_4), Press mud + biofertilizer (O_5) and control (100% RDF) (O_6). The total microbial population *viz*., bacteria, fungi, and actinomycetes was found higher in the main plot treatment of minimum tillage (T_2) during first year and were comparable with conventional tillage (T_1) during second year. In the subplot, vermicompost + biofertilizer (O_2) recorded a higher microbial population followed by poultry manure + biofertilizer (O_4) during first year and was comparable with poultry manure + biofertilizer (O_4) during second year. Among the treatment combinations, the minimum tillage with vermicompost + biofertilizer (T_2O_2) recorded a higher microbial population during first year and was comparable with minimum tillage combination with poultry manure + biofertilizer (T_2O_4) during second year. Higher yield of finger millet recorded with conventional tillage with 100% RDF as control (T_1O_6) during first year and was comparable with minimum tillage combination with poultry manure + biofertilizer (T_2O_4) during second year. Even as the conventional tillage practice with 100% RDF as control recorded higher yield. The holistic approaches of minimum tillage combination with poultry manure + bio fertilizer (T_2O_4) can be recommended as best practice to the farmers.

Keywords: Finger millet yield, microbial population, sources of nutrients, tillage practices

Introduction

Conservation tillage is a concept evolved to respond to the concerns of sustainability of agriculture (FAO, 2012) [9]. This resource-saving agricultural production system aims to achieve high and sustaining yields. It would 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) [1]. Traditional agriculture involves intensive tillages and responsible for soil erosion problems, surface and underground water pollution, and more consumption of irrigation water (Wolff and Stein, 1998) [25]. Moreover, implicated land resource degradation, low energy efficiency and contributes to global warming (Boatman *et al*., 1999) [5]. Hence, the conservation tillage 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 beneficial impacts on the global environment as compared to traditional agriculture (Derpsch *et al*., 2010) [7].

Soil harbors a dynamic population of microorganisms, which play a major role in the decomposition of organic matter and the transformation of plant nutrients. The availability of organically bound nitrogen through a transformation in the soil to the plant mainly depends on the population of microorganisms, which influenced by the application of organic manure. The microbial biomass, which is the total mass of bacteria, fungi, actinomycetes present in the soil, serves as a temporary sink for nutrients including nitrogen and it considered as an index of soil fertility. The factors like cropping system, manure application, etc., affect the soil microbial growth, activity, and diversity.

Microbial biomass carbon and enzyme activity increases with the continuous application of organic manure (Zhao *et al.*, 2016) [26]. Enzymes are important soil components involved in the dynamics of soil nutrient transformations and enzyme activity considered a major contributor to overall soil microbial activity. Microorganisms and their mediated processes can give an integrated measure of soil health. It also plays an important role in organic matter decomposition and the dynamics of nutrient transformations in the soil. The addition of organic manures significantly increases the urease, alkaline phosphatase and dehydrogenase activity in the soil as compared to chemical fertilizers. Hence, the present investigation was taken up to develop the soil microorganism and maintains soil quality for sustainable productivity of finger millet.

Material and Methods

A field experiment conducted at Department of Agronomy, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai to investigate the effect of tillage practice and sources of nutrients on the soil microbial population and grain yield of finger millet. The experimental field is located in the Southern agro-climatic zone of Tamil Nadu at 9º 54' N latitude and 78º 54' E longitude and an altitude of 147 m above MSL. A mean annual rainfall is 848 mm and distributed on 46 rainy days. The soil of the experimental site is clay loam in texture with 220.6:11.5: 308.4 kg available soil N: P_2O_5: K_2O ha^{-1}. The pH of the soil was 7.9 with EC of 0.52 dS m^{-1} and with 0.48 per cent soil organic carbon. Initial soil microbial population of bacteria, fungi, and actinomycetes was 98.9 CFU g^{-1}, 16.7 CFU g^{-1} and 80.6 CFU g^{-1} of soil. The Tillage and nutrient sources formed as main and sub-plots. The experiment laid out in a split-plot design with three replications. The three tillage practices was consisted in main plot treatment *viz.*, T_1- Conventional tillage (Mould board plough + cultivator + rotavator once each), T_2 - Minimum tillage (cultivator + rotavator once each) and T_3 - Plough sole tillage (using country plough once) and the subplot treatments consisted of six sources of nutrients *viz.*, O_1 - FYM + biofertilizer, O_2-Vermicompost + biofertilizer, O_3- Goat manure + biofertilizer (S_3), O_4 -Poultry manure + biofertilizer, O_5 - Press mud + biofertilizer and O_6 - Control (100% RDF). Finger millet variety CO 15 was used for the study. Bacteria, fungi, and actinomycetes populations were observed at pre and post-harvest sowing of finger millet. Soil samples collected from each treatment after harvesting crop and stored at the temperature of 4º C for estimation of microbial population. One gram of soil was serial diluted to 10^6, 10^3 and 10^4 for bacterial, fungi and actinomycetes, respectively. These data analyzed statistically by following Gomez and Gomez (1984) [10]. Treatment differences were found significant (F test), critical differences worked out at a five percent probability level and the values were furnished.

Table 1: Analytical methods employed in microbial analysis

Parameters	Method	Reference
Total bacteria	Serial dilution method using Nutrient Agar medium	Allen (1953) [2]
Total fungi	Serial dilution method using Rose Bengal Agar medium	Martin (1950)[19]
Total actinomycetes	Serial dilution method using Ken knights Agar medium	Allen (1953) [2]

Table 2: Composition of organic manures used in the experiment

Organic manure	2018-2019		2019-2020	
	N (%)	Quantity used(t/ha)	N (%)	Quantity used(t/ha)
Farm yard manure	0.50	12.00	0.51	12.00
Vermicompost	1.50	4.00	1.52	4.00
Goat manure	2.81	2.13	2.90	2.06
Poultry Manure	2.96	2.02	2.98	2.01
Press mud	2.35	4.13	2.30	4.08
100% RDF	60:30:30 kg NPK ha^{-1}		60:30:30 kg NPK ha^{-1}	

Results and Discussion

Effect of tillage practices and sources of nutrients on post - harvest soil Bacterial population of finger millet

In the present study, the effect on tillage practices and sources of nutrients on the bacterial population of rhizosphere soil of finger millet assessed and the results are given in figure 1. Among the tillage practices, minimum tillage (T_2) recorded a higher total bacterial population (58.74 x 10^{-6} and 95.37 x 10^{-6} CFU g^{-1}) at post-harvest soil during 2018-19 and 2019-20 respectively and this followed by conventional tillage (T_1) during 2018-2019 and was on par with the above treatment during 2019-20. Lower total bacteria population of 41.42 x 10^{-6} and 73.79 x 10^{-6} CFU $g^{-1}$was recorded under plough sole tillage (T_3) at post-harvest soil during 2018-19 and 2019-20 respectively. The favourable effect of reduced tillage on soil microbial population are mainly due to increased soil aeration, cooler and wetted condition, lower temperature and moisture, fluctuation and higher carbon contents in surface soil (Verhulst *et al.*, 2011) [24]. Therefore, a shift in micro flora population significantly influences the maintenance of soil fertility and productivity owing to the faster rate of decomposition and mineralization of organic materials. Similar findings were reported by Biederbeck *et al.*, (2005) [3].

Table 3: Effect of tillage practices and sources of nutrients on post - harvest soil Bacterial population of finger millet

Treatment	Total bacterial population (CFU/g of soil)							
	2018-2019				2019-2020			
	T1 – Conventional tillage	T2 – Minimum tillage	T3 - Plough sole tillage	Mean	T1 – Conventional tillage	T2 – Minimum tillage	T3 - Plough sole tillage	Mean
O1 - FYM + Bio fertilizer	52.60	64.03	45.41	54.01	101.20	103.12	85.58	96.63
O2 - Vermicompost + Bio fertilizer	65.20	70.65	56.08	63.97	105.31	107.41	89.79	100.83
O3 - Goat manure + Bio fertilizer	43.26	55.54	36.32	45.04	90.40	92.58	63.75	82.24
O4 - Poultry manure+ Bio fertilizer	53.76	65.96	46.60	55.44	103.34	105.42	87.77	98.84
O5 - Press mud+ Bio fertilizer	42.09	54.42	35.15	43.89	88.59	90.51	61.27	80.12
O6 – Control (100% RDF)	34.73	42.58	28.95	35.42	71.17	73.31	54.57	66.35
Mean	48.61	58.86	41.42	-	93.33	95.39	73.79	-
	T	O	T x O	O x T	T	O	T x O	O x T
SEd	2.17	0.96	2.45	1.66	2.58	1.72	3.75	2.98
CD(p=0.05)	4.84	1.96	5.37	3.40	5.75	3.51	7.95	6.08

Regarding sources of nutrients, application of vermicompost + biofertilizer (O_2) recorded a higher total bacterial population of 64.23 x 10^6 and 100.87x 10^6 CFU g^{-1} at post-harvest soil. This was followed by the application of poultry manure + biofertilizer (O_4) during 2018-19 and comparable during 2019-20. Significantly lower total bacterial population of 35.42 x 10^6 and 66.35 x 10^6 CFU g^{-1} of soil noticed under application of 100% RDF as control (O_6) at post-harvest soil during both years. The bacterial populations were significant enhanced in the treatment irrespective of organic sources. Biswas *et al.* (2017) [4] ascribed higher bacterial count to the positive effects of manure by providing nutrients for the growth of microbes directly or indirectly by stimulating plant growth and enhancing root carbon flow. Also, the organic manures show superiority in enriching the richness and diversity of soil bacteria (He *et al*., 2008) [12] due to enhanced soil microbial biomass and activities of organic-treated soils (Islam *et al.*, 2011) [15].

The interaction effect between tillage practices and sources of nutrients found to be significant in post-harvest soil. The minimum tillage in combination with vermicompost + biofertilizer (T_2O_2) registered a higher total bacterial population of 70.65 x 10^6 and 107.41 x 10^6 CFU g^{-1} at post-harvest soil during 2018-19 and 2019-20, respectively and this was followed by minimum tillage combination with poultry manure + biofertilizer (T_2O_4) during 2018-19 and was comparable with the above treatment during 2019-20. The lower total bacterial population of 28.95 x 10^6 and 54.57 x 10^6 CFU g^{-1} of soil recorded under, plough sole tillage in combination with 100% RDF as control (T_3O_6) during 2018-19 and 2019-20, respectively.

Effect of tillage practices and sources of nutrients on post - harvest soil Fungi population of finger millet

Among tillage practices, minimum tillage (T_2) recorded a higher total fungi population (36.58 x 10^{-5} and 76.17 x 10^{-5} CFU g^{-1}) at post-harvest soil during 2018-19 and 2019-20 respectively and this followed by conventional tillage (T_1) during 2018-19 and was on par with the above treatment during 2019-20. The lower total fungi population of 25.79 x 10^{-5} and 58.93 x 10^{-5} CFU $g^{-1}$was recorded under plough sole tillage (T_3) at post-harvest soil during both years. Conservation tillage can also influence soil suitability for the growth of crops (Hewins *et al*., 2017) [13], promoting the formation of fungal hyphal networks, and leading to higher soil fungal population sizes (Gottshall *et al*., 2017) [11].

Regarding the source of nutrients, the application of vermicompost + biofertilizer (O_2) recorded a higher total fungi population of 39.99 x 10^{-5} and 80.56 x 10^{-5} CFU g^{-1} post-harvest soil during 2018-19 and 2019-20 respectively. This was followed by the application of poultry manure + biofertilizer (O_4) during 2018-19 and comparable during 2019-20. The lower total fungi population of 22.06 x 10^{-5} and 52.99 x 10^{-5} CFU g^{-1} of soil was noticed fewer than 100% RDF as control (O_6) at post-harvest soil during both years. Ingle *et al*., (2014) [14] reported an increase in the fungal population with the addition of organics since most of these organisms are chemo heterotrophs, which require organic sources of carbon as food, and oxidation of organic substances provides energy, thereby increasing their population.

Table 4: Effect of tillage practices and sources of nutrients on post - harvest soil Fungi population of finger millet (Table. 4)

Treatment	Total fungi population (CFU/g of soil)							
	2018-2019				2019-2020			
	T1 – Conventional tillage	T2 – Minimum tillage	T3 - Plough sole tillage	Mean	T1 – Conventional tillage	T2 – Minimum tillage	T3 - Plough sole tillage	Mean
O1 - FYM + Bio fertilizer	32.75	39.87	28.28	33.63	80.82	82.36	68.35	77.18
O2 - Vermicompost + Bio fertilizer	40.60	43.99	34.92	39.84	84.10	85.78	71.71	80.53
O3 - Goat manure + Bio fertilizer	26.94	34.59	22.62	28.05	72.20	73.94	50.92	65.68
O4 - Poultry manure+ Bio fertilizer	33.48	41.07	29.02	34.52	82.54	84.19	70.10	78.94
O5 - Press mud+ Bio fertilizer	26.21	33.89	21.89	27.33	70.75	72.29	48.93	63.99
O6 – Control (100% RDF)	21.62	26.52	18.03	22.06	56.84	58.55	43.58	52.99
Mean	30.27	36.65	25.79	-	74.54	76.18	58.93	-
	T	O	T x O	O x T	T	O	T x O	O x T
SEd	0.97	0.49	1.25	0.86	1.98	1.28	2.83	2.21
CD(p=0.05)	2.17	1.01	2.70	1.76	4.41	2.61	6.01	4.52

The interaction effect between the tillage practices and sources of nutrients found to be significant in influencing the fungi population at post-harvest soil. The minimum tillage combination with the application of vermicompost + biofertilizer (T_2O_2) registered a higher total fungi population of 43.99 x 10^{-5}, and 85.78 x 10^{-5} CFU g^{-1} at post-harvest soil during 2018-19 and 2019-20 respectively, this was followed by minimum tillage with combination of poultry manure + biofertilizer (T_2O_4) during 2018-19 and was comparable with the above treatment during 2019-20. The lower total fungi population is 18.03 x $10^{-5}$and 43.58 x 10^{-5} CFU g^{-1} of soil recorded under plough sole tillage combination with 100% RDF as control (T_3O_6) during 2018-19 and 2019-20 respectively.

Effect of tillage practices and sources of nutrients on post - harvest soil Actinomycetes population of finger millet

Among tillage practices, minimum tillage (T_2) recorded a higher total actinomycetes population (50.36 x 10^{-3} and 81.51 x 10^{-3} CFU g^{-1}) at post-harvest soil during 2018-19 and 2019-20 respectively. This followed by conventional tillage (T_1) during 2018-19 and was on par with the above treatment during 2019-20. The lower total actinomycetes population of 35.51 x 10^{-3} and 63.07 x 10^{-3} CFU g^{-1} recorded under plough sole tillage (T_3) at post-harvest soil during 2018-19 and 2019-20. Similar to the present study, Li *et al*., (2020) [18] reported an increase in soil bacteria, fungi, and actinomycetes 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) [6]; those factors, in turn, can alter soil microbial population size and diversity (Li *et al*., 2018) [17]. 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) [22].

Regarding the source of nutrients, the application of vermicompost + biofertilizer (O_2) recorded a higher total actinomycetes population of 55.07 x 10^{-3} and 86.21 x 10^{-3} CFU g^{-1} of soil at post-harvest soil. This followed by the application of poultry manure + biofertilizer (O_4). The lower total actinomycetes population of 30.37 x 10^{-3} and 56.71 x 10^{-3} CFU g^{-1} of soil was recorded noticeably fewer than 100% RDF as control (O_6) at post-harvest soil during both years. The increased microbial population may be because organic manure provided necessary food and microenvironment for their quicker multiplication and growth (Kumari and Kumari, 2002) [16]. This could be ascribed to the organic sources which supplied a large amount of readily available carbon, resulting in a more diverse and dynamic microbial system. Soil enzymatic activities increased as the soil microbes degrade organic matter through the production of diverse extracellular enzymes, after the application of vermicompost to soils (Tejada and Gonzalez, 2008) [23]. This may attributed to a higher amount of growth-promoting substances, vitamins, and enzymes that in turn increased the microbial population and root biomass production.

The interaction effect between tillage practices and sources of nutrients found to be significant in enhancing post-harvest soil. The minimum tillage in combination with the application of vermicompost + biofertilizer (T_2O_2) registered a higher total actinomycetes population of 60.57 x 10^{-3} and 91.80 x 10^{-3} CFU g^{-1} of soil at post-harvest soil during 2018-2019 and 2019-2020 respectively. This followed by minimum tillage combination with poultry manure + biofertilizer (T_2O_4) during 2018-2019 and was comparable with the above treatment during 2019-20. The lower total actinomycetes population of 24.82 x 10^{-3} and 46.64 x 10^{-3} CFU g^{-1} of soil recorded under plough sole tillage combination with 100% RDF as control (T_3O_6) during 2018-19 and 2019-20 respectively.

Table 5: Effect of tillage practices and sources of nutrients on post - harvest soil Actinomycetes population of finger millet

Treatment	Total actinomycetes population (CFU/g of soil)							
	2018-2019				2019-2020			
	T1 – Conventional tillage	T2 – Minimum tillage	T3 - Plough sole tillage	Mean	T1 – Conventional tillage	T2 – Minimum tillage	T3 - Plough sole tillage	Mean
O1 - FYM + Bio fertilizer	45.09	54.89	38.93	46.31	86.49	88.13	73.15	82.59
O2 – Vermicompost + Bio fertilizer	55.90	60.57	48.08	54.85	90.01	91.80	76.74	86.18
O3 – Goat manure + Bio fertilizer	37.09	47.62	31.14	38.62	77.26	79.13	54.49	70.29
O4 - Poultry manure+ Bio fertilizer	46.09	56.55	39.95	47.53	88.33	90.10	75.01	84.48
O5 - Press mud+ Bio fertilizer	36.09	46.66	30.13	37.63	75.72	77.36	52.37	68.48
O6 – Control (100% RDF)	29.77	36.51	24.82	30.37	60.83	62.66	46.64	56.71
Mean	41.67	50.47	35.51	-	79.77	81.53	63.07	-
	T	O	T x O	O x T	T	O	T x O	O x T
SEd	1.26	0.74	1.72	1.28	1.98	1.19	2.73	2.06
CD(p=0.05)	2.81	1.52	3.68	2.63	4.43	2.43	5.84	4.21

Effect of tillage practices and sources of nutrients on grain yield of finger millet

Tillage is an important management practice involving the 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 mainly mediated by agricultural management practices (Doran and Zeiss, 2000) [8]. Among the tillage practices, the conventional tillage (T_1) registered significantly highest grain yield of 2337 and 2535 kg ha^{-1} during 2018-19 and 2019-20 respectively. This followed by minimum tillage (T_2) during 2018-19 and was on par with the above treatment during 2019-20. The lowest grain yield of 1648 and 1961kg ha^{-1} recorded under plough sole tillage (T_3) during 2018-19 and 2019-20 respectively.

In the sources of nutrients, application of 100% RDF as control (O_6) recorded the highest grain yield of 2556 and 2679 kg ha^{-1} during 2018-19 and 2019-20 respectively. This followed by poultry manure + biofertilizer (O_4) during 2018-19 and was comparable with the above treatment during 2019-20. Though, as there was increased grain yield of 100% RDF and it was found to give reduced microbial population than poultry manure + biofertilizer (O_4), that will not give a long term effect in improving soil health which is essential for sustaining the production and productivity of crops that can be accomplished by the poultry manure + biofertilizer it ranked next to 100% RDF in record yield. Improvement in yield attributes could be due to higher quantity of macro and micronutrients added to soil in the form of organic sources resulting in increased availability of nutrients in root zone thus more uptakes by crop resulting in higher values of yield attributing characters. These results conform to the result of Poornesh *et al.*, (2004) [21]. The lowest grain yield (1409 and 1763 kg ha^{-1}) recorded under application FYM + biofertilizer (O_1) during both years.

Interaction effect between tillage practices and sources of nutrients was not significant on grain yield with the first-year experiment during 2018-2019 and was found significant during 2019-20. The combination of conventional tillage with 100% RDF as a control (T_1O_6) was registered with the highest grain yield of 2854 kg ha^{-1} during 2019-20. This was comparable with minimum tillage in combination with poultry manure (T_2O_4) (2798 kg ha^{-1}). The lowest grain yield (1450 kg ha^{-1}) was recorded under plough sole tillage combined with FYM + biofertilizer (T_3O_1) during 2019-20. Similar to the present study, Mutonga *et al.*, (2019) [20] reported a higher grain yield in wheat under conservation tillage than conventional practices by conserving more moisture.

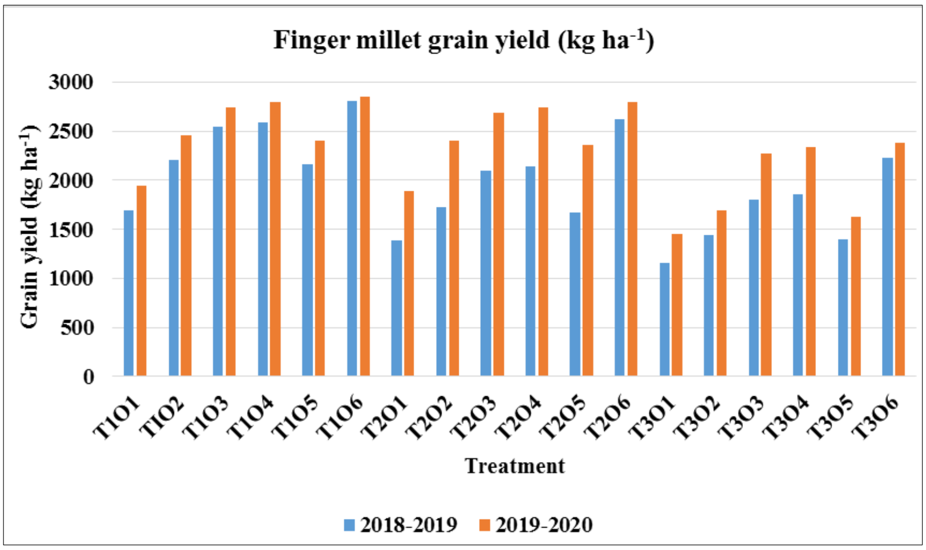

Fig 1: Effect of tillage practices and sources of nutrients on grain yield of finger millet

Conclusion

As per the results obtained from the experiment it concluded that the practice of minimum tillage is best management is enhancing the microbial population compared to conventional tillage even though it registered higher yield. Even though, this cannot be sustain with long-term effect due to reduced microbial population recoded in this practice. The different sources of nutrients, the organic sources of vermicompost recorded with more populations that are microbial. However, it recorded with a lesser grain yield over poultry manure. It found to be the next best source in recording the microbial population. Taking into account of above results, the combination of minimum tillage and poultry manure + biofertilizer by the organic source will be the best option to sustain the grain yield with long-term effects besides improving soil health in finger millet.

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