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Soil microbial dynamics and enzyme activities as influenced by biofertilizers and split application of vermicompost in rhizosphere of wheat (*Triticum aestivum*. L.)

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Abstract

Aim: A field experiment was conducted during *rabi* season to determine the effect of biofertilizers and split application of vermicompost on biological properties (microbial biomass carbon and nitrogen, microbial populations and enzyme activities) in rhizosphere of wheat.

Methodology: The experiment was laid out in factorial randomized block design with three replications consisting of twenty treatment combinations. Soil samples were collected from the plots at 0-15 cm depth after harvest of wheat crop and soil biological properties analyzed using standard analytical procedure.

Results: The experiment results indicated that among biofertilizers treatments, seed inoculation with *Azotobacter* + PSB + KMB + ZnSB (B₅) resulted in a significant higher soil microbial biomass carbon, microbial biomass nitrogen, population of bacteria, fungi and actinomycetes, dehydrogenase activity and acid phosphatase enzyme activity in comparison to control. Similarly, application of vermicompost as 50 % VC at sowing + 50 % VC at tillering (V₂) were obtained improved microbial biomass carbon and nitrogen, microbial population, dehydrogenase activity and acid phosphatase enzyme activity while remaining at par with 75 % VC at sowing + 25 % VC at tillering (V₄) proved superior in comparison to rest of the treatments due to continuous supply of nutrients throughout the crop cycle. Grain and straw yield of wheat also increased due to the application of biofertilizers and vermicompost over the control.

Interpretation: Biofertilizers (*Azotobacter*, PSB, KMB and ZnSB) and split application of vermicompost enhanced the soil microbial population and enzymatic activities which sustained the soil health for better wheat production.

Key words: Biofertilizers, Dehydrogenase activity, Microbial population, Vermicompost, Wheat

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Introduction

Wheat (*Triticum aestivum* L.) is the most extensively grown cereal crop for the majority of world's populations. Currently, India is the second largest producer of wheat in the world after China with about 12% share in total world wheat production. It is the extensive staple food of about two billion people (36% of the globe population). Worldwide, wheat world staple food crop and contributes nearly 36% of the world population, provides nearly 55% of the carbohydrates and 20% of the food calories consumed globally. During 2017-18 in India, wheat occupied over 29.65 million hectare area with a production level of about 99.86 million tonnes of grain with a productivity 33.68 q ha⁻¹. In Rajasthan, wheat occupies 2.81 million ha land and produces 9.36 million tonnes of grain with a productivity of 31.33 q ha⁻¹ (FAI, 2017-18.). The chemical fertilizers increases productivity but also had a long term negative effect of harming the environment and human health, failure in sustaining yield have given the way to use organic fertilizers rather than chemical fertilizers.

The success and efficiency of biofertilizers for agricultural crops are influenced by various factors, among which the ability of these bacteria to colonized plant roots, the exudation by plant roots and the soil health. Biofertilizers are regarded as environmentally sustainable and cost-effective alternative to synthetic fertilizers (Kawalekar, 2013). Biofertilizers contain living microorganisms that increases the organic matter content, improve soil fertility in arable soils, conserve and mobilize plant nutrients within the soil (Behera et al., 2007). Biofertilizers being cheaper, effective and ecofriendly are gaining importance in crop production (Kachroo and Razdan, 2006). *Azotobacter* stimulates root hair formation, and lateral and adventitious root initiation through hormonal (auxins) exchange (Zeffa et al., 2019), phosphate and potassium-solubilizing bacteria improved nutrient availability through rhizosphere acidification (Meena et al., 2014) some bacteria like zinc solubilizing bacteria can enter plant roots intercellularly and colonize the xylem of wheat and other crops without forming real symbiotic structures (Cocking, 2003) and improve zinc uptake by plant. Biofertilizers regulate soil biological properties improve plant growth and restore soil fertility (Singh et al., 2015).

The combined application of biofertilizers (viz. *Azotobacter*, Phosphorus Solubilizing Bacteria, Potassium Mobilizing Bacteria and zinc solubilizing bacteria) may have beneficial effects on wheat production. Vermicompost is produced by earthworms' digestion of organic waste. Vermicompost, being a rich source of macro and micronutrients, plant growth regulators, vitamins and beneficial microflora, is considered as the best organic source for maintaining soil fertility on a sustainable basis toward an eco-friendly environment (Edwards, 1998; Pathma and Sakthiwal, 2012). The use of

vermicompost as an organic fertilizer is considered a better alternative to inorganic fertilizers (Joshi et al., 2013) and rich in diversity of microbial populations (Edwards, 1998). Earthworms are mainly accountable for fragmentation and conditioning of the substrate, increasing area for microbial activity and significantly altering the biological activity (Dominguez, 2004). Vermicompost has been shown to have microbial and enzyme activities and growth regulators (Chaoui et al., 2003) as well as a beneficial effect on the growth of a variety of plants (Atiyeh et al., 2002). Vermicompost application to wheat (Yousefi and Sadeghi, 2014) as well as other crops has reduced the requirement of chemical fertilizers. Keeping this in view, the present study was undertaken to find out the suitable combination of vermicompost and biofertilizers which can boost biological property of soil and better yield of scented wheat.

Materials and Methods

A field experiment was conducted to study the soil microbial dynamics and enzyme activities as influenced by biofertilizers and split application of vermicompost in the rhizosphere of wheat (*Triticum aestivum* L.) during 2017-18 and 2018-19 at Instructional Farm, Rajasthan College of Agriculture, Udaipur. The region comes under the agro-climatic zone IVa (Sub-Humid Southern Plain and Aravalli Hills) of Rajasthan. The wheat crop experienced maximum and minimum temperature range between 28.56 to 37.29°C and 8.81 to 19.29°C during rabi 2017-18, respectively. The corresponding temperature fluctuations during second year (2018-19) of experimentation was 27.58 to 33.70°C and 8.34 to 17.70°C, respectively.

The total amount of rainfall received in both the years was 10 and 15 mm during 2017-18 and 2018-19, respectively. The texture of soil was clay loam (sand 38.82%, silt 26.58% and clay 34.60 %). The soils were slightly alkaline, medium in available nitrogen, phosphorus and high in available potassium. The initial values of soil properties are given in Table 1. The study was carried out on wheat var Raj-4037 with different biofertilizers and vermicompost treatments during two consecutive rabi seasons. For conducting experiments, 20 treatment combinations consisting five levels of biofertilizers (B₁: Control, B₂: *Azotobacter*, B₃: *Azotobacter* + PSB, B₄: *Azotobacter* + PSB + KMB and B₅: *Azotobacter* + PSB + KMB + ZnSB) and four levels of vermicompost (V₁: Control, V₂: 100% VC at sowing, V₃: 50% VC at sowing+50% VC at tillering and V₄: 75% VC at sowing+25% VC at tillering) were selected. During both the years 60 kg ha⁻¹ N and 40 kg ha⁻¹ P₂O₅ were applied in the soil as initial nutrient requirements.

Ploughing and harrowing operations were done using tractor drawn cultivator and disc harrow, and inter cultivations were done 25 and 45 days after sowing. The wheat variety of Raj-4037 was sown at a spacing of 22.5 cm x 10 cm @ 125 kg ha⁻¹ on 29th November during 2017-18 and 2018-19, respectively. The

fertilizer sources used were urea and DAP. Biofertilizers viz. *Azotobacter* and PSB were obtained from the Department of Soil Science and Agricultural Chemistry while KMB and ZnSB were obtained from the Department of Molecular Biology and Biotechnology, Rajasthan College of Agriculture, MPUAT, Udaipur. For the seed inoculation a plastic bag was used and put the seed in the bag. Added required quantity of biofertilizers (5 ml kg^{-1} seed of each biofertilizers) in the bag and twisted the bag until all the seeds were uniformly wetted. After this opened the bag and seeds were spread under shade for 20-30 minutes.

At firstly seeds were coated with *Azotobacter* after that used phosphorus solubilizing bacteria (*Bacillus megatherium* var. *phosphaticum*), potassium mobilizing bacteria (*Fraturia aurentia*) and zinc solubilising bacteria (*Bacillus megatherium*). After seed treatment done, seeds were sown in each marked plots. Vermicompost was obtained from Dairy Farm of Rajasthan College of Agricultural, MPUAT, Udaipur.

The calculated amount of vermicompost was incorporated into the soil at the time of sowing (Basal application) and tillering stage as per the treatments. The detail of nutrients present in vermicompost is given in Table 2. The crop growing period was from November to April in both the years and also all other weather parameters were normal during both the years. The previous crop grown at the experimental site was sorghum and left fallow during rainy and summer. The crop was irrigated seven times (10.2 mm) at critical stages and harvested on 8-04-2018 and 10-04-2019. Crop was harvested manually and post

harvested, the grain and straw yield were air dried and weighed. For soil analysis, soil samples up to 0-15 cm depth was drawn from different sites of the field and a representative composite sample was prepared by mixing for biological analysis using standard methods. Immediately after collection, portion of the respective soil samples were stored at 4°C in a refrigerator for further biological analysis with the help of standard methods.

The details of biological properties were determined and the methods followed for determination are given in Table 1. The microbial population in the soil was enumerated by serial dilution (Allen, 1959) and plating the appropriate dilutions in the media were used nutrient extract agar for bacteria, peptone dextrose agar medium for fungi and casein agar (SCA) is used for the detection of actinomycetes. The plates were incubated at room temperature ($30 \pm 2^{\circ}\text{C}$). The colonies were counted and expressed as population per gram on dry basis. The experimental data on soil biological properties and wheat yield were subjected to Fisher's Method of Analysis of Variance (ANOVA) (Gomez and Gomez, 1984). The pooled analysis was also done for soil biological properties, grain and straw yield. All the data were analyzed and the results were described and discussed at a probability level of 5% and correlation study was done as suggested by Gomez and Gomez (1984).

Results and Discussion

The perusal of data showed that microbial biomass, carbon and nitrogen increased significantly ($p < 0.05$) with the application of biofertilizers and vermicompost in post harvest soil

Table 1: Chemical and biological properties of soil before initiation of experiment

Soil properties	Values	Methods adopted
Chemical properties		
Soil pH (1:2 soil water suspension)	8.24	Potentiometric method using pH meter Richards (1954)
Electrical conductivity (dS m^{-1})	0.83	Using solubridge method (Conductivity meter) Richards (1954)
Organic carbon (%)	0.56	Walkley and Black wet oxidation method (Walkley and Black (1934))
Available N (kg ha^{-1})	251.24	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P_2O_5 (kg ha^{-1})	18.00	Olsen's method (Olsen <i>et al.</i> (1954))
Available K_2O (kg ha^{-1})	443.50	Flame photometer method (Richards (1954)
Biological properties		
Microbial biomass carbon (mg kg soil^{-1})	168.12	Chloroform fumigation-extraction method by Vance <i>et al.</i> (1987)
Microbial biomass nitrogen (mg kg soil^{-1})	24.74	Chloroform-Fumigated incubation method by Shen <i>et al.</i> (1984)
Bacterial population (CFU g^{-1} of soil)	54.9×10^7	Allen, (1959)
Fungal population (CFU g^{-1} of soil)	20.4×10^5	Allen, (1959)
Actinomycetes population (CFU g^{-1} of soil)	21.3×10^6	Allen, (1959)
Dehydrogenase activity ($\mu\text{g TPF g soil } 24 \text{ hr}^{-1}$)	8.80	Casida <i>et al.</i> (1964)
Acid phosphatase activity (g PNP g soil^{-1})	16.01	Tabatabai and Bremner, (1969)

Table 2: Nutrient composition of vermicompost used in the experiments

Nutrients	pH	OM (%)	C/N	N (%)	P_2O_5 (%)	K_2O (%)
Vermicompost (2017-18)	7.82	48.92	15/1	2.26	0.98	1.04
Vermicompost (2018-19)	7.80	49.09	15/1	2.20	0.91	1.08

Table 3: Effect of biofertilizers and split application of vermicompost on soil biological properties (Mean data of 2017-18 and 2018-19)

Treatments	Soil microbial biomass C (mg kg ⁻¹)	Soil microbial biomass N (mg kg ⁻¹)	Dehydrogenase activity (µg TPF kg ⁻¹ 24hr ⁻¹)	Acid phosphatase activity (g PNP g ⁻¹ hr ⁻¹ soil)
Biofertilizers				
B ₁ (Control)	173.27	25.05	9.38	18.28
B ₂ (<i>Azotobacter</i>)	199.75	26.36	9.92	21.54
B ₃ (Azot.+PSB)	213.31	28.27	10.66	24.06
B ₄ (Azot.+PSB+KMB)	215.17	31.29	11.43	25.32
B ₅ (Azot.+PSB+KMB+ZnSB)	219.49	31.47	11.99	26.39
SEm±	1.54	0.24	0.09	0.17
C.D. (P=0.05)	4.37	0.69	0.25	0.49
Vermicompost				
V ₁ (Control)	173.72	24.41	9.34	18.29
V ₂ (100% VC at sowing)	213.31	29.63	10.43	22.15
V ₃ (50% VC at sowing+50% VC at tillering)	215.70	30.10	11.50	26.06
V ₄ (75% VC at sowing+25% VC at tillering)	213.27	29.80	11.44	25.98
SEm±	1.38	0.21	0.08	0.15
C.D. (P=0.05)	3.91	0.62	0.22	0.44

CD- Critical Difference; SEm± sum error of mean; Azot. *Azotobacter*; PSB- Phosphorus solubilizing bacteria; KMB- Potash Mobilizing bacteria; ZnSB- Zinc solubilizing bacteria and VC-Vermicompost

Table 4: Microbial population in rhizosphere of wheat as influenced by biofertilizers and split application of vermicompost (Mean data of 2017-18 and 2018-19).

Treatments	Bacteria (10 ⁷ CFU g ⁻¹)	Fungi (10 ⁵ CFU g ⁻¹)	Actinomycetes (10 ⁶ CFU g ⁻¹)
Biofertilizers			
B ₁ (control)	59.46	21.37	21.02
B ₂ (<i>Azotobacter</i>)	63.38	24.80	24.10
B ₃ (Azot.+PSB)	65.32	26.41	26.79
B ₄ (Azot.+PSB+KMB)	70.28	28.77	29.23
B ₅ (Azot.+PSB+KMB+ZnSB)	72.13	30.08	30.46
SEm±	0.29	0.16	0.17
C.D. (P=0.05)	0.81	0.46	0.47
Vermicompost			
V ₁ (Control)	58.84	21.39	20.73
V ₂ (100% VC at sowing)	63.89	25.43	24.46
V ₃ (50% VC at sowing+50% VC at tillering)	71.14	29.32	30.16
V ₄ (75% VC at sowing+25% VC at tillering)	70.57	29.00	29.94
SEm±	0.26	0.14	0.15
C.D. (P=0.05)	0.73	0.41	0.42

CD- Critical Difference; SEm± sum error of mean; Azot. *Azotobacter*; PSB- Phosphorus solubilizing bacteria; KMB- Potash Mobilizing bacteria; ZnSB- Zinc solubilizing bacteria and VC-Vermicompost

after harvest of wheat crop (Table 3). Amongst biofertilizers treatments, the highest mean microbial biomass carbon (219.49 mg kg⁻¹) was obtained from the application of *Azotobacter* + PSB + KMB + ZnSB (B₅), while the lowest was observed in control.

Treatment B₅ remaining at par with *Azotobacter* + PSB + KMB (B₄) and on par with rest of the treatment. Treatment B₄ and B₃ was also found at par with each other. The mean microbial biomass carbon increased up to 26.68% under the application of

Azotobacter + PSB + KMB + ZnSB (B₅) as compared to control (no inoculation). The microbial biomass nitrogen showed same response with biofertilizers treatments. The mean microbial biomass nitrogen increased up to 25.63 % under the application of *Azotobacter* + PSB + KMB + ZnSB (B₅) as compared to control (no inoculation). However, it was statistically at par with *Azotobacter* + PSB + KMB. By and large, a consistence increase in soil microbial biomass was noticed due to the application of different biofertilizers in the soil, which are mineralized rapidly

Fig. 1 : Interaction effect between biofertilizers and vermicompost on (a) microbial biomass carbon and (b) bacterial population of wheat (Mean data of 2017-18 and 2018-19)

organic substances by the action of microbial cells and increase the soil microbial biomass carbon and nitrogen. Singh *et al.*, (2015) reported higher values of soil microbial biomass carbon and nitrogen with microbial inoculants. Similar findings were also reported by Behera *et al.*, (2007). The data further revealed that the higher mean microbial biomass carbon (24.17%) and nitrogen (23.31%) were recorded under the application of V₃ treatment in comparison to control (Table 3). However, treatment V₃, V₄ and V₂ remained at par with each other in microbial biomass carbon as well as nitrogen. There was significant increase in vermicompost amended soil over the control. This increment in microbial

biomass carbon and nitrogen were mainly due to build up soil organic matter and improve microbial activity in the soil (Cerny *et al.*, 2008; Ghosh *et al.*, 2013). These findings also supported by Tu *et al.*, 2005 who observed that higher soil biomass carbon and nitrogen in organic amendment soils.

The perusal of data revealed that dehydrogenase and acid phosphatase enzymatic activities improved significantly ($p < 0.05$) in the rhizosphere of inoculated treatments as compared to non-inoculated treatments (Table 3). Amongst different biofertilizers practices, B₅ treatment recorded significantly higher

Fig. 2 : Interaction effect between biofertilizers and vermicompost on: (a) Grain yield; (b) Straw yield of wheat (Mean data of 2017-18 and 2018-19).

dehydrogenase activity ($11.99 \mu\text{g TPF kg}^{-1} 24 \text{ hr}^{-1}$) and it was on par with the treatments. The acid phosphatase activity showed similar trend in response of biofertilizers. The mean dehydrogenase activity and acid phosphatase activity in post harvest soil increased by 27.83 and 44.37 % under B_5 treatment as compared to control plots (no inoculation), respectively. Dehydrogenase activity reflects the total oxidative activity of viable soil microflora and is directly related to the change in microbial biomass and activities as an application of biofertilizers. The enzymatic activity in the soil is of microbial origin and is

derived from intracellular, cell-associated or free enzymes. The greater biological activities in the soil due to biofertilizers inoculation increase dehydrogenase and acid phosphatase activities (Saini *et al.*, 2005, Prasad *et al.*, 2016). Further, analysis of data showed that the split application of vermicompost significantly ($p < 0.05$) increased dehydrogenase and acid phosphatase activities in post harvest soil (Table 3). The maximum dehydrogenase enzyme activity ($11.50 \mu\text{g TPF kg}^{-1} 24 \text{ hr}^{-1}$) was obtained under V_3 treatment and it remained at par with V_4 treatment, except for V_2 and V_1 treatment. A similar trend in

Fig. 3: Effect of biofertilizers and vermicompost on grain and straw yield of wheat (Mean data of 2017-18 and 2018-19).

dehydrogenase activity was also observed in the acid phosphatase activity during the study. The mean dehydrogenase and acid phosphatase activity increased up to 23.13 and 42.48% under the application of V_3 treatment as compared to V_1 (control), respectively (Table 3). This increase might be due to manure which promote biological and microbial activities and accelerated the breakdown of organic substances in the added manure, which stimulated dehydrogenase activity (Liang *et al.*, 2014; Ghosh *et al.*, 2013; Wang *et al.*, 2007; Patidar *et al.*, 2019).

Soil microbial population like bacteria, fungi and actinomycetes in post harvest soil increased significantly ($p < 0.05$) under the inoculation with different biofertilizers and application of vermicompost (Table 4). The trend of bacterial, fungal and actinomycetes population in reference to biofertilizers were same in all the biofertilizer treatments. The significantly ($p < 0.05$) maximum bacterial (72.13×10^7 CFU g^{-1}), fungal (30.08×10^5 CFU g^{-1}) and actinomycetes population (30.46×10^6 CFU g^{-1}) were obtained under B_5 treatment while remained on par with rest of the treatments and minimum population were recorded under control (B_1). The results indicated that the mean bacterial, fungal and actinomycetes population significantly ($p < 0.05$) increased up to 21.31, 40.76 and 44.91 % under the application of B_5 as compared to control (B_1), respectively (Table 4). This may be attributed to the establishment of inoculated microbial cells and secretion of polysaccharides, which might have increased the growth of microbial population (Jilani *et al.*, 2007; Canbolat *et al.*, 2006; Brar *et al.*, 2017). Biofertilizers inoculated plots exhibited a higher population of microflora in general than initial sample

(Ramalakshmi *et al.*, 2008). The results further revealed that maximum population of bacteria (71.14×10^7 CFU g^{-1}), fungi (29.32×10^5 CFU g^{-1}) and actinomycetes (30.16×10^6 CFU g^{-1}) flourished in treatment V_3 and lowest population was obtained in control (Table 4). However, V_3 treatment remained at par with V_4 at tillering and on par with basal (V_2) application. The mean bacterial, fungal and actinomycetes population in post harvest soil increased up to 20.90, 37.07 and 45.49 % due to the application of 50% at sowing + 50% at tillering (V_3) as compared to control (Table 4). The increase in microbial population with the incorporation of organics (vermicompost) might be due to improvement of hydrothermal regime and supply of large amount of carbon, a major food source for several bacteria and all fungi involved in decomposition. Ghate *et al.* (1994). Split application of vermicompost significantly increased microbial population in the rhizosphere of chickpea (Patidar *et al.*, 2019).

The present study showed that grain and straw yields of wheat significantly increased ($p < 0.05$) with the application of biofertilizers and split application of vermicompost (Fig. 3). The maximum mean grain (4564.75 kg ha^{-1}) and straw yields (6606.7 kg ha^{-1}) were recorded with B_5 treatment and it was statistically at par with B_4 treatment. The mean grain and straw yields improved up to 26.41 and 24.54% with B_5 treatment as compared to control. The grain and straw yield were found superior with seed inoculation as compared to control and this could be assigned to better growth and development of plants with higher dry matter accumulation (Wu *et al.*, 2005 ; Meena and Maurya, 2017).

The grain and straw yields significantly ($p < 0.05$) increased with split application of vermicompost (Fig. 3). The maximum mean grain ($4587.25 \text{ kg ha}^{-1}$) and straw yield ($6648.50 \text{ kg ha}^{-1}$) were recorded under V_3 treatment which was significantly higher over the control as well as basal application of vermicompost (100% VC at sowing) and it remained at par with V_4 treatment. The mean grain and straw yield increased by 26.33 and 24.76 % under V_3 treatment as compared to control. The improvement in grain and straw yield with the application of vermicompost was due to the beneficial effect of vermicompost on nutrient availability. The more response of vermicompost as split application in terms of higher yield of wheat may be associated with continuous release of nutrients, including macro and micronutrients resulting higher availability of balanced plant nutrients in soil throughout the crop growth period, especially at critical stages of plants (Patidar et al., 2019; Bejbaruah et al., 2013).

The interaction effect between biofertilizers and vermicompost failed to produce significant influence on the microbial biomass nitrogen, dehydrogenase activity, phosphates activity, fungal population and actinomycetes population, while interaction effect of biofertilizers and vermicompost on soil microbial biomass carbon, bacterial population, grain yield and straw yield was found to be significant. Data outlined in Fig. 1, 2 showed that treatment combination B_5V_3 recorded significant higher microbial biomass carbon ($237.21 \text{ mg kg}^{-1}$) and bacterial population ($79.86 \times 10^7 \text{ CFU g}^{-1}$) in comparison to the remaining treatments due to the stimulation effect between biofertilizer and vermicompost on improving the physical properties of soil, increasing microflora activity in the soil. The results collaborates with the findings of Metin et al. (2010). Further, the treatment combination, (Fig. 2) B_5V_3 recorded significantly higher on grain ($5132.56 \text{ kg ha}^{-1}$) and straw yield ($7396.02 \text{ kg ha}^{-1}$) over other treatments, except B_4V_4 while lowest was observed under B_1V_1 treatment. It can be concluded that biofertilizers in combination with organic fertilizers (vermicompost) may increase availability and uptake of nutrients for wheat plants. These results were in the same line with those recorded by Shoman et al. (2006). It is concluded that seed inoculation with biofertilizers (*Azotobacter*+PSB+KMB+ZnSB) along with vermicompost (50% VC at sowing+50% VC at tillering) had positive effect on soil biological properties and also improved wheat production.

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Add-on Information

Authors' contribution: S. Aechra: Conduct/writing the manuscript; R.H. Meena: Planning and help in writing the

manuscript; S.C. Meena: Check the manuscript; S.L. Mundra: Check the manuscript; S.S. Lakhawat: Check the manuscript; A. Mordia: Help in statistical data; G. Jat: Statistical Analysis.

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References

- Allen, O.N.: Experiments in Soil Bacteriology. 3rd Edn. Burgess, Minnesota (1959).
- Atiyeh, R.M., S. Lee, C.A. Edwards, N.Q. Arancon and J.D. Metzger: The influence of humic acids derived from earthworms- processed organic wastes on plant growth. *Bioreso. Technol.*, **84**, 7-14 (2002).
- Behera, U.K., S. Pradhan and A.R. Sharma: Effect of integrated nutrient management practices on productivity of durum wheat (*Triticum durum*) in the vertisols of Central India. *Indian J. Agricul. Sci.*, **77**, 635-638 (2007).
- Bejbaruah, R., R.C. Sharma and P. Banik: Split application of vermicompost to rice (*Oryza sativa* L.): Its effect on productivity, yield components and N dynamics. *Orga. Agricul.*, **3**, 123-128 (2013).
- Brar, A., S.K. Gosal and S.S. Walia: Effect of biofertilizers and farmyard manure on microbial dynamics and soil health in maize (*Zea mays* L.) rhizosphere. *Chem. Sci. Revi. Lett.*, **6**, 1524-1529 (2017).
- Breiman, A. and D. Gaur: Wheat evolution. *Israel J. Plant Sci.*, **43**, 85-98 (1995).
- Canbolat, S., R.B. Cakmaker, F. Sahin and A. Aydm: Effect of plant growth-promoting bacteria and soil compaction on barley seedling growth, nutrient uptake, soil properties and rhizosphere microflora. *Biol. Fertil. Soils*, **42**, 350-357 (2006).
- Casida, L.E., D.A. Klien and T. Santoro: Soil dehydrogenase activity. *Soil Sci.*, **98**, 371-376 (1964).
- Cerny, J., J. Balik, M. Kulhanek and V. Neded: The changes in microbial biomass C and N in long-term field experiments. *Plant Soil Environ.*, **54**, 212-218 (2008).
- Chaoui, I., M. Zibiliske and T. Ohno: Effects of earthworm casts and compost on soil microbial activity and plant nutrient availability. *Soil Biol. Bioche.*, **35**, 295-302 (2003).
- Cocking, E.C.: Endophytic colonization of plant roots by nitrogen-fixing bacteria. *Plant Soil*, **252**, 169-175 (2003).
- Dominguez, J.: State of the art and new perspectives on vermicomposting research. In: Earthworm Ecology (Ed.: C.A. Edwards). pp. 401-424 (2004).
- Edwards, C.A.: Breakdown of animal, vegetable and industrial organic wastes by earthworms. In: Earthworm Ecology (Ed.: C.A. Edwards). CRC, Boca Raton, pp. 292-300 (1998).
- FAI :Fertiliser Statistics. The Fertiliser Association of India, New Delhi, 2017-18.

- Ghate, R.M., H.N. Rawankar, K. More and J. Miranjane: Residual effect of wheat straw and fertilizer applied to *kharif* mung on soil microbial population. *Madras Agril. J.*, **81**, 231-233 (1994).
- Ghosh, B.C., N. Bera, D. Das and D.K. Swain: Effect of varying soil and vermicompost mixtures on growing media and yield and quality of sweet corn. *Int. Confer. Food Agric. Sci.*, **55**, 38-42 (2013).
- Gomez, K.A. and A.A. Gomez: Statistical Procedures for Agricultural Research. John Willey and Sons, New York (1984).
- Jilani, G.A., R. M. Akram, F.Y. Ali, I. H. Hafeez Shamsi, A.N. Chaudhry and A.G. Chaudhry: Enhancing crop growth, nutrients availability, economics and beneficial rhizosphere microflora through organic and biofertilizers. *Annals. Microbiol.*, **57**, 177-183 (2007).
- Joshi, R., A.P. Vig and J. Singh: Vermicompost as soil supplement to enhance growth, yield and quality of *Triticum aestivum* L.: A field study. *Int. J. Recycl Org. Waste Agric.*, **2**, 16 (2013).
- Karchoo, D. and R. Razdan: Growth, nutrient uptake and yield of wheat as influenced by biofertilizers and nitrogen. *Ind. J. Agron.*, **51**, 37-39 (2006).
- Kawalekar, S.J.: Role of biofertilizers and biopesticides for sustainable agriculture. *J. Bio. Innov.*, **2**, 73-78 (2013).
- Liang, Q., H.Q. Chen, Y.S. Gong, H.F. Yang, M.S. Fan and Y. Kuzyakov: Effects of 15 years of manure and mineral fertilizers on enzyme activities in particle-size fractions in a North China Plain soil. *Europ. J. Soil Biol.*, **60**, 112-119 (2014).
- Meena V.S., B.R. Maurya and J.P. Verma: Does a rhizospheric microorganism enhance K⁺ availability in agricultural soils? *Microbiol. Res.*, **169**, 337-347 (2014).
- Meena, G. and B.R. Maurya: Potentiality of potassium solubilizing bacteria on enhancing the growth, yield and nutrient acquisition on wheat (*Triticum aestivum* L.). *Int. J. Curr. Microbiol. Appl. Sci.*, **6**, 2443-2450 (2017).
- Metin, T.A., G.B. Medine, C.C. Ramazan, O.F. Taskin and D. Sahin: The effect of PGPR strain on wheat yield and quality parameters. Proceeding of World Congress of Soil Science, Soil Solutions for a Changing World. Brisbane, Australia (2010).
- Olsen, S.R., C.V. Cole, F.S. Watanable and L.A. Dean: Estimation of available phosphorus in soil by extraction with sodium carbonate. Circular. USDA, 939 pages (1954).
- Pathma, J. and N. Sakthivel: Microbial diversity of vermicompost bacteria that exhibit useful agricultural traits and waste management potential. Springer Plus, **1**, pp. 1-19 (2012).
- Patidar, K.K., R.H. Meena, G. Jat, S.K. Sharma, H. Jat and V.S. Meena: Split application of vermicompost: Strategies to improve nitrogen use efficiency and productivity of chickpea. *Climate Change Environ. Sustain.*, **7**, 137-142 (2019).
- Prasad, S., I. Syed and P. Anuradha: Effect of zinc solubilizing microorganisms in enhancing enzyme activity and nutrient availability in groundnut grown on vertisol. *Int. J. Agricul. Sci.*, **8**, 2099-2102 (2016).
- Ramalakshmi, A., M. Iniyakumar and S.A. Raj: Influence of biofertilizers on soil physico-chemical and biological properties during cropping period. *Asian J. Bio Sci.*, **3**, 348-351 (2008).
- Richards, L.A.: Diagnosis and improvement of saline and alkali soils. United States Salinity Laboratory Staff. Agriculture Hand Book No. 60, USDA, Washington, DC, USA (1954).
- Saini, V.K., S.C. Bhandari, S.K. Sharma and J.C. Tarafdar: Assessment of microbial biomass under integrated nutrient management in soybean-wheat maize cropping sequence. *J. Indian Soci. Soil Sci.*, **53**, 346-351 (2005).
- Shen, S.M., G. Pruden and D.S. Jenkinson: Mineralization and immobilization of nitrogen in fumigated soil and the measurement of microbial biomass nitrogen. *Soil Biol. Bioche.*, **16**, 437-444 (1984).
- Shoman, H.A., A.M. Abo-Shtaia, K.A. El-Shouny and Abd M.A. El-Gawad: Effect of biological and organic fertilization on yield and its components of two wheat cultivars under Al-Wady Al Gadeed conditions. *Alex. J. Agron. Res.*, **51**, 49-65 (2006).
- Singh, R., S. Babu, R.K. Avasthe, G.S. Yadav, T.K. Chettri, C.D. Phempunadi and T. Chatterjee: Bacterial inoculation effect on soil biological properties, growth, grain yield, total phenolic and flavonoids contents of common buckwheat (*Fagopyrum esculentum* Moench) under hilly ecosystems of North-East India. *African J. Microbiol. Res.*, **9**, 1110-1117 (2015).
- Subbiah, B.V. and G.L. Asija: A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci.*, **25**, 259-260 (1956).
- Tabatabai, M.A. and J.M. Bremner: Use of nitrophenyl phosphate assay of soil phosphatase activity. *Soil Biol. Bioche.*, **1**, 301-307 (1969).
- Tu, C., J.B. Ristaino and S. Hu: Soil microbial biomass and activity in organic tomato farming systems: Effects of organic inputs and surface mulching. *Soil Biol. Bioche.*, **38**, 247-255 (2006).
- Vance, E.D., P.C. Brookes and D.S. Jenkinson: An extraction method for measuring soil microbial biomass carbon. *Soil Biol. Bioche.*, **19**, 703-707 (1987).
- Walkley, A. and I. A. Black: Rapid titration method for organic carbon of soil. *Soil Sci.*, **37**, 29-32 (1934).
- Wang, Y., J. Shi, H. Wang, Q. Lin, X. Chen and Y. Chen: The influence of soil heavy metals pollution on soil microbial biomass, enzyme activity, and community composition near a copper smelter. *Ecotoxicol. Environ. Safe.*, **67**, 75-81 (2007).
- Wu, S.C., Z.H. Cao, Z.G. Li, K.C. Cheung and M.H. Wong: Effects of biofertilizer containing N-fixer, P and K solubilizers and AM fungi on maize growth: A greenhouse trial. *Geoderma*, **125**, 155-166 (2005).
- Yousefi A. A. and M. Sadeghi: Effect of vermicompost and urea chemical fertilizers on yield and yield components of wheat (*Triticum aestivum*) in the field condition. *Int. J. Agric. Crop Sci.*, **7**, 1227-1230 (2014).
- Zeffa D. M., L.J. Perini, M.B. Silva, N.V. de Sousa, C. A. Scapim and A.L. M. Oliveira: *Azospirillum brasilense* promotes increases in growth and nitrogen use efficiency of maize genotypes. *PLoS ONE*, **14**, 1-19 (2019).