www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(12): 1463-1467

www.thepharmajournal.com
Received: 12-09-2021
Accepted: 23-11-2021

Naveen Kumar A
Department of Environmental Sciences, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

G Balasubramanian
Department of Environmental Sciences, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

M Maheswari
Department of Environmental Sciences, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

K Iyanar
Department of Millets, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Corresponding Author:
G Balasubramanian
Department of Environmental Sciences, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Soil micro-biota and soil enzyme changes in the pearl millet cultivated soil under paperboard mill treated effluent irrigation

Naveen Kumar A, G Balasubramanian, M Maheswari and K Iyanar

Abstract
The paperboard mill treated effluent on land as irrigation water and a source of plant nutrients resolving disposal issues. In the present study, the pearl millet irrigated with well water, treated paperboard mill effluent as flood and drip irrigation added with amendment of effluent treatment plant (ETP) sludge and vermicompost ETP sludge. The soil microbiota, soil enzymes and yield attributes of pearl millet were studied under various treatments. Among all the treatments, soil application of ETP sludge vermicompost @5 t ha^{-1} along with treated effluent through drip irrigation (T_8) showed that higher bacterial (29.49 × 10^6 CFU ml^{-1}), fungal (15.50 × 10^4 CFU ml^{-1}) and actinomycetes (9.75 × 10^2 CFU ml^{-1}) population at harvest stage. Correspondingly, soil enzyme activity showed higher range of 103.29 µg of NH_4-N released g^{-1} of soil h^{-1}, 46.67 g PNPP g^{-1} of soil, 61.64 µg TPF g^{-1} of soil for soil urease, phosphatase and dehydrogenase, respectively at harvest stage. The grain yield of 3.45 tonnes/ha and green fodder yield of 178.54 Kg/ha for paperboard mill effluent added with vermicompost sludge (T_8) supplied pearl millet. The higher range of microbial population and enzyme activity in T_8 was associated with the presence of organic matter and adequate nutrient flow. The addition of vermicompost sludge improved the soil microbial activity which induces the soil enzyme. Hence, the soil application of ETP sludge vermicompost @5 t ha^{-1} along with treated effluent through drip irrigation significantly improved the soil health which also increased the yield of the pearl millet.

Keywords: Paper board mill effluent, soil biota, soil enzyme, pearl millet

Introduction
In India, the industries have contributed to rise in economic growth in recent decades but they have also wreaked havoc on the environment by producing massive amounts of solid waste and effluent. There are over 600 paper mills in India with an annual output capacity of 8.5 million tonnes of paper. Since, fresh water availability for agriculture is depleting at a faster rate, wastewater reuse in agriculture is predicted to skyrocket in upcoming years. Paperboard mill industry discharges 300 m^3 of effluent per tonne of paper produced. The use of wastewater for irrigation and source of plant nutrients is gaining momentum (Udhayasooriyan and ponmani, 2009). Soil biota are an important component of agroecosystems, playing an important role in ecosystem services such as nutrient capture and cycling, building and controlling soil organic matter (SOM), soil physical structure, and vegetation dynamics, all of which have a synergistic effect on crop yield. Plant-soil feedbacks mediated by soil biota are involved in signaling processes (Soil enzymes) that contribute to the integrity of the agroecosystems and sustain crop production (Ponge *et al.*, 2013) [8]. To estimate the possible influence of soil management and environmental changes on ecosystem, it is vital to understand the interaction between distinct enzyme pools.
Pearl millet (*Pennisetum glaucum*) is the sixth most important cereal crop in the world and the fourth most important tropical grain. Low-input, rainfed agriculture practices are favorable for pearl millet cultivation which is predominant in India. The pearl millet area, production and productivity in India is about 6.93 million ha., 8.61 million tonnes, production- 1243 kg/ hectare as per the 2018-2019 report (Agricultural statistics at a glance, 2019) [1]. Keeping this in mind, the suitability of paperboard mill treated effluent for cultivation of pearl millet was studied. In order to check for soil quality, soil nutrient and micro-biota characteristics were monitored for the entire period of cultivation.

Material and Methods
An experiment was carried out at Thekkampatti village, Mettupalayam taluk, Coimbatore district, Tamil Nādu with the experimental layout of split-split plot design having eight

treatments and four replications with pearl millet Co-10 as a test crop. The Co-10 is a recently released variety mainly for drought resistant and high yielding. Treatments comprised of three main factors with two levels in each factor *viz*., Factor 1: Source of irrigation (I_1- well water, I_2- Treated effluent), Factor 2: Method of irrigation (M_1- Flood irrigation, M_2 – Drip irrigation) and Factor 3: Sludge application (S_1- ETP sludge compost at 5t ha^{-1}, S_2- vermicompost ETP sludge at 5 t ha^{-1}) (ETP - Effluent Treatment Plant) and the treatment combinations were $I_1M_1S_1$, $I_1M_1S_2$, $I_1M_2S_1$, $I_1M_2S_2$, $I_2M_1S_1$, $I_2M_1S_2$, $I_2M_2S_1$ and $I_2M_2S_2$. The amendments mentioned in the treatment were applied before planting and the study was conducted during the year 2020-2021. In each replication, plants were grown on a plot of 4 m x 4 m size, accommodating12 plants with a row to row spacing of 45cm and plant to plant spacing of 15cm. All the intercultural operations were carried out as per the recommended package of practices. In each treatment and replication, 5 plants and soil were randomly taken for the analysis. The enumeration of soil microbes was procedures given by Waksman and Fred (1922) [14]. The soil enzymes ie., urease (Kandeler and Gerber, 1988) [3], dehydrogenase (Thalmann, 1968) [12] and phosphatase (Tabatabai and Bremner, 1969) [11] were analysed. The yield attributes were recorded i.e., 1000 grain weight, Grain yield, green fodder yield and plant height.

Results and Discussion

Soil microbes

The details of bacterial population in the experimental field are given in Figure 1. Considering all the treatments, the mean bacterial population ranged from 14.75 and 7.75 x 10^6 CFU g^{-1} of soil, 27.50 to 15.50 x 10^6 CFU g^{-1} of soil and 29.49 to 17.61 x 10^6 CFU g^{-1} of soil for the corresponding vegetative, flowering and harvest stages of the pearl millet. The bacterial population was high under treated effluent irrigation than the well water irrigation. Also, the vermicompost ETP sludge applied field showed higher bacterial population compared to the ETP sludge applied field. Among the treatments, T_8 - $I_2M_2S_2$ was observed to have high soil bacterial population of 29.49 x 10^6 CFU g^{-1} followed by the treatment T_6 - $I_2M_2S_2$ (24.94 x 10^6 CFU g^{-1}) and the least population of 17.615 x 10^6 CFU g^{-1} was reported in T_1 – $I_1M_1S_1$ at harvest stage. The higher range of bacterial population in T_8 might be due to the prevalence of adequate amount of nutrients and organic matter supplied to the field through effluent irrigation (Elayarajan *et al.*, 2009) [15]. The fungal population in the experimental field are detailed in figure 2. The mean fungi population were ranged from 8 to 2.50 x 10^4 CFU g^{-1} of soil, 11 to 5.75 x 10^4 CFU g^{-1} of soil and 15.50 to 7.00 x 10^4 CFU g^{-1} of soil for the vegetative, flowering and harvest stages of the pearl millet. The fungal population was higher in the treated effluent irrigation soil than the well water irrigation soil. In comparison with the ETP sludge applied field, the vermicompost ETP sludge applied field showed higher bacterial population in the soil. Among the treatments, T_8 - $I_2M_2S_2$ was observed to have high soil fungal population of 15.50 x 10^4 CFU g^{-1} followed by the treatment T_7 - $I_2M_2S_1$ (13.5 x 10^4 CFU g^{-1}) and the least population of 7.00 x 10^4 CFU g^{-1} in T_1 – $I_1M_1S_1$ at harvesting stage of the pearl millet. The addition of organics from effluent led to increase in soil temperature, soil moisture availability and humus content which might have increased the microbial fungi population (Udayasooriyan and Ponmani, 2009). The actinomycetes population in the experimental field are shown in figure 3. The average fungal population ranged from 3.50 and 0.75 x 10^2 CFU g^{-1} of soil, 6.25 to 3 x 10^2 CFU g^{-1} of soil and 9.75 to 4.75 x 10^2 CFU g^{-1} of soil were observed during the vegetative, flowering and harvest stages of the pearl millet. Also, the actinomycetes population was higher in the treated effluent irrigation than the well water irrigation. Compared to the ETP sludge applied field, the vermicompost ETP sludge applied field showed higher soil bacterial population. The treatment T_8 - $I_2M_2S_2$ was observed to have high soil actinomycetes population of 9.75 x 10^2 CFU g^{-1} followed by the treatment T_7 - $I_2M_2S_1$ (8 x 110^2 CFU g^{-1}) and the least population of 4.75 x 10^2 CFU g^{-1} in T_1 – $I_1M_1S_1$ at harvesting stage of the pearl millet. The increased organic matter and other nutrients influenced the multiplication and sustenance of microbes in T_8 followed by other treatments.

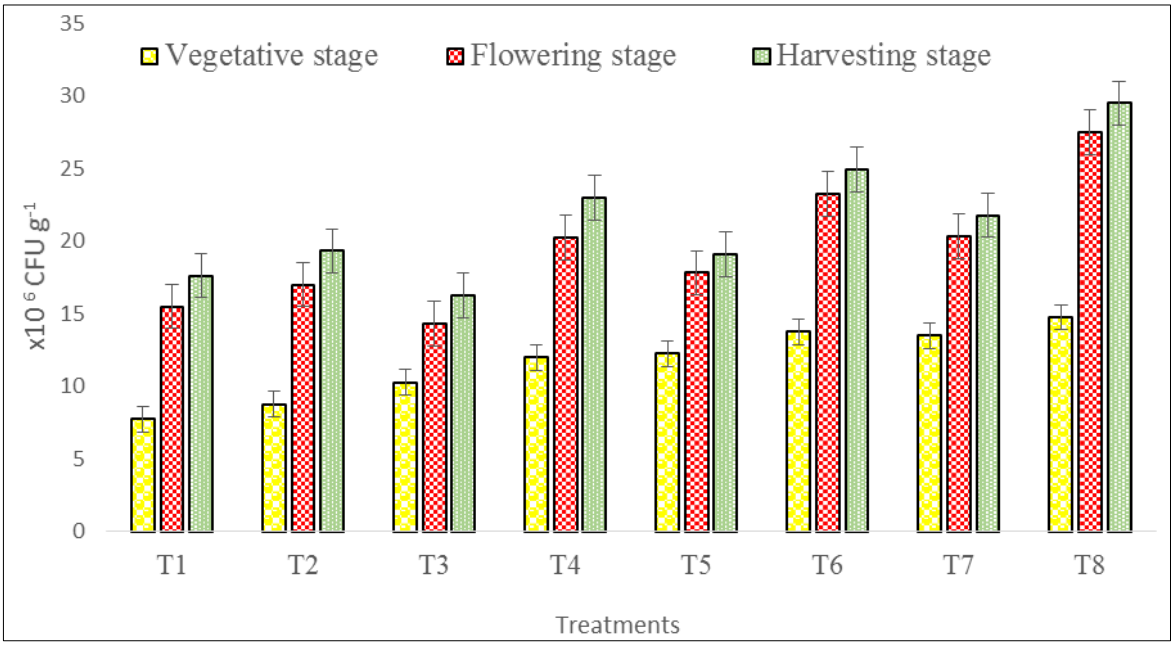

Fig 1: Effect of well water, paper board mill treated effluent and vermicompost ETP sludge on Soil bacteria

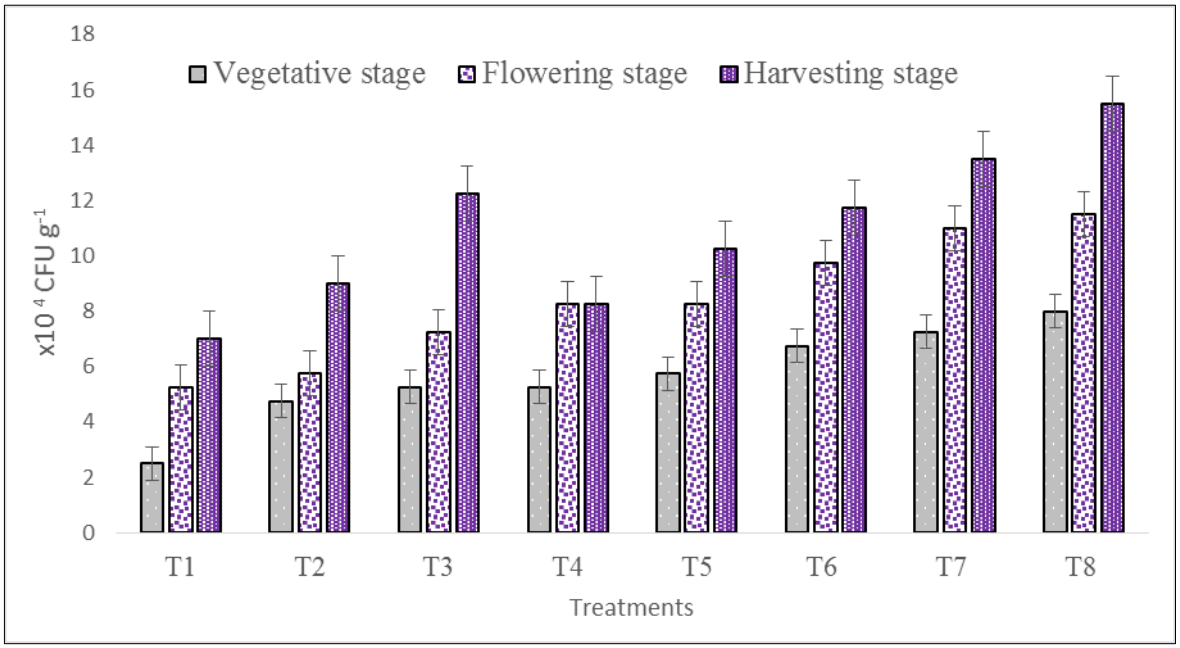

Fig 2: Effect of well water, paper board mill treated effluent and vermicompost ETP sludge on soil fungi actinomycetes

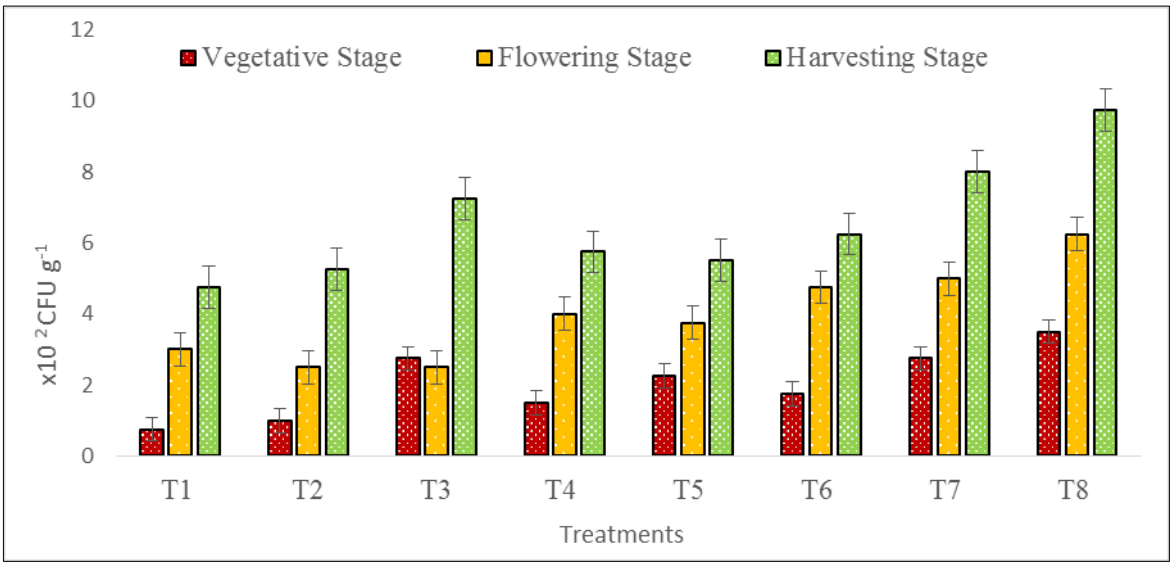

Fig 3: Effect of well water, paper board mill treated effluent and vermicompost ETP sludge on soil actinomycetes

Soil enzymes

The details of soil enzyme activity in the experimental field are presented in Figure 4. The mean soil urease was ranged from 46.26 to 28.04 µg of NH_4-N released g^{-1} of soil h^{-1}, 66.29 to 46.63 µg of NH_4-N released g^{-1} of soil h^{-1} and 103.29 to 63.51 µg of NH_4-N released g^{-1} of soil h^{-1} for vegetative, flowering and harvest stage of the pearl millet. Among the treatments, the highest value of soil urease was recorded in T_8 - $I_2M_2S_2$ (46.26 µg of NH_4-N released g^{-1} of soil h^{-1}) and lowest value was noted at 28.04 µg of NH_4-N released g^{-1} of soil h^{-1} (T_1 - $I_1M_1S_1$) vegetative stage of the pearl millet respectively. In flowering stage of the pearl millet, the maximum value of soil urease was recorded at T_8 - $I_2M_2S_2$ (69.59 µg of NH_4-N released g^{-1} of soil h^{-1}) and lowest value observed at T_3 - $I_1M_2S_1$ (46.63 µg of NH_4-N released g^{-1} of soil h^{-1}) correspondingly. In addition, the soil urease values of T_8 - $I_2M_2S_2$ (103.29 µg of NH_4-N released g^{-1} of soil h^{-1}) and T_3 - $I_1M_2S_1$ (63.51 µg of NH_4-N released g^{-1} of soil h^{-1}) were detected at the harvest stage of the pearl millet. The urease activity is influenced by various soil properties including pH, soil nutrient supply, Soil N, soil microbial biomass, and N fertilizers (Moghimian *et al*., 2017) [7]. The supply of urea increased the soil N and urease activity and therefore, the increased urease activity in T_8 - $I_2M_2S_2$ was observed due to increase soil N supplied through the treated effluent in three stages (Meena and Rao, 2021) [6]. The mean soil phosphatase was ranged from 17.90 to 8.71 µg PNPP g^{-1} of soil, 33.62 to 17.82 µg PNPP g^{-1} of soil and 46.67 to 33.58 µg PNPP g^{-1} of soil for the vegetative, flowering and harvest stage of the pearl millet. The vegetative stage of the pearl millet showed the highest and lowest soil phosphatase activity at T_8 - $I_2M_2S_2$ (17.90 µg PNPP g^{-1} of soil) and T_1 - $I_1M_1S_1$ (8.71 µg PNPP g^{-1} of soil) respectively between the treatments. During the flowering stage, the maximum and minimum soil phosphatase activity were recorded at T_8 - $I_2M_2S_2$ (33.62 µg PNPP g^{-1} of soil) T_1 - $I_1M_1S_1$ (17.82 µg PNPP g^{-1} of soil) correspondingly. The harvesting stage of the pearl millet has the highest soil phosphatase activity T_8 - $I_2M_2S_2$ (103.29 µg PNPP g^{-1} of soil) followed by T_7 - $I_2M_2S_1$ (45.09 µg PNPP g^{-1} of soil). Moreover, the lowest values for the same was recorded at T_1 -

$I_1M_1S_1$ (33.58 µg PNPP g^{-1} of soil). The influence of soil carbon, nitrogen, phosphorous, organic matter and microbial community structure influences the phosphatase activity. Thus, T_8 - $I_2M_2S_2$ with maximum phosphatase activity indicates the improvement in soil phosphatase level with increase in microbial biomass (Meena and Rao, 2021) [6]. The mean soil dehydrogenase was ranged from 48.19 to 27.38 µg TPF g^{-1} of soil, 55.13 to 36.41 µg TPF g^{-1} of soil and 71.11 to 55.02 µg TPF g^{-1} of soil for the vegetative, flowering and harvest stage of the pearl millet. Among the treatments, the vegetative stage of the pearl millet has recorded the corresponding highest and lowest soil dehydrogenase at T_8 - $I_2M_2S_2$ (48.19 µg TPF g^{-1} of soil) and T_1 - $I_1M_1S_1$ (36.41 µg TPF g^{-1} of soil). In flowering stage of the pearl millet, it was observed to be highest at T_8 - $I_2M_2S_2$ (55.13 µg TPF g^{-1} of soil) and lowest at T_1 - $I_1M_1S_1$ (71.11µg TPF g^{-1} of soil). Then, in harvesting stage of the pearl millet, it recorded the highest and lowest values at T_8 - $I_2M_2S_2$ (103.29 µg TPF g^{-1} of soil) and T_1 - $I_1M_1S_1$ (55.02 µg TPF g^{-1} of soil) respectively. The higher nutrient levels, especially N increases dehydrogenase activity which indicated the oxidative activity of soil microflora and microbial activity in T_8 (Rao *et al.*, 2014) [9].

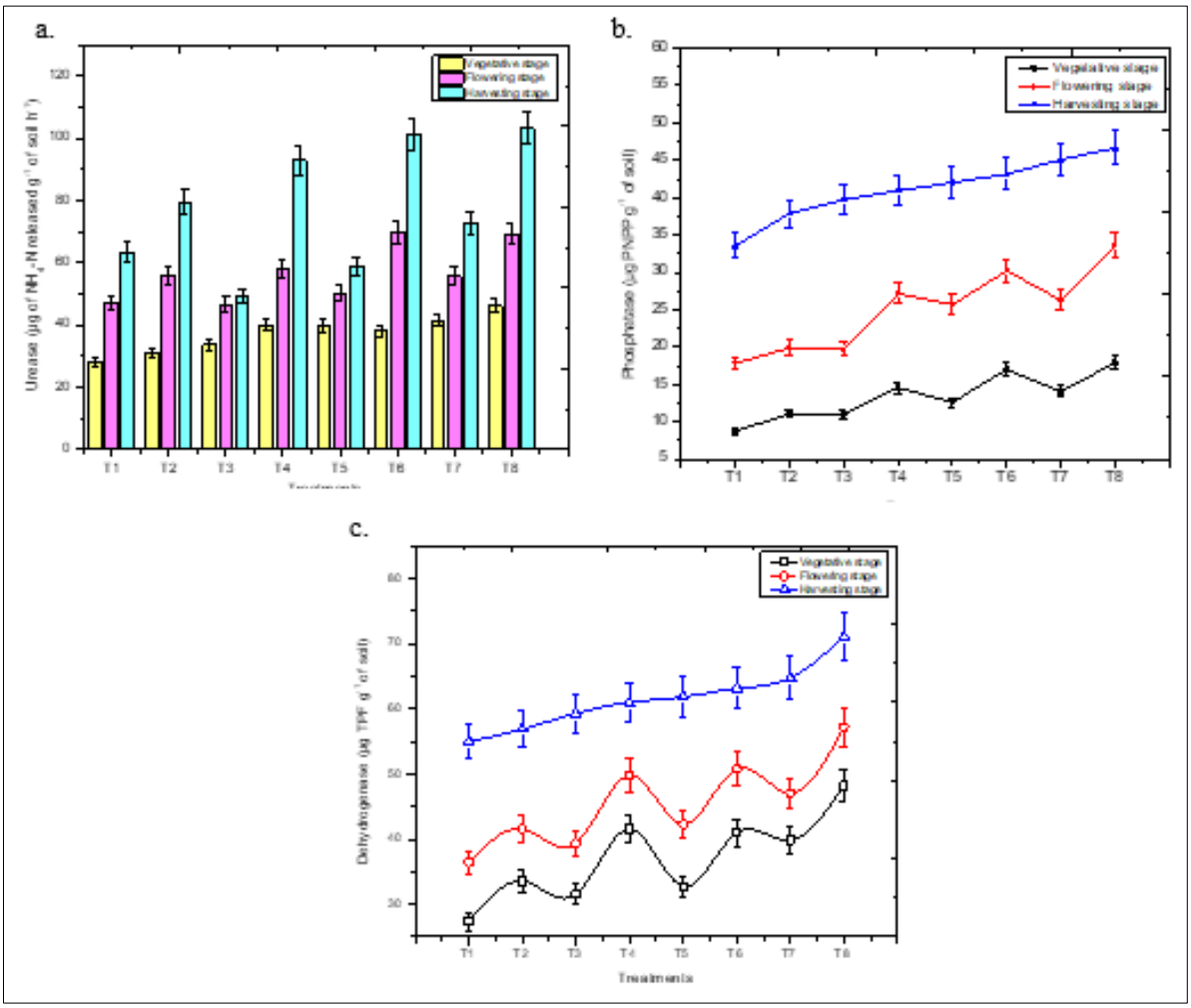

Fig 4: Soil enzyme activity (a. Soil urease, b. Soil phosphotase, c. Soil dehydrogenase) in the Pearl millet field

Yield attributes

The mean plant height ranged from 135.26 to 181.52 cm at harvest. During the harvesting stage, among the treatments T_8- $I_2M_2S_2$ recorded maximum plant height (181.52 cm) and minimum in T_1- $I_1M_1S_1$(135.26 cm). The highest total yield was observed in the treatment of T_8- $I_2M_2S_2$ (3.45 t/ha) and lowest were recorded in the T_1- $I_1M_1S_1$ (3 t/ha). The yield trend was observed in the order of T_8 - $I_2M_2S_2$ > T_7 - $I_2M_2S_1$ > T_4 - $I_1M_2S_2$ > T_6 - $I_2M_1S_2$ > T_2 - $I_1M_1S_2$ > T_5 - $I_2M_1S_1$ > T_3 - $I_1M_2S_1$ > T_1 - $I_1M_1S_1$.

The mean test weight of the pearl millet seed crop is ranged from13.4 to 11.1 gram. The highest test weight of the seed was observed in the treatment of T_8- $I_2M_2S_2$ (13.4g) and lowest were recorded in the T_1- $I_1M_1S_1$ (11.1g). The mean stover weight of the pearl millet crop is range between 178.54 to 147.23 Kg/ha. The highest total stover weight was observed in the treatment of T_8- $I_2M_2S_2$ (178.54 Kg/ha) and lowest were recorded in the T_1- $I_1M_1S_1$ (147.23 Kg/ha). The yield attributes of plant height, green fodder, 1000 grain test weight and seed yield were showed significant differences in the interactions of all the three factors (I*M*S).

The grain yield of the pearl millet high in treatment effluent and vermicompost amendment similar studies by using the paperboard mill treated effluent gave high productivity in different crop cultivation like maize (*Suganthi et al.*, 2019) [10] and brinjal (Anushya *et al.*, 2020) [2]. The foliage yield of the pearl millet is increased in treatment 8 (T_8) showed related to the high production in fodder yield of pearl millet by applying treatment effluent from stabilization ponds (Khan *et al.*, 2004) [4]. On contrary with production of pearl millet by the application of treatment effluent from sugarcane mill effluent gave high production of foliage and grain yield by Kumar and Chopra (2014) [5].

Table 1: Effect of well water, paper board mill treated effluent and vermicompost ETP sludge on Pearl millet (Co-10) yield attributes (Plant height, green fodder, 1000 grain test weight and seed yield)

Treatments	Plant height (cm)		Green fodder (kg/ha)		1000 grain test weight (g)		Grain Yield (t/ha)	
T_1: $I_1M_1S_1$	135.26		147.23		11.1		3.00	
T_2: $I_1M_1S_2$	144.56		151.77		11.4		3.17	
T_3: $I_1M_2S_1$	149.21		157.08		12.1		3.14	
T_4: $I_1M_2S_2$	155.10		161.88		12.3		3.32	
T_5: $I_2M_1S_1$	153.26		162.95		12.4		3.14	
T_6: $I_2M_1S_2$	169.22		165.99		12.7		3.25	
T_7: $I_2M_2S_1$	179.56		174.22		12.9		3.32	
T_8: $I_2M_2S_2$	181.52		178.54		13.4		3.45	
Mean	158.46		162.46		12.29		3.22	
	$S.E_d$	CD (0.05)	$S.E_d$	CD (0.05)	$S.E_d$	CD (0.05)	$S.E_d$	CD (0.05)
I	1.755	5.585	0.798	0.798	0.109	0.348	0.008	0.025
M	0.511	1.252	1.056	1.056	0.095	0.232	0.038	0.092
S	1.106	2.410	1.000	1.000	0.110	0.240	0.023	0.051
I X M	1.828	5.712	1.323	1.323	0.145	0.415	0.039	0.096
I X S	2.074	6.010	1.279	1.279	0.155	NS	0.025	NS
M X S	1.219	NS	1.454	1.454	0.145	0.333	0.044	0.105
I X M X S	1.646	3.629	1.764	1.764	0.182	0.411	0.050	0.117

Conclusion

Application of wastewater is emerging as a possible irrigation source for satisfying water demand for crop cultivation. The paper board mill treated effluent contains significant amounts of plant nutrients and that improves crop production. Vermicompost ETP sludge application provided the additional nutrient supplement. In this study, it was confirmed that soil application of vermicompost ETP sludge along with treated effluent through the drip irrigation showed higher soil microbial population, soil enzyme and pearl millet yield. Based on these experimental results, it is suggested that soil application vermicompost ETP sludge in addition to paper board mill treated effluent is found to be for sustainable crop production in the scarce environment of fresh water for irrigation.

References

1. Agricultural statistics at a glance, 2019. http://www.indiaenvironmentportal.org.in/content/468912/agricultural-statistics-at-a-glance-2019/
2. Anushya M, Balasubramanian G, Thangavel P, Saraswathi T, Maheswari M, Priyadharshini M. Evaluation of Yield and Quality Attributes of Grafted Brinjal under Treated Paperboard Mill Effluent Irrigation and Sludge Application. International Journal of Environment and Climate Change, 2020, 490-497.
3. Kandeler E, Gerber H. Short-term assay of soil urease activity using colorimetric determination of ammonium. Biology and fertility of Soils. 1988;6(1):68-72.
4. Khan AH, Naeem M, Chohan MSM, Kainth RA. Fodder yield potential of pearl millet cultivars under irrigated conditions. International Journal of Agriculture and Biology. 2004;6(4):749-750.
5. Kumar V, Chopra AK. Pearl millet (*Pennisetum glaucum* L.) response after ferti-irrigation with sugar mill effluent in two seasons. International Journal of Recycling of Organic Waste in Agriculture 2014;3(3):6.
6. Meena A, Rao KS. Assessment of soil microbial and enzyme activity in the rhizosphere zone under different land use/cover of a semiarid region, India. Ecological Processes. 2021;10(1):1-12.
7. Moghimian N, Hosseini SM, Kooch Y, Darki BZ. Impacts of changes in land use/cover on soil microbial and enzyme activities. Catena. 2017;157:407-414.
8. Ponge JF, Pérès G, Guernion M, Ruiz-Camacho N, Cortet J, Pernin C, *et al*. The impact of agricultural practices on soil biota: a regional study. Soil Biology and Biochemistry. 2013;67:271-284.
9. Rao MA, Scelza R, Gianfreda L. Soil enzymes. Enzymes in agricultural sciences. OMICS Group, Foster City, 2014, 1-18.
10. Suganthi R, Sebastian SP, Indhuparameshwari C, Avudainayagam S, Meena L, Sadish O. potential use of reclaimed water from recycled paper board mill through micro irrigation system for maize crop production.
11. Tabatabai MA, Bremner JM. Use of p-nitrophenyl phosphate for assay of soil phosphatase activity. Soil biology and biochemistry 1969;1(4):301-307.
12. Thalmann A. Zur Methodik der Bestimmung der Dehydrogenaseaktivität im Boden mittels Triphenyl tetrazolium chlorid (TTC). Land wirtsch Forsch. 1968;21:249-258.
13. Udayasoorian C, Ponmani S. Effect of treated paperboard mill effluent irrigation on soil health and yield of vegetable crops. J Environ Res Dev. 2009;3(3):879-889.
14. Waksman SA, Fred EB. A tentative outline of the plate method for determining the number of micro-organisms in the soil. Soil Science. 1922;14(1):27-28.
15. Elayarajan M, Udayasoorian C, Boopathi PM. Influence of paper board mill effluent on soil properties. Madras Agricultural Journal. 2009;96(1/6):173-178.