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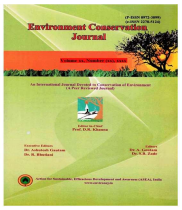

Soil biological properties as affected by the conjunction of chemical fertilizers, bacterial consortia and bio-enhancers in foxtail millet cultivation

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ABSTRACT

During *Kharif* 2019, a field experiment was conducted with eight treatments replicated three times in Randomized Block Design at College farm, PJTSAU, Rajendranagar, Hyderabad. The aim of the study is to investigate the combined effect of chemical fertilizers and bio-agents (bacterial consortia and bio-enhancers) on soil biological parameters (bacterial population, urease, dehydrogenase, acid phosphatase and alkaline phosphatase) under foxtail millet cultivation in semi-arid region where soil and climatic constraints prevail in general. The bacterial population in the rhizosphere soil was found to be greater in all the treatments that received bacterial consortia appended with bio-enhancers compared to the remaining treatments as they are rich in microbial population. The soil enzyme activity was found to be higher when bioagents were used in conjunction with fertilizers, similar to bacterial population. The use of bacterial consortia or bio-enhancers alone also improved enzyme activity when compared to the control, while fertilizers alone, were poor in the activity of above enzymes. The percentage increase in the overall biological activity over the initial value was found to be highest when bioagents were used along with the chemical fertilizers at 50% flowering and harvest stages whereas it was found least in the control and lower in the treatments applied with chemical fertilizers alone.

Introduction

Soil should not be regarded as a simple medium for crop growth; rather, it should be considered as a complex biological ecosystem. This was understood by Indian farmers and they used to follow natural laws, which aided in the preservation of soil health over a substantial period of time. But, with green revolution, the use of fertiliser responsive varieties and agrochemicals has resulted in a huge increase in yield which enabled India to become self-sufficient in food grain production but caused serious damage to the soil health due to dumping of huge chemicals into the agricultural soils. Eco-friendly technologies must be developed and made available to farmers in order to restore the soil health. As a result, scientists and policymakers are rethinking agricultural systems that rely heavily on bio- inputs rather than synthetic/chemical fertilizers alone. Preserving long-term soil fertility by protecting organic content and supporting biological nature of the soil are important measures. Using biofertilizers, bacterial consortia (combination of biofertilizers), bio-enhancers (*beejamrutha* & *jeevamrutha*), green manures, farm yard manures, composts etc. are the

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options found to enhance the biological activity of the soil (Ananda *et al.,* 2017; Boraiah *et al.,* 2017; Hameedi *et al.,* 2018; Krishnaprabhu (2018); Vinay *et al.,* 2020). Use of such organic manures was found to be more feasible and beneficial in low fertilizer requiring crops like millets (Maitra *et al.,* 2020) compared to other crops which are mostly fertilizer responsive type (cereals) and need voluminous amounts of manures (cash crops). Infact, millets grown in some areas are by default organic in nature. This might be a reason for poor millet production levels leading to a large gap between demand and supply leading to escalating price of millets. Proper combination of chemical fertilizers and bioagents can enhance the productivity of the crop as well as the quality (Basha, 2015; Ravi *et al.,* 2012). Since the efficiency of organic manures in meeting crop nutrient requirements is not as certain as it is with mineral fertilizers, the combined use of chemical fertilizers and organics is capable of improving soil quality as well as productivity over a period of time. Organic and mineral fertilizers used together have been proven to be more successful in sustaining higher productivity and soil fertility on the one hand, and favourable soil ecological conditions on the other (Chhonkar, 2002).

Soil fertility is also influenced by the biochemical activities of microflora, particularly in the rhizosphere, which, when influenced by roots, can change the degree of nutrient availability to higher plants (Mallikarjun and Maity, 2017). These microbes also play a major role in the organic matter decomposition, as well as the degradation of toxic materials and other contaminants. Several other soil parameters, such as soil reaction, moisture, temperature, and so on, influence the type and amount of these microorganisms. Soil biological research sheds light on this lively nature of the soil. Further, soil enzyme measurements can be used to determine the biological activity in the rhizosphere soil. These are important in agriculture because they play a crucial part in the biochemical process of organic matter decomposition in the soil, as well as catalysing several vital reactions required for the life processes of microorganisms in the soil. These enzyme activities commonly correlate with microbial population (Kandeler and Murer, 1993; Vinay *et al.,* 2020). Urease is an essential extracellular enzyme that affects the availability of plant utlilizable nitrogen forms in soils. It's one-of-a-kind enzyme that catalyses the conversion of urea to ammonia (NH_4), which is then converted to ammonium (NH_4^+) and nitrate (NO_3^-) ions. Whereas, dehydrogenase is involved in the biological oxidation of soil organic matter, which releases nutrients into the accessible pool. It calculates overall microbial activity in the soil (Taylor *et al.,* 2002). The phosphorus cycle in soil is linked to phosphatase activity (Aon and Colaneri, 2001). The phosphate molecule is removed from organic substances such as phospholipids and nucleic acids by this enzyme in the soil. When phosphate is split, it becomes soluble and can be absorbed by microbes or plants. Thus enzyme assay can predict the biological activity of the soil which is an important soil health indicator.

With these facts in view, a unique effort was made to study the biological parameters under the influence of combined application of recommended dose of chemical fertilizers and bioagents with bacterial consortia and bio-enhancers (*beejamrutha* and *jeevamrutha*) as organic sources which are gaining importance among farming community these days.

Material and Methods

A field study was performed during *kharif*, 2019 at College of Agriculture, Rajendranagar, PJTSAU, Hyderabad. The experimental site is located at an altitude of 534 m above mean sea level on 17°32’22’’N latitude and 78°41’11’’E longitude. It is in the Southern Zone of Telangana State. The site consists of sandy loam soil with 6.42 pH, 0.08 ds/m EC, 0.45% OC, low available Nitrogen (172 kg/ha), medium in Phosphorus (22 kg/ha), high in Potassium (398 kg/ha) and sufficient in Zinc status (0.65 ppm). The initial values of biological properties of soil are furnished in Table 1. The size of gross and net plots was 4.8 m x 3.9 m and 4.2 m x 3.3 m respectively. The experiment was laid out in Randomized Block Design with 3 replications and 8 treatments. The treatment details are mentioned in the Table 2.

Preparation of *beejamrutha*

Cow dung was collected, tied in a cloth and dipped in a container with 50 litres of water for overnight. Next day, the dung was squeezed into the water.

Table 1: Initial values of biological properties of soil

Biological properties	Initial value	Method adopted
Bacteria (X 10^5 CFU/g soil)	18	Vlassak *et al.* (1992)
Urease (µg NH_4^+/ g/2h)	17.5	Tabatabai and Bremner (1972)
Dehydrogenase (µg TPF/ g/day)	8.56	Casida *et al*. (1964)
Alkaline phosphatse (µg pNP/ g/soil h)	17.08	Tabatabai and Bremner (1969)
Acid phosphatase (µg pNP/ g/soil h)	18.50	Tabatabai and Bremner (1969)

Table 2: Treatment details imposed in the experiment

Treatment no.	Treatment	Dose and method of application
T_1	Control	No chemical fertilizers/ bacterial consortia/ *beejamrutha* and *jeevamrutha*
T_2	Chemical Fertilizers	Full recommended dose (40:20:0 kg N:P_2O_5: K_2O/ha) Entire p (SSP) as basal, N (Urea) in two splits, one as basal and other as top dressing at 30 DAS
T_3	Chemical Fertilizers	Half of recommended dose (20: 10:0 kg N:P_2O_5: K_2O/ha)
T_4	Bacterial consortia	2.5 kg / 250 kg FYM/ha through soil application before sowing
T_5	Bio-enhancers	*Beejamrutha* @ 50 L/ha through seed treatment and *Jeevamrutha* @ 500 L/ha through soil application at fortnightly interval
T_6	Bacterial consortia + Bio-enhancers	2.5 kg / 250 kg FYM/ha 50 L/ha and 500 L/ha
T_7	Bacterial consortia +Bio-enhancers +Chemical fertilizers	2.5 kg / 250 kg FYM/ha 50 L ha^{-1} and 500 L/ha Full recommended dose
T_8	Bacterial consortia + Bio-enhancers +Chemical fertilizers	2.5 kg / 250 kg FYM/ha 50 L/ha and 500 L/ha Half of recommended dose

Table 3: Ingredients required for preparation of *beejamrutha* hectare^{-1}

a)	Water	50 lit
b)	Desi cow dung*	12.5 kg
c)	Desi cow urine*	12.5 lit
d)	Ant hill soil	250 g
e)	Lime	125 g

Later cow urine and lime were added to this extract. The above solution was stirred well before application (Table 3).

*Dung and urine were collected from the same desi cow (Gir) during the entire cropping period.

Preparation of *jeevamrutha*

All the ingredients (Table 4) were mixed in 500 litres water in a drum and kept for 72 hrs under shade. The above solution was stirred twice a day with a stick. *Jeevamrutha* was prepared for each application three days ahead of application date.

The preparation of *beejamrutha* and *jeevamrutha* is in accordance with Vinay *et al.* (2020). Microbial population found in *beejamrutha* and *jeevamrutha* are 20 x 10^6 CFU/ml and 13 x 10^6 CFU/ml respectively.

Bacterial Consortia

Bacterial consortia, a combination of biofertilizers such as *Azotobacter*, Phosphorus Solubilizing Bacteria (PSB), Potassium Releasing Bacteria (KRB) and Zinc Solubilizing Bacteria (ZnSB) obtained from the Department of Microbiology and Bioenergy, Rajendranagar, PJTSAU. 2.5kg/ha of this consortia is mixed @ 250 kg of FYM/ha.

Table 4: Ingredients required for preparation of *jeevamrutha* hectare^{-1}

a)	Water	500 lit
b)	Desi cow dung*	25 kg
c)	Desi cow urine *	25 lit
d)	Jaggery	5 kg
e)	Flour of any pulse	5 kg
f)	Ant hill soil	250 g

Bacterial population

Soil bacterial population was enumerated from soil samples of rhizosphere zone collected from 0-15 cm depth at 50% flowering and harvest stage of crop in each treatment plot randomly using serial dilution- agar plating method (Vlassak *et al.,* 1992). A gram of soil sample was placed into 10 ml of distilled water, mixed thoroughly and diluted tenfold. 1 ml of soil suspension was transferred to another 9 ml water blank with a sterile pipette and vigorously mixed, resulting in a sample diluted to 10^{-2}. In a similar way, dilutions were made up to 10^{-6}. These 1 ml of diluted samples were transferred into sterile petri-plates in a laminar airflow chamber. Then 15 ml of Nutrient agar media (45^0C) was poured into each plate and mixed the contents by gentle rotation and allowed to solidify. The plates are then, incubated for about 2-3 days at 37°C temperature in BOD incubator. Colonies found on plates were recorded and population per gram of soil was enumerated by using digital colony counter. The number of colonies were multiplied by the dilution factor and expressed as colony forming units (CFU).

Urease activity

Urease activity was analysed by the release of NH_4^+ from the hydrolysis of urea (Tatabai and Bremner, 1972). 5 grams of soil sample was taken into a 50 ml volumetric flask, after adding 0.2 ml of toluene and 9 ml THAM buffer, the flask was shaked to mix the contents thoroughly and 1ml of 0.2M urea solution was added and swirled once again. The flask was stoppered and placed in an incubator at a temperature of 37^0C. After 2 hours, 35 mL of KCL-Ag_2SO_4 solution was added and the flask was left to stand until the contents had cooled to room temperature. By adding KCL-Ag_2SO_4 solution, the contents were increased to 50 mL, and the flask was sealed and inverted several times to mix the contents. By pipetting out a 20 ml aliquot of the soil solution and distilling it with 0.2 g of MgO for 4 minutes, $NH4^+$-N was measured in the resultant soil suspension. Controls were made by using the same protocol as the urease activity assay, but adding 1ml of 0.2 M urea solution after the KCL-Ag_2SO_4 solution was added.

Dehydrogenase Activity

In a 50 ml glass tube, 1 g of soil was added, followed by 50 mg of $CaCO_3$, 2.5 ml of distilled water, and 1 ml of 3 percent 2,3,5-triphenyl tetrazolium chloride. Swirled for a few minutes before incubating for 24 hours at 37°C. The TPF red precipitate was dissolved in 10 ml methanol, agitated for 30 minutes, filtered, and the volume was increased to 25 ml by adding methanol. At 485 nm, the intensity of the red colour was measured using a twin beam UV-Visible spectrophotometer (Casida *et al.,* 1964).

Acid and Alkaline Phosphatase Activity

The activity of phosphophatase was determined using a conventional technique (Tatabai and Bremner, 1972). Enzyme activity was determined by mixing 1 g of soil with 0.2 ml toluene, 4 ml modified universal buffer (MUB) (pH 6.5 and 11 for acid and alkaline phosphatase respectively) and 1 ml p-nitrophenyl phosphate solution in a 50 ml flask. 1 ml of 0.5 M $CaCl_2$ and 4 ml of 0.5 M NaOH were added after an hour of incubation. The suspension was filtered and the absorbance of the filtrate was measured at 420 nm using UV-Visible spectrophotometer. Controls were prepared by repeating the phosphatase activity assay technique but adding 1ml of p-nitrophenol solution after the additions of 0.5 M $CaCl_2$ and 4 ml of 0.5 M NaOH.

Results and Discussion

The bacterial population count in the form of colony forming units (CFU) was taken in the rhizosphere soil at 50% flowering and harvest stage apart from the initial status (Table 5). Before sowing of the crop, the count was 18 x 10^5 CFU/g soil. The perusal of the data at 50% flowering stage reveals highest bacterial population in T_7 in which the conjunctive application of 100% RDF + bacterial consortia + *beejamrutha* and *jeevamrutha* was imposed. It was superior to all the other treatments except T_6 (bacterial consortia + *beejamrutha* and *jeevamrutha* alone) and their combination at 50% RDF (T_8). However, compared

to control plot, the population was significantly superior with their individual application (T_3 or T_4) and combination (T_6) but not with 50% RDF (T_3). At harvest, the population was reduced and in control it reached to the initial level. The treatments which received the conjunctive application of bacterial consortia + *beejamrutha* and *jeevamrutha* (T_6, T_7 and T_8) were at par but superior to control. At harvest also, the bacterial population with 50 % RDF (T_3) was found to be similar with control plot (T_1).The percentage increase in the bacterial population in treatment T_7 (combined application of 100% RDF, bacterial consortia and bio-enhancers) is 124.06 and 114.78% over the initial status at 50% flowering and harvest stage of the crop respectively. Whereas application of bioagents (bacterial consortia and bio-enhancers) i.e., in T_6, the percentage increase is about 107.39 and 91.67% at 50% flowering and harvest stage of the crop respectively. This indicates a complementary effect between the chemical fertilizers and bioagents in improving the microbial status of the soil. But application of chemical fertilizers alone at 50% and 100% level showed 50, 37.22% at 50% flowering and 30.56, 12.94% increase only at harvest stage over initial value (Figure 1&2). The enhanced growth of bacteria with the combined application of bacterial consortia + *beejamrutha* and *jeevamrutha* alone (T_6) or with inorganic fertilizers (T_7 or T_8) might be due to increased colonization of the bacteria owing to the increased root growth and their exudates which might have supported the growth of bacteria. As the micro-organisms are well activated in soil following the *jeevamrutha* application (Manjunatha *et al.,* 2009; Kiran *et al.,* 2015; Kumar *et al.,* 2016) increase in the total soil bacterial population was attributed to the addition of bacterial consortia as well as repeated application of *jeevamrutha* which further improved the conditions congenial for the microbial growth.

The activity of the urease enzyme was assessed at 50% flowering and harvest stage and compared to the activity before sowing (17.5 µg NH_4^+ g/2h). It was improved in all the treatments including control at both the observations. Higher activity of the enzyme was observed at 50% flowering and declined at harvest (Table 5). Corresponding to the bacterial population, peak activity of the enzyme was observed with the combination of 100% RDF + bacterial consortia + *beejamrutha* and *jeevamrutha* applied at fortnightly interval (T_7) followed by 50% RDF and bioagents (T_8) and combination of the bioagents alone (T_6) which were at par at both the observations. The next best treatment was *beejamrutha* and *jeevamrutha* alone (T_5) and bacterial consortia alone (T_4), both of which were superior to 100% RDF (T_2), 50% RDF (T_3) and control (T_1). It is evident that urease activity was higher in the biological treatments compared to application of inorganic fertilizers alone.

This might be ascribed to the fact that fortnightly application of *jeevamrutha* might have served as source of carbon, energy and other nutrients essential for the ureolytic micro-organisms (Reddy, 2002). The lower urease activity in inorganic treatments (T_2 and T_3) might be due to lack of sufficient number of colony forming microbes as well as substrate *i.e*., organic matter which is the energy source for multiplying the microbe number (Nagendra, 2015). The activity of dehydrogenase is high even before sowing, which might be due to the fact that the soil was kept fallow continuously for 5-6 years before the experiment. It was further enhanced in all the treatments including control at 50% flowering and harvest stage (Table 5). The activity of the dehydrogenase had the similar trend to that of the urease activity among the treatments, except that the inorganic treatments alone (T_2 or T_3) were comparable to control (T_1) at both the observations. Higher dehydrogenase in the biological treatments might be due to the improved microbial activity (Mallikarjun and Maity, 2018). Addition of manures or carbon and energy sources enhances the population of heterotrophs and enzymatic activities. Dehydrogenase activity increases with increasing active viable cells as it occurs intracellular in all living microbial cells.

Alkaline and acid phosphatase enzyme activities were analysed at 50% flowering and harvest stage and the data is furnished in Table 5. Compared to the initial activity, it was increased at 50% flowering and reduced at harvest, irrespective of treatments. Both the enzymes followed the similar trend. Highest activity was recorded with 100% RDF + combination of bioagents (T_7) which was at par with 50% RDF + combination of bioagents (T_8) and bioagents alone (T_6). Similarly, (T_6) was also at par with the individual application of bioagents (T_4 or T_5). But the activity of the enzymes was lower with chemical fertilizers alone (T_2 and T_3)

Table 5: Bacterial population and soil enzyme activity in the rhizosphere of foxtail millet @ 50% flowering and harvest stage as influenced by combined application of chemical fertilizers and bio-agents

Treatment	Bacterial population		Urease		Dehydrogenase		Alkaline phosphatase		Acid phosphatase	
	50% flowering	harvest	50% flowering	Harvest	50% flowering	harvest	50% flowering	harvest	50% flowering	harvest
T_1	20.00	18.66	20.00	18.50	8.98	8.61	18.73	17.38	20.87	19.10
T_2	27.00	23.50	23.75	22.50	9.18	8.93	20.27	18.30	22.17	20.17
T_3	24.70	20.33	22.50	21.00	9.12	8.82	19.94	17.98	21.47	19.82
T_4	33.17	28.67	26.00	24.75	11.00	10.46	23.02	21.80	25.07	22.93
T_5	34.33	32.00	27.50	25.50	11.11	10.63	22.37	20.83	24.99	22.80
T_6	37.33	34.50	31.25	30.00	12.43	11.57	24.06	22.60	27.78	24.73
T_7	40.33	38.66	32.00	31.00	12.67	12.08	25.97	24.37	28.47	25.83
T_8	38.00	35.50	31.75	30.75	12.5	11.98	24.72	23.87	27.67	25.03
SEm±	1.66	1.58	1.01	0.85	0.44	0.44	0.86	0.75	0.89	0.86
CD (P=0.05)	5.02	4.78	3.07	2.58	1.33	1.35	2.62	2.27	2.70	2.59

compared to T_7 and T_8, respectively. Among all, lowest phosphatase activity was recorded with control. The enhanced activity of phosphatase is attributed to the application of PSB through bacterial consortia. Among the macronutrients, P is the less mobile in the soil and gets adsorbed by 'Fe' and 'Al' oxides. PSB plays a major role in phosphorus nutrition by increasing its availability through release soil P pools by solubilization (Khan *et al.,* 2007). The percentage increase in enzyme activity over the control was depicted clearly in figure 1& 2 at flowering and harvest stages.

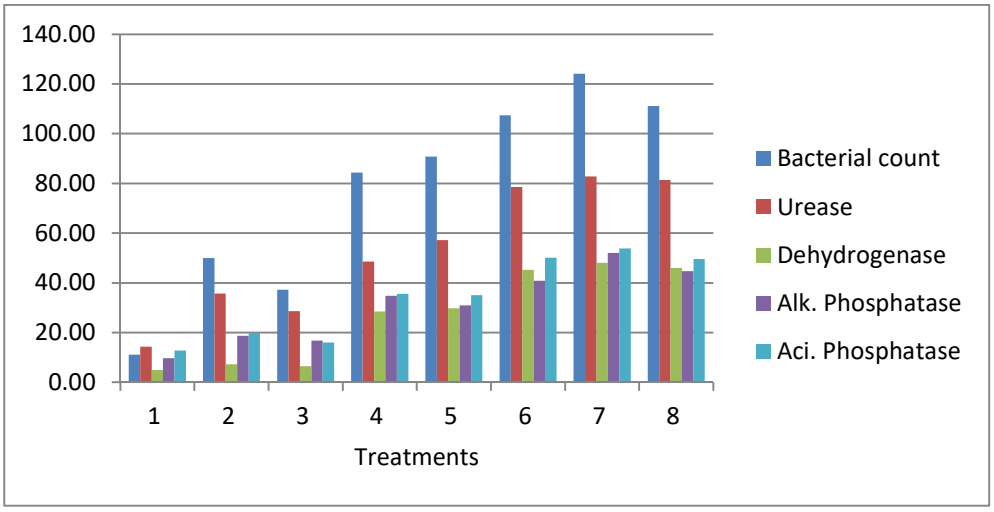

Figure 1. Percentage increase in the biological parameters at 50% flowering stage over initial value as influenced by the treatments

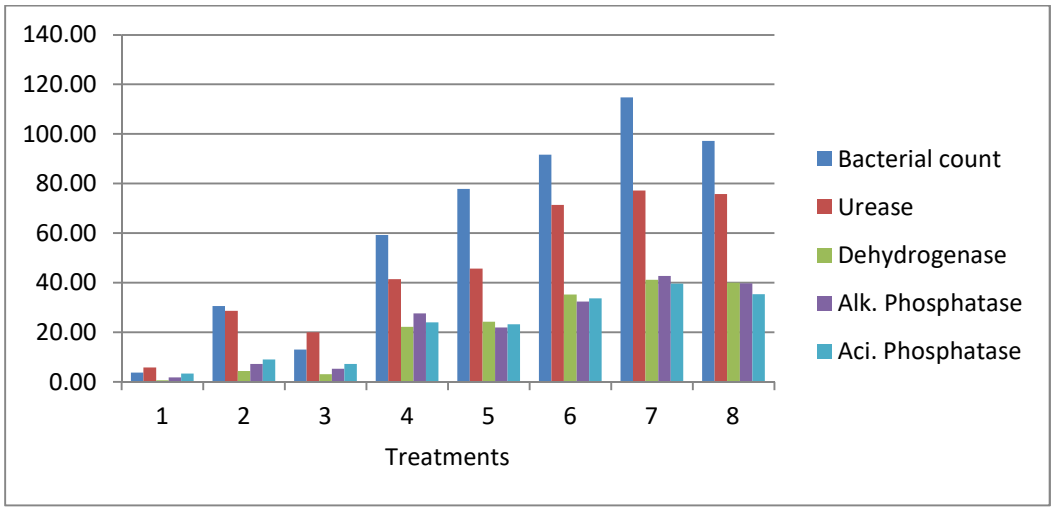

Figure 2. Percentage increase in the biological parameters at harvest stage over initial value as influenced by the treatments

Increased enzymatic activity in the soil can be attributed to the key role played by the microbial population due to the addition of bacterial consortia and application of bio-enhancers which acted as a tonic for better bacterial growth. Thus, overall congenial conditions for microbes might have resulted in enhanced enzymatic activity in the soil.

Conclusion

Bacterial population was significantly more in all the treatments which received bioagents compared to others at both the observations. Similar to bacterial population, the rhizosphere soil enzyme activity was found to be the highest with conjunctive use of bioagents either alone or with chemical fertilizers. Thus, with the application of bioagents like consortia of biofertilizers and bio-enhancers like *beejamrutha* and *jeevamrutha* along with recommended dose of fertilizers, the biological activity of the soil under millet cultivation in semi-arid regions can be boosted without any negative effects on the soil health and productivity by maintaining natural cycling of nutrients.

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Conflict of interest

The authors declare that they have no conflict of interest.

References

Ananda, M.R., Sharanappa., & Murthy, K.N.K. (2017). Response of finger millet under organic nutrient management in groundnut-finger millet cropping system. *International Journal of Pure and Applied Bioscience*, *5*(5), 200-206.

Aon, M.A., & Colaneri, A.C. (2001). Temporal and spatial evolution of enzymatic activities and physico-chemical properties in an agricultural soil. *Applied Soil Ecology*, *18*, 255-270.

Basha, J.S. 2015. Plants geometry, irrigation and organic nutrient management practices for aerobic rice in northern transitional Zone of Karnataka. *Ph.D Thesis* submitted to University of Agricultural Sciences, Dharwad, Karnataka, India.

Boraiah, B., Devakumar, N., Shubha, S., & Palanna, K.B. (2017). Effect of panchagvya, jeevamrutha and cow urine on beneficial micro-organisms and yield of capsicum. *International Journal of Microbiology and Applied Sciences*, *6*(9), 3226-3234.

Casida, L.E., Klein, D.A., & Santoro, T. (1964). Soil dehydrogenase activity. *Soil Science*, *98*, 371–376.

Chhonkar, P.K. *Organic farming myth and reality*, in Proceedings of the FAI Seminar on Fertilizer and Agriculture Meeting the Challenges, New Delhi, India, December 2002.

Hameedi, A., Thakur, K.S., Kansal, S., Mehta, D.K., Yousafzai, A., & Mohammadi, M.H. 2018. Effect of organic nutrient sources on growth, yield and quality of bell pepper (*Capsicum annuum L.*) under mid hill condition of Himachal Pradesh. *International Journal of Multidisciplinary Research and Development*, *5*(1), 135-138.

Kandeler, E., & Murer, E. (1993). Aggregate stability and soil microbial processes in a soil under different cultivations.

In: Brussard L. and M.I. Koistra (eds.): International workshop on methods of research on soil strucuture/soil biota interrelationships. *Geoderma*, *56*, 503-513.

Khan, M. S., Zaidi, A., & Wani, P.A. (2007). Role of phosphate-solubilizing microorganisms in sustainable agriculture - A review. *Agronomy for Sustainable Development*, *27*, 29-43.

Kiran, Rao, S., Reddy, V., & Shubha, S. (2015). Effect of Nutrient management practices through organics on soil biological properties in organic chickpea cultivation under rainfed condition. *The Ecoscan, 7*, 183-187.

Krishnaprabhu, S. (2018). Influence of integrated nutrient management in pearl millet. *International Journal of Pure and Applied Bioscience*, *6*(6), 508-510.

Kumar, B., Nagarjuna, D., Kalpana, A., & Mukhopadhyay, S.K. (2016). Effect of integrated nutrient management on soil microbial population and yield of wheat-rice cropping system in new alluvial zone of west Bengal. *Journal of Innovative Research and Solutions*, *2*(2), 85-95.

Maitra, S., Pine, S., Shankar, T., & Pramanick, B**.** (2020). Nutrient Management in Foxtail millet: A Review. *Indian Journal of Natural Sciences*, *10*, 60: 23156-23160.

Mallikarjun, M., & Maity, S.K. (2017). Energetic Evaluation of Integrated Nutrient Management for Nitrogen in *Kharif* Rice and its Residual Effect on Yellow Sarson. *Research Journal of Agricultural Sciences*, *8*(6), 1362-1365.

Manjunatha, G.S., Upperi, S.N., Pujari, B.T., Yeledahalli, N.A., & Kuligod, V.B. (2009). Effect of Farm yard manure treated with *Jeevamrutha* on yield attributes, yield and economics of sunflower. *Karnataka Journal of Agricultural Sciences*, *22*(1), 198-199.

Nagendra,V., (2015). Influence of Rice Production Systems and Nutrient Management Practices on Rice Yield and Soil Properties, *Ph. D Thesis* submitted to Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, India.

Ravi, N., Basavarajappa, R., Chandhrasekhar, C.P., Harlapur, S.I., Hosamani, M.H., & Manjunatha, M.V. (2012). Effect of integrated nutrient management on growth and yield of quality protein maize. *Karnataka Journal of Agricultural Sciences*, *25*(3), 395-396.

Reddy, M.S. 2002. Relationship between organic carbon and soil enzymes. *Journal Research ANGRAU*, *30*(2), 143-146.

Tabatabai, M. A., & Bremner, J. M. (1972). Assay of urease activity in soils. *Soil biology and Biochemistry*, *4*, 479-487.

Taylor, J.P., Wilson, B., Mills, M.S., & Burns, R.G. (2002). Comparison of microbial number and enzymatic activities in surface soils and subsoil using various techniques. *Soil Biology and Biochemistry*, *34*, 387401.

Vinay, G., Padmaja, B., Reddy, M.M., Jayasree, G., & Triveni, S. (2020). Effect of Natural, Organic and Inorganic Farming Methods on Microorganisms and Enzymes Activity of Maize Rhizosphere. *International Research Journal of Pure & Applied Chemistry*, *21*(6), 11-16.

Vlassak, K.L., Holm, L.V., & Duchateau, L. (1992). Isolation and characterization of fluorescent Pseudomonas associated with roots of rice and banana grown in Srilanka. *Plant and Soil*, *145*, 51-63.