Influence of Different Nutrient Management Approaches on Soil Biological Properties under Maize Based Cropping System in Vertisol

ABSTRACT

An experiment was conducted at Zonal Agricultural and Horticultural Research Station, Hiriyur with four different nutrient management approaches during 3 consecutive years of 2019-20, 2020-21 and 2021-22. The experiment consist of 4 treatments, *viz.,* T_1 – Natural farming - Seed treatment with Beejamrutha + Ghana jeevamrutha @ 1000 kg ha^{-1} before sowing + Jeevamrutha @ 200 L ha^{-1} @ 15 days interval + mulching at 30 DAS; T_2 – Organic farming - Seed treatment with Rhizobium + PSB + N equivalent basis of vermicompost; T_3 – Package of Practice – Recommended dose of N, P_2O_5, K_2O and FYM; T_4 – Farmers practice - FYM @ 7 t ha^{-1} and 45: 115 kg ha^{-1} N, P_2O_5, respectively in a randomized complete block design (RCBD) with 5 replications. The results revealed that application of organic manures such as vermicompost and FYM and concoctions like jeevamrutha and ghanajeevamruta for 3 years has improved soil biological properties in both seasons. Treatments varied significantly among different nutrient management approaches with respect to dehydrogenase, urease, phosphatase and arylsulfatase activity in the rhizosphere soil of the summer and *kharif* maize. Significantly higher enzyme activities were noticed in organic farming treatment followed by package of practice and natural farming treatment. The lowest activities were observed in farmers practice treatment. Similarly, microbial biomass carbon, nitrogen, phosphorus and sulphur were highest in organic farming treatment and lowest in farmers practice treatment.

Key words: Natural farming, Organic farming, Package of practice, Farmers practice, Biological properties

1. INTRODUCTION

Soil microorganisms and enzymes play an important role in biogeochemical processes such as nutrient cycling, nutrient availability, nutrient uptake and also in soil formation [1]. This biological property is affected by soil pH, EC, temperature, moisture, nutrient status, and management practices [2]. Adopting integrated nutrient management practices (organic manures, liquid manures with fertilizers) and certified organic agriculture (organic manures and biofertilizers) can reduce reliance on chemical inputs as well as make agriculture environmentally and economically sound. Organic farming is a production system which largely excludes or avoids the use of chemical fertilizers, pesticides, growth regulators, preservatives, livestock feed additives and totally rely on crop residues, animal manures, legumes, green manures, off-farm wastes, mechanical cultivation, mineral nutrient bearing rocks and biological pest control to maintain soil health, supply plant nutrients and minimize insects, weeds and other pests. Organic farming systems rely on the management of soil organic matter to enhance the chemical, biological and physical properties of the soil. Soil fertility management in organic systems depends on 'biologically-derived nutrients' instead of using readily soluble forms of nutrients; less available forms of nutrients such as those in bulky organic materials. This requires release of nutrients to the plant *via* the activity of soil microbes and soil animals. Apart from organic farming, other farming system called natural farming also involves similar components, that mainly depends on the use of naturally available inputs [3]. Natural farming is a resource efficient farming system which minimizes the use of external resources and also restores the quality of soil and water resources. The importance of natural farming is to minimize the use of external inputs to the farm land and enriching soil through propagation of soil microbes. It encourages the natural symbiosis of soil micro flora and crop plants. Beejamrutha, jeevamrutha and ghanajeevamrutha are the major inputs used in natural farming which supply both micro and macronutrients, but most importantly enhances soil biological activity.

In view of the above facts, a study entitled "Influence of different nutrient management approaches on soil enzymes and biomass under maize based cropping sequences in *Vertisol*'' was undertaken in Horticultural Research Station (ZAHRS), Shivamogga and ZAHRS, Babbur farm, Hiriyur, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Iruvakki, Shivamogga,

2. MATERIAL AND METHODS

The materials and methods used to study the comparative effects of natural, organic, integrated and farmers practices and physical and chemical properties of soil have been described and presented here as per details given below:

2.1 Location of the experimental site

The experiment was conducted at Zonal Agricultural and Horticultural Research Station, Babbur farm, Hiriyur, situated in Central Dry Zone (Agro-Climatic Region IV) of Karnataka. The geographical reference point of the experimental site was 13º 57' North latitude and 75º 38' East longitude, with an altitude of 606 meters above mean sea level (MSL).

2.2 Soil properties

An experiment with different nutrient supplying approaches such as natural, organic, integrated system was conducted since 2019-20 at a fixed location under maize based cropping system. The treatment wise composite soil samples were collected from each replication at 0 to 15 cm depth before the cropping season and collected samples were grounded with a wooden pestle and morter and passed through 2 mm sieve to separate coarse fragments (> 2 mm) and stored in plastic bags. The processed soil samples were used for further analysis by following standard procedures

The soil belongs to clay loam texture and black in color. The initial soil analysis data (Table 1) indicated that the soil was moderately alkaline in reaction with a normal electrical conductivity and low in organic carbon. Further, the soil was low in available nitrogen status, medium status for available phosphorus and available potassium. The experimental site was deficient in zinc and iron and sufficient in copper andmanganese.

Table 1:Initial properties of the soil in the experimental site

Parameters	**Values**

Texture	Clay loam
Bulk density (Mg m^{-3})	1.16
Particle density (Mg m^{-3})	1.96
Maximum water holding capacity (%)	59.28
Porosity (%)	30.20
pH (1:2.5)	8.80
Electrical conductivity (1:2.5) (dS m^{-1})	0.48
Organic carbon (g kg^{-1})	4.12
Available N (kg ha^{-1})	265.41
Available P_2O_5 (kg ha^{-1})	40.52
Available K_2O (kg ha^{-1})	392.25
Exchangeable Ca [cmol (p+) kg^{-1}]	30.89
Exchangeable Mg [cmol (p+) kg^{-1}]	12.92
Available S (mg kg^{-1})	22.15
DTPA-Fe (mg kg^{-1})	4.16
DTPA-Mn (mg kg^{-1})	4.04
DTPA-Zn (mg kg^{-1})	0.33
DTPA-Cu (mg kg^{-1})	1.23

2.3 Weather conditions during the experiment

The monthly weather data such as rainfall, relative humidity, mean monthly maximum and minimum temperature during the experiment recorded from the agro meteorological observatory of Gramin Krushi Mausam Seva (GKMS) located at ZAHRS, Babbur farm, Hiriyur is presented in the Fig. 1. The mean monthly minimum temperature ranged from 14.2 to 21.6 °C and the mean monthly maximum temperature ranged from 27.7 to 36.1 °C during the crop growth period. The highest and lowest mean monthly minimum temperature was recorded during May and February, respectively, whereas the highest and lowest monthly maximum temperature was recorded during April and November, respectively. The mean monthly maximum relative humidity during the crop growth period ranged from 63 to 83 per cent, whereas the mean monthly minimum relative humidity during the crop growth period ranged from 27 to 47 per cent. The total rainfall received during crop growth period was 945.60 mm which was received from South-West and North- East monsoon. The highest rainfall was received during October (242.60 mm) followed by November (159.2 mm).

2.4 Cropping history of the experimental site

For the last two years (2019-20), experiments on different farming types are being conducted as permanent plots, consisting of natural, organic, conventional and Farmers practice plots. Under these plots, the maize crop was grown during summer and *Kharif* 2019 and 2020.

2.5 Experimental details

The experiment was laid out in a randomized block design with four different nutrient management approaches and five replications. The maize crop was grown during summer and *Kharif* 2021. The details of the treatments imposed in the experiment is given below;

List 1 :Treatment details of summer maize

T_1	Natural farming	Seed treatment with Beejamrutha + Ghanajeevamrutha @ 1000 kg ha^{-1} before sowing + Jeevamrutha @ 200 L ha^{-1} @ 15 days interval + mulching at 30 DAS
T_2	Organic farming	Seed treatment with *Rhizobium* + PSB + N equivalent basis of vermicompost
T_3	Package of Practice	Seed treatment with *Rhizobium* + PSB+ Recommended dose of FYM (10 t ha^{-1}) + 150:65:65 kg ha^{-1} N, P_2O_5, K_2O + $ZnSO_4$ @ 10 kg ha^{-1} + $FeSO_4$ @ 25 kg ha^{-1}
T_4	Farmers practice	FYM @ 7 t ha^{-1} and45: 115 kg ha^{-1} N, P_2O_5

List 2 :Treatment details of kharif maize

T_1	Natural farming	Seed treatment with Beejamrutha + Ghanajeevamrutha @ 1000 kg ha^{-1} before sowing + Jeevamrutha @ 200 L ha^{-1} @ 15 days interval + mulching at 30 DAS
T_2	Organic farming	Seed treatment with *Rhizobium* + PSB + N equivalent basis of vermicompost
T_3	Package of Practice	Seed treatment with *Rhizobium* + PSB+ Recommended dose of FYM (10 t ha^{-1}) + 100:50:25 kg ha^{-1} N, P_2O_5, K_2O + $ZnSO_4$ @ 10 kg ha^{-1}
T_4	Farmers practice	FYM @ 7 t ha^{-1} and45: 115 kg ha^{-1} N, P_2O_5

The result of analysis of FYM, vermicompost, jeevamrutha and Ghana jeevamrutha is given in Table 2.

Table 2 :Result of analysis of FYM, vermicompost, jeevamrutha and Ghana jeevamrutha

	Ghanajeevamrutha	**Jeevamrutha**	**Vermicompost**	**FYM**
Total nitrogen (%)	1.98	1.13	1.32	0.76
Total phosphorus (%)	0.62	0.26	0.47	0.41
Total potassium (%)	0.75	0.34	0.78	0.37
Total sulphur (%)	0.53	0.29	0.42	0.39
Total calcium (%)	0.82	0.78	1.12	1.04

Total magnesium (%)	0.62	0.52	0.82	0.76
Total zinc (ppm)	86.32	28.52	102.15	65.23
Total manganese (ppm)	112.23	21.05	121.25	98.23
Total copper (ppm)	48.22	6.25	45.17	42.15
Total iron (ppm)	821.14	232.12	2051	582.16

2.6 Soil sampling and analysis

The composite soil samples were collected from all the treatments and replications from 0-15 cm depth and samples were processed and analyzed for different parameters. The dehydrogenase activity (µg TPF g^{-1} soil day^{-1}) was determined by the procedure as given by [4]. The urease activity (µg p-^{1} nitrophenol g^{-1}soil hr^{-1}) was estimated as per the procedure given by [5]. The acid and alkaline phosphatase activities (µg NH_4-N g^{-1} soil 2 h^{-1}) were estimated as per the procedure given by [6]. The arylsulfataseactivity (µg p-nitrophenol g^{-1}soil hr^{-1}) was estimated as per the procedure given by [7]. The microbial biomass carbon was analyzed by following chloroform fumigation method. Ten grams of soil sample was fumigated for 24 hr. under vacuum in vacuum desiccator using ethanol-free chloroform. After fumigation, chloroform fumes were removed by evacuation. Non-fumigated and fumigated soil samples were extracted using 50 ml of 0.5 M K_2SO_4 and extracts were used for determining carbon [8] and nitrogen [9]. For the estimation of microbial biomass phosphorus, non-fumigated and fumigated soil samples were extracted using 50 ml of Bray’s No. 1 or Olsen’s extractant and extracts were used for determining microbial biomass phosphorus [10]. For the estimation of microbial biomass sulphur, non-fumigated and fumigated soil samples were extracted using 50 ml of 10 mM $CaCl_2$ and extracts were used for determining microbial biomass sulphur by turbidometry method [11].

3. RESULTS AND DISCUSSION

3.1 Dehydrogenase activity

Treatments varied significantly among different nutrient management approaches with respect to dehydrogenase activity in the rhizosphere soil of the summer and *kharif* maize (Table 3). Significantly higher activity of dehydrogenase enzyme was noticed in organic farming (113.45 and 95.64 µg TPF g^{-1} soil day^{-1}at 60 DAS and at harvest of summer maize respectively), which was at par with package of practice treatment (111.52 and 94.21 µg TPF g^{-1} soil day^{-1}at 60 DAS and at harvest, respectively). The lowest activity was observed in farmers practice treatment (83.32 and 63.34µg TPF g^{-1} soil day^{-1}at 60 DAS and at harvest, respectively).

Under maize crop, significantly higher dehydrogenase activity was observed under organic farming (117.18 and 99.90 µg TPF g^{-1} soil day^{-1}at 60 DAS and at harvest of summer maize, respectively) followed by package of practice (115.42 and 99.82 µg TPF g^{-1} soil day^{-1}at 60 DAS and at harvest, respectively) and natural farming treatments (107.50 and 89.70µg TPF g^{-1} soil day^{-1}at 60 DAS and at harvest, respectively). Significantly lowest activity was observed in farmers practice treatment (85.48 and 65.38µg TPF g^{-1} soil day^{-1}at 60 DAS and at harvest, respectively).

Table 3: Influence of nutrient management approaches on dehydrogenase and urease activity at different growth stages of summer and *kharif* maize under maize-maize cropping sequence in Vertisol

Treatments	Dehydrogenase (µg TPF g^{-1} soil day^{-1})				Urease (µg NH_4-N g^{-1} soil 2 h^{-1})			
	Summer maize		*Kharif maize*		Summer maize		*Kharif maize*	
	60 DAS	Harvest	60 DAS	Harvest	60 DAS	Harvest	60 DAS	Harvest
Natural farming	104.34	86.28	107.50	89.70	43.12	29.27	45.66	31.44
Organic farming	113.45	95.64	117.18	99.90	47.28	33.41	50.20	35.12
Package of practice	111.52	94.21	115.42	99.82	46.25	32.01	49.04	34.94
Farmers practice	83.32	63.34	85.48	65.38	28.31	15.85	30.08	18.00
S. Em±	4.50	4.67	0.96	1.18	2.48	1.46	0.70	0.44
C. D (5 %)	13.86	14.38	2.97	3.65	7.65	4.49	0.17	1.37

Dehydrogenase activity was strongly correlated with soil organic C content. Higher dehydrogenase activity in organic farming, package of practice and natural farming treatment may be owing to higher organic matter content. The effect of organic sources on enzyme activities is probably a combined effect of a higher degree of stabilization of enzymes to humic substances and an increase in microbial biomass with increased soil carbon concentration [12]. Studies comparing conventional and organic farming have reported an increase in dehydrogenase activity [13] and [14] in organically managed soils. Although these organic amendments can often contain enzymes, the increase in the activity of soils amended with organic residues is likely due to the stimulation of microbial activity rather than the direct addition of enzymes from organic sources [15].The dehydrogenase activity measured in this study increased from sowing to 60 DAS in summer and *kharif* maize and declined towards harvest. Similarly, [16] revealed that the dehydrogenase activity was maximum at panicle initiation stage and thereafter it decreased in rice at acidic sandy soils of Bhubaneswar, India.

3.2 Urease activity

The data with respect to urease activity in rhizosphere soil of the crop is presented in Table 3. Organic farming recorded significantly highest urease activity (47.28 and 33.41 µg NH_4-N g^{-1} soil 2 h^{-1}) as compared to package of practice (46.25 and 32.01 µg NH_4-N g^{-1} soil 2 h^{-1}) and natural farming (43.12 and 29.27 µg NH_4-N g^{-1} soil 2 h^{-1}) treatments. Significantly lower urease activity observed under farmers practice (28.31 and 15.85 µg NH_4-N g^{-1} soil 2 h^{-1}) at 60 DAS and at harvest of summer maize, respectively. Similarly, under *kharif* maize crop, organic farming recorded significantly highest urease activity (50.20 and 35.12 µg NH_4-N g^{-1} soil 2 h^{-1}) followed by package of practice (49.04 and 34.94 µg NH_4-N g^{-1} soil 2 h^{-1}) and natural farming (45.66 and 31.44 µg NH_4-N g^{-1} soil 2 h^{-1}) treatments. Farmers practice treatment recorded lower activity (30.08 and 18 µg NH_4-N g^{-1} soil 2 h^{-1}) at 60 DAS and at harvest, respectively than other treatments.

The increase in urease activity with application of organic manures might be due to increasing population of microorganisms like bacteria and fungi and increased availability of substrate through organic manures. Similar to the present study, [15] observed significantly higher urease activity in the organic system than in the conventional system. Our findings were in line with the findings of [14] and [17]. This finding suggests that organic manures improves microbial N transformation in the soil by providing sufficient available C sources.

Irrespective of the nutrient management approaches, the urease activity increased from sowing to 60 DAS and thereafter decreased at harvest of both the crops. The results corroborate the findings of [18], which reported highest urease activity in organic method at 30 and 60 DAS and at harvest and, it was superior to inorganic and natural farming which were at a par with each other under maize crop.

3.3 Phosphatase activity

The data furnished in Table 4 indicated the phosphatase activity in the rhizosphere soil as influenced by different nutrient management approaches. Under summer maize crop, maximum acid phosphatase activity was noticed in organic farming(27.95 and 20.12 µg p-nitrophenol g^{-1}soil hr^{-1}) as compared to package of practice (26.12 and 19.29 µg p-nitrophenol g^{-1}soil hr^{-1}) and natural farming (24.18 and 17.71 µg p- nitrophenol g^{-1}soil hr^{-1}) treatments at 60 DAS and at harvest, respectively. Statistically lower activity recorded with farmers practice treatment(8.18 and 6.25 µg p- nitrophenol g^{-1}soil hr^{-1}) at 60 DAS and at harvest, respectively.

Statistically maximum alkaline phosphatase activity was noticed in organic farming (35.62 and 30.12 µg p- nitrophenol g^{-1}soil hr^{-1}) as compared to package of practice (33.24 and 26.23 µg p- nitrophenol g^{-1}soil hr^{-1}) and natural farming treatments(29.58 and 24.01 µg p- nitrophenol g^{-1}soil hr^{-1}) at 60 DAS and at harvest, respectively. The significantly lower activity of alkaline phosphatase enzyme was recorded in farmers practice treatment(11.21 and 8.58 µg p- nitrophenol g^{-1}soil hr^{-1}) at 60 DAS and at harvest, respectively.

Under *kharif* maize crop, among the nutrient management approaches, significantly higher acid phosphatase was noticed in organic farming (29.06 and 22.80 µg p- nitrophenol g^{-1}soil hr^{-1}) compared to package of practice (27.76 and 21.58 µg p- nitrophenol g^{-1}soil hr^{-1}) and natural farming treatments (25.06 and 18.02 µg p- nitrophenol g^{-1}soil hr^{-1}), respectively. Significantly lower acid phosphatase activity was recorded in farmers practice treatment(9.80 and 7.68 µg p- nitrophenol g^{-1}soil hr^{-1}) at 60 DAS and at harvest, respectively.

Organic farming recorded significantly highest alkaline phosphatase activity (37.85 and 32.20 µg p- nitrophenol g^{-1}soil hr^{-1}) compared to package of practice (34.46 and 27.75 µg p-nitrophenol g^{-1}soil hr^{-1}) and natural farming treatments(31.98 and 25.18 µg p- nitrophenol g^{-1}soil hr^{-1}) at 60 DAS and at harvest, respectively. However, lower activity was recorded in farmers practice treatment(13.21 and 10.99 µg p- nitrophenol g^{-1}soil hr^{-1}) at 60 DAS and at harvest, respectively.

Table 4: Influence of nutrient management approaches on acid and alkaline phosphatase activity (µg p-nitrophenol g^{-1} soil h^{-1}) at different growth stages of summer and *kharif* maize under maize-maize cropping sequence in *Vertisol*

Treatments	Summer maize				*Kharif maize*			
	Acid phosphatase		Alkaline phosphatase		Acid phosphatase		Alkaline phosphatase	
	60 DAS	Harvest	60 DAS	Harvest	60 DAS	Harvest	60 DAS	Harvest
Natural farming	24.18	17.71	29.58	24.01	25.06	18.02	31.98	25.18
Organic farming	27.95	20.12	35.62	30.12	29.06	22.80	37.85	32.20
Package of practice	26.12	19.29	33.24	26.23	27.76	21.58	34.46	27.75

Farmers practice	8.18	6.25	11.21	8.58	9.80	7.68	13.21	10.99
S. Em±	0.87	0.60	1.37	1.04	0.29	0.24	1.26	1.29
C. D (5 %)	2.68	1.86	4.22	3.20	0.91	0.74	3.89	3.97

The results infer that organic fertilizers enhance the microbial activity in the soil, as well as enzyme cell multiplication by creating a favorable environment. But the degree of variation depends on the interaction between microbial communities and the substrate quality in the soil. Similar effects of quality and quantity of organic amendment on microbial dynamics of the soil was mentioned in the studies of [19]. [20]Observed an increase in enzymatic activity as a result of microbes that utilizes nutrients delivered by organic material, leading in an increase in microbial activity. Acid phosphatase activity was lesser than alkaline phosphatase for the entire crop growth period due to alkaline soil reaction. Maximum activity of acid and alkaline phosphatase was observed at 60 DAS due to increased root exudates production at critical crop growth stages. These results were supported by [21] who observed higher phosphatase activity during initial days of incubation.

3.4 Arylsulfatase activity

Significant differences in soil arylsulfatase activity was observed at different crop growth stages (60 DAS and at harvest) as influenced by different nutrient management approaches (Table 5). Among the nutrient management approaches, organic farming recorded significantly higher arylsulfatase activity (16.12 and 12.95 µg p- nitrophenol g^{-1}soil hr^{-1} at 60 DAS and at harvest of summer maize, respectively) compared to package of practice (15.23 and 10.62 µg p- nitrophenol g^{-1}soil hr^{-1}) and natural farming (12.23 and 9.34 µg p- nitrophenol g^{-1}soil hr^{-1}) treatments at 60 DAS and at harvest, respectively. However, lower enzyme activity was recorded in farmers practice treatment(7.42 and 6.21 µg p-nitrophenol g^{-1}soil hr^{-1}) at 60 DAS and at harvest, respectively.

Under *kharif* maize crop, organic farming recorded significantly higher arylsulfatase activity (17.25 and 13.96 µg p- nitrophenol g^{-1}soil hr^{-1}) compared to package of practice (16.01 and 11.23 µg p- nitrophenol g^{-1}soil hr^{-1}) and natural farming (13.25 and 10.98 µg p-nitrophenol g^{-1}soil hr^{-1}) treatments at 60 DAS and at harvest, respectively. However, lower activity recorded in farmers practice (8.12 and 7.84 µg p- nitrophenol g^{-1}soil hr^{-1}) at 60 DAS and at harvest, respectively.

Table 5: Influence of nutrient management approaches on arylsulfatase activity at different growth stages of summer and *kharif* maize under maize-maize cropping sequence in *Vertisol*

Treatments	**Arylsulfatase activity (µg p-nitrophenol g^{-1} of soil h^{-1})**			
	Summer maize		***Kharif* maize**	
	60 DAS	**Harvest**	**60 DAS**	**Harvest**
Natural farming	12.23	9.34	13.25	10.98
Organic farming	16.12	12.95	17.25	13.96
Package of practice	15.23	10.62	16.01	11.23

Farmers practice	7.42	6.21	8.12	7.84
S. Em±	0.46	0.35	0.46	0.45
C. D (5 %)	1.42	1.07	1.43	1.38

The higher arylsulfatase activity in organic farming, package of practice and natural farming treatments could be attributed to the addition of C substrate and the intra- and extracellular enzymes contained in the added organic amendment. Similarly, in a long term experiment the arylsulfatase activity increased from 10.5 µg p-nitrophenol g^{-1} h^{-1} in control to 13. 5 and 15 µg p-nitrophenol g^{-1} h^{-1} in medium and high manure application rates [22]. [23]Also reported the higher arylsulfatase activity in organic manure applied soil. The higher arylsulfatase activity at 60 DAS might be due to increased production of crop root exudates, enhanced root activity and higher rate of mineralization of nutrients in the soil.

4.2.3.5 Microbial biomass carbon

The appraisal of the results of the present study (Table 6) demonstrated that microbial biomass carbon was significantly affected by nutrient management approaches and crop growth stages. Highest biomass carbon was recorded in organic farming (237.62 and 203.17 mg kg^{-1} at 60 DAS and at harvest of summer maize, respectively), which was statistically at par with package of practice (228.91 and 196.02 mg kg^{-1}) and natural farming (223.26 and 188.66 mg kg^{-1}) treatments. Significantly lower biomass carbon was observed in farmers practice treatment (175.49 and 140.02 mg kg^{-1}) at 60 DAS and at harvest, respectively.

Under *kharif* maize crop, in organic farming recorded higher biomass carbon (252.68 and 214.47 mg kg^{-1} at 60 DAS and at harvest, respectively), which was at par with package of practice (244.78 and 206.91 mg kg^{-1}) and natural farming (232.62 and 194.87 mg kg^{-1}) treatments. Significantly lower biomass carbon was observed in farmers practice treatment (184.34 and 146.53 mg kg^{-1}) at 60 DAS and at harvest, respectively.

Table 6: Influence of nutrient management approaches on microbial biomass carbon and nitrogen (mg kg^{-1}) at different growth stages of summer and *kharif* maize under maize-maize cropping sequence in *Vertisol*

Treatments	**Microbial biomass carbon**				**Microbial biomass nitrogen**			
	Summer maize		***Kharif maize***		**Summer maize**		***Kharif maize***	
	60 DAS	**Harvest**	**60 DAS**	**Harvest**	**60 DAS**	**Harvest**	**60 DAS**	**Harvest**
Natural farming	223.26	188.66	232.62	194.87	23.75	20.89	24.75	21.58
Organic farming	237.62	203.17	252.68	214.47	26.28	22.60	28.23	23.86
Package of practice	228.91	196.02	244.78	206.91	24.61	21.73	26.32	22.94
Farmers practice	175.49	140.02	184.34	146.53	17.38	13.97	18.25	14.62
S. Em±	7.75	8.68	10.38	9.81	1.12	0.73	1.05	1.18
C. D (5 %)	23.86	26.75	31.98	30.22	3.46	2.26	3.24	3.64

Results from the present experiment demonstrated that difference in C inputs (including quantity and quality) can significantly impact microbial biomass and activity under maize crop. Over the period of experimentation, organic amendments generally increased soil microbial biomass C and activity. However, various qualities of organic substrates may differentially impact soil microbes since substrate composition has profound influence on microbial utilization of C and nutrients in the substrate. A marked increase in microbial biomass carbon induced by organic manure addition to the soil has been reported in some previous studies [24].

In addition to the higher organic matter, the manured plots have better moisture retention capacity, it may also be suggested that the microbial populations in these soils are better able to survive the effects of moisture deficit than the biomass in those treated with mineral fertilizers [25]. These increases are most likely related to the incorporations of plant residues and dead roots, which provided substantial energy for the growth of the microbial biomass.

The differences in microbial biomass and activity under different organic amendments may have implications for nutrient availability to crops. High microbial biomass and activity often lead to high nutrient availability to crops through enhancing both the microbial biomass turnover and the degradation of non-microbial organic materials [26]. Enhanced N mineralization by stimulated microbial biomass and activity has also been observed in previous experiments at other locations. For example, [17] reported that high microbial biomass carbon can indicate an increase in N storage in soil under celery growing field soil in North China.

Irrespective of treatments, microbial biomass carbon was influenced by the crop growth stages and maximum value was obtained at 60 DAS of summer and *kharif* maize crop and declined thereafter which might be due to the less root exudation coupled with the soil drainage at maturity. It might be expected that at early stage of crop microbes will consume the fresh inputs and thereafter the microbial biomass maintained in the soil would decline at harvesting stage due to less availability of labile carbon.

3.6 Microbial biomass nitrogen

The data pertaining to microbial biomass nitrogen as influenced by different nutrient management approaches under both the crops is furnished in Table 6. Significantly higher biomass nitrogen was registered in organic farming (26.28 and 22.60 mg kg^{-1} at 60 DAS and at harvest of summer maize, respectively), which was statistically at par with package of practice (24.61 and 21.73 mg kg^{-1}) and natural farming (23.75 and 20.89 mg kg^{-1}) treatments. Significantly lower biomass nitrogen was observed in farmers practice treatment (17.38 and 13.97 mg kg^{-1}) at 60 DAS and at harvest, respectively.

Under *kharif* maize crop, organic farming recorded higher biomass nitrogen (28.23 and 23.86 mg kg^{-1} at 60 DAS and at harvest, respectively), which was at par with package of practice (26.32 and 22.94 mg kg^{-1}) and natural farming (24.75 and 21.58 mg kg^{-1}) treatments. Significantly lower biomass nitrogen was observed in farmers practice (18.25 and 14.62 mg kg^{-1}) at 60 DAS and at harvest, respectively.

The microbial biomass nitrogen values were higher in soil under organic farming than in conventional treatments. This could be linked with high organic carbon and nitrogen values in organically amended soil which imparted a favorable environment for microbes to grow and proliferate. In organically managed systems, microbial biomass nitrogen is considerably and rapidly enhanced by the supplementation of organic matter and reprocessing of C and N for nutrient availability and energy gains. These results are supported by previous findings of [24] who observed increased soil microbial biomass under long-term manure application, as manures provide better soil conditions for crop growth.

In all the treatments, the microbial biomass nitrogen was higher at 60 DAS and decreased with the advancement of crop growth stages. Similar result was observed by [17], who noticed highest microbial properties such as the amount of microbial biomass carbon and microbial biomass nitrogen accumulation in 100 % NPK + FYM at maximum tillering stage of the rice crop.

3.7 Microbial biomass phosphorus

The data pertaining to microbial biomass phosphorus in soil is furnished in Table 7. The different nutrient management approaches had significant effect on microbial biomass phosphorus at all the growth stages of summer and *kharif* maize. Higher microbial biomass phosphorus was registered in organic farming (6.42 and 5.28 mg kg^{-1} at 60 DAS and at harvest of summer maize, respectively) followed by package of practice (5.72 and 4.71 mg kg^{-1}), which was statistically at par with natural farming treatment (5.36 and 4.15 mg kg^{-1}). Significantly lower biomass phosphorus was observed in farmers practice treatment (3.69 and 3.22 mg kg^{-1}) at 60 DAS and at harvest, respectively.

Under *kharif* maize crop, organic farming recorded higher biomass phosphorus (7.33 and 6.22 mg kg^{-1} at 60 DAS and at harvest, respectively) followed by package of practice (6.61 and 5.39 mg kg^{-1}) and natural farming (6.05 and 4.48 mg kg^{-1}) treatments. Significantly lower biomass phosphorus was observed in farmers practice treatment (4.06 and 3.37 mg kg^{-1}) at 60 DAS and at harvest, respectively.

Since addition of organic fertilizer increases mobilization of phosphorus and microbial activities in soil, it might also be a contributing factor in improving nutrition, as well as root system. Similar studies by other worker [27] have shown that the organic manures have beneficial effect on the microbial biomass phosphorus in soil. This is not too surprising, given that organic manures not only provides the necessary energy and nutrients to support an increase in microbial biomass, but also improves soil aeration and water retention [25].

Table 7: Influence of nutrient management approaches on microbial biomass phosphorus and sulphur (mg kg^{-1}) at different growth stages of summer and *kharif* maize under maize-maize cropping sequence in *Vertisol*

Treatments	**Microbial biomass phosphorus**				**Microbial biomass sulphur**			
	Summer maize		***Kharif maize***		**Summer maize**		***Kharif maize***	
	60 DAS	**Harvest**	**60 DAS**	**Harvest**	**60 DAS**	**Harvest**	**60 DAS**	**Harvest**
Natural farming	5.36	4.15	6.05	4.48	7.14	6.23	7.68	6.48
Organic farming	6.42	5.28	7.33	6.22	9.27	7.52	10.61	8.79
Package of practice	5.72	4.71	6.61	5.39	8.49	6.29	9.57	6.63
Farmers practice	3.69	3.22	4.06	3.37	5.44	4.34	5.71	4.69
S. Em±	0.26	0.25	0.27	0.19	0.39	0.27	0.47	0.39
C. D (5 %)	0.79	0.76	0.83	0.60	1.19	0.82	1.46	1.21

The microbial biomass phosphorus increased at the start of the crop growth period and highest value was recorded at 60 DAS. After 60 DAS, a declining trend was recorded, which might be due to the depleting and washing out of these mineralizable substances during the final days of crop growth period. A similar trend was reported by [13] during the incubation period in soil amended with organic sources. Before sowing of maize, the biomass P was lower compared to harvest stage, which represents the microbial turnover that could release nutrients for plant uptake in later phases.

3.8 Microbial biomass sulphur

The data indicated in Table 7 found that microbial biomass sulphur differed significantly among the different nutrient management approaches. At 60 DAS and at harvest of summer maize, among the nutrient management approaches, organic farming recorded significantly highest biomass sulphur (9.27 and 7.52 mg kg^{-1}), which was followed by package of practice (8.49 and 6.29 mg kg^{-1}). The lower biomass sulphur was observed in farmers practice (5.44 and 4.34 mg kg^{-1}), which differed significantly from natural farming treatment (7.14 and 6.23 mg kg^{-1}) at 60 DAS and at harvest, respectively.

Under *kharif* maize crop, highest biomass sulphur was recorded in organic farming (10.61 and 8.79 mg kg^{-1} at 60 DAS and at harvest of *kharif* maize, respectively), which was at par with package of practice (9.57 and 6.63 mg kg^{-1}) and superior over natural farming (7.68 and 6.48 mg kg^{-1}) and farmers practice treatments(5.71 and 4.69 mg kg^{-1}) at 60 DAS and at harvest, respectively.

The organic amendments had a substantial prompting effect on soil microbial biomass sulphur. Since the soil was highly deficient in organic matter (< 0.5 %), a slight variation in organic C availability in these soils, exerted a prominent effect on their microbial properties. Organic amendments promoted the growth and multiplication of heterotrophic microorganisms in soil by providing labile organic C as an energy source to the soil microorganisms. Whereas, the lower biomass sulphur in farmers practice could be attributed to imbalanced fertilization, which had adverse effect on microbial activity of soil. Similar results was found by [28], who reported that the continuous application of FYM significantly increased soil biomass sulphur in an acid *Alfisol* of Palampur, India.

4. CONCLUSION

Among nutrient management approaches, the organic farming treatment recorded significantly higher enzyme activities, while significantly lower enzyme activities were recorded in farmers practice treatment. The carbon, nitrogen, phosphorus and sulphur content in microbial biomass were significantly higher in organic farming treatment, which was significantly at par with package of practice under both the crops.

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