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EVALUATING THE IMPACT OF ORGANIC MANURES ON SOIL HEALTH AND PLANT NUTRITION FOR SUSTAINABLE STRAWBERRY FARMING IN A POLYHOUSE

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ABSTRACT

Organic manures play a vital role in sustainable agriculture by improving soil fertility, crop productivity and overall soil health. A study was conducted to evaluate the effect of different organic manures on nutrient uptake, soil chemical and biological properties of strawberry. The experiment conducted with combinations of farmyard manure, vermicompost, poultry manure and sheep manure. Among the treatments, T6 exhibited superior performance. It significantly enhanced 28.39 kg/ha - Nitrogen, 43.98 kg/ha- Phosphorous, 186.04 – kg/ha Potassium uptake and improved soil organic carbon content (0.16 g/ha). Soil treated with T6 displayed enhanced enzyme activities such as dehydrogenase (16.10 µg TPF/g/h), urease (35.50 µg NH_4 -N/g/h) and phosphatase (27.43 µg PNP/g/h). The application of organic manures not only improved nutrient availability and soil chemical properties but also boosted microbial activity and enzyme functions, demonstrating their potential to enhance strawberry production sustainably. This research underscores the importance of integrating organic amendments like vermicompost and poultry manure into strawberry cultivation practices for optimal growth, yield and long-term soil health under controlled environments.

***Key words*:** Organic manures, Nutrient Uptake, Organic carbon, Enzyme Activity, Polyhouse Cultivation.

Introduction

Strawberry scientifically known as *Fragaria* × *ananassa*, belongs to family Rosaceae, order Rosales and genus *Fragaria*, consists of 23 species. It is a polyploid species, the ploidy level ranges from diploid species *Fragaria vesca* (2n = 2x = 14) to decaploid species, such as some accessions of *Fragaria intrupensis* (2n = 10x = 70). The present-day cultivar is an octoploid cultivar is a hybrid between two American species *Fragaria chiloensis* of western north and south America *and Fragaria virginiana* of eastern north America having a chromosome number 2n = 8x = 56. It is native to North America and originated in Europe, early in 17th century. It was introduced to India, in early sixties at National Bureau of Plant Genetic Resources regional station (NBPGR), Shimla (Himanchal Pradesh) from where it has spread to other states of India. Strawberry is a false and aggregate fruit. Each fruit is known as achene having a single seed. The fruit is appreciated for its bright reddish, glossiness, juicy texture, characteristic aroma, sweetness and for its pleasing tangy flavour. Fruits are largely consumed as a fresh and also processed into fruit juices, preserves, pies, ice-cream, milkshakes and other deserts.

Strawberry is one of the most delicious and nutritious soft fruit of the world. Fruit is a rich source of Vitamin C and other antioxidants. The flavour of strawberry is due to the esters, mainly ethyl butyrate. Fruit contains fibre, Manganese, Folates, Potassium and other minerals. It is loaded with antioxidants such as Pelargonidin, Ellagic acid, Ellagitannins and Procyanidins. Bright reddish colour of strawberry fruit is due to the anthocyanins, particularly it is rich in pelargonidin. Ellagic acid content in strawberry is one of the most important antioxidants having antibacterial and anti-cancerous properties. Consumption of strawberry may improve blood antioxidant status, decreases oxidative stress, reduces inflammation, improves vascular function, improves blood lipid profile and reduces the oxidation of bad cholesterol.

Strawberry cultivation demands efficient nutrient management to achieve sustainable growth, high yield and superior fruit quality. Chemical fertilizers were used extensively to increase yield, but nowadays it has become limited because of its negative impacts such as topsoil erosion (10-13 mm/year), increased soil acidity (40%) and reduction of organic matter in soil had directly affected the soil nutrient availability and thus significantly reduced the yield of crop (Getachew *et al*., 2016). This lead to the emergence of organic manures as a sustainable alternative to chemical fertilizers, offering multiple benefits such as improved soil fertility, enhanced nutrient uptake and reduced environmental impact. Unlike synthetic fertilizers, organic amendments such as farmyard manure (FYM), vermicompost, sheep manure and poultry manure enrich the soil with organic carbon, boost microbial activity and contribute to long-term soil health.

It was observed that organic fertilizers not only enhance the nutrient content of strawberries but also improve fruit quality characteristics like sugar content, acidity and vitamin levels. For example, vermicompost has been noted for its ability to increase soil porosity and nutrient availability, while poultry manure, rich in nitrogen, phosphorus and potassium, significantly improves plant growth and yield. The combination of these amendments often yields results superior to the exclusive use of inorganic fertilizers, as evidenced in various research trials (Reganold *et al*., 2010) and (Beer *et al*., 2017).

This studies “The effect of different organic manures on nutrient uptake, soil chemical and biological properties of strawberry polyhouse conditions”. By evaluating treatments, the research aims to identify optimal combination of manures for enhancing soil properties, crop productivity and soil sustainability. These findings hold promise for integrating organic amendments into commercial strawberry cultivation, addressing the dual goals of horticultural productivity and sustainable ecological balance.

Materials and Methods

The experiment was conducted in a low-cost polyhouse at the Department of Horticulture, College of Agriculture, University of Agricultural Sciences, GKVK, Bengaluru. This location falls within the Eastern Dry Zone (Zone-5) of Karnataka, situated at 13°05' N latitude and 77°34' E longitude, with an elevation of approximately 924 meters above sea level. During the experimental period, from November 2022 to March 2023, meteorological data was recorded. The temperatures ranged between 25°C and 33°C for the maximum and 13°C to 20°C for the minimum. The average relative humidity varied from 36 per cent to 89 per cent.

The experimental site had red sandy loam soil, which was well-drained and exhibited a uniform texture. Prior to initiating the experiment, composite soil samples were randomly collected from a depth of 30 cm across the site. These samples were air-dried, ground using a mortar, sieved through a 2 mm mesh, thoroughly mixed, and subjected to physico-chemical analysis. A representative soil sample was analysed to determine parameters such as pH, electrical conductivity (EC), nitrogen (N), phosphorus (P), potassium (K), organic carbon (OC), dehydrogenase activity, urease activity and phosphatase activity.

The experiment utilized the strawberry variety ‘Winter Dawn,’ with tissue culture plants sourced from KF Bio Plants Private Limited, Pune, Maharashtra. Organic manures, including farmyard manure (FYM), poultry manure (PM), sheep manure (SM) and vermicompost (VC), were obtained from the Zonal Agricultural Research Station (ZARS) at the University of Agricultural Sciences, GKVK, Bengaluru.

The study was conducted using a randomized block design with three replications and nine treatments. The experimental plot measured 131 m², with plant spacing of 60 cm and row spacing of 30 cm in a paired row system. The recommended nutrient dosage for the crop was 100:60:100 kg N, P and K per hectare. Since the study emphasized organic cultivation, the required quantities of organic manures were calculated to provide 100% nitrogen equivalence, ensuring the recommended fertilizer dose was met. Before transplanting, these manures were evenly distributed across individual plots according to the treatment combinations and thoroughly incorporated into the soil.

Nitrogen content in plant samples was estimated using the micro-Kjeldahl method, where 0.5 g of dried plant material was digested in a Kjeldahl flask with a salt mixture (10:2:1) of $K_2 SO_4$, $CuSO_4 \cdot 5H_2O$ and metallic selenium, along with 10 ml of concentrated sulfuric acid. Phosphorus content was analyzed using the Vanado-molybdo phosphoric acid yellow color method, as described by Jackson (1973) and measured at 442 nm using a Syntronics spectrophotometer (Model 106). Potassium in the acid digest of plant samples was determined with a Systronics flame photometer (Model 128) following the

Table 1: Impact of different organic manures on nutrient uptake of strawberry.

Treatments	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})
T1 – Absolute control	137.77	16.06	99.84
T2 – 100 % N equivalent through FYM	170.00	17.29	101.99
T3 – 100 % N equivalent through PM	236.69	20.09	132.11
T4 – 100 % N equivalent through VC	211.92	17.01	117.06
T5 – 100 % N equivalent through SM	250.01	21.85	132.92
T6 – 50 % N equivalent through VC + 50 % N equivalent through PM	283.39	43.98	186.04
T7 – 50 % N equivalent through VC + 50 % N equivalent through FYM	214.42	19.01	129.07
T8 – 50 % N equivalent through FYM + 50 % N equivalent through PM	250.81	24.02	157.00
T9 – 50 % N equivalent VC + 50 % N equivalent through SM	283.42	32.91	174.99
'F' test	*	*	*
S. E. m±	**1.29**	**0.51**	**0.61**
C. D at 5 %	**3.88**	**1.53**	**1.84**

same procedure used for analyzing available potassium in soil.

Soil parameters were assessed using standard methods. Soil pH was measured potentiometrically, while soil electrical conductivity (EC) was determined by the conductometric method, both following Jackson (1973). Soil organic carbon content was assessed using the wet oxidation method of Walkley and Black (1934). Available soil nitrogen was determined using the alkaline KMnO„ method described by Subbiah and Asija (1956). Available phosphorus content in the soil was measured using Bray's method, as outlined by Bray and Kurtz (1945). Available potassium content was determined using the neutral normal ammonium acetate method, as described by Jackson (1973).

Soil enzyme activities were also evaluated. Dehydrogenase activity was measured following the procedure of Casida *et al.*, (1964). Urease and phosphatase activities were assessed using methods described by Eivazi and Tabatabai (1977).

The experimental data was statistically analysed using randomised block design. Treatment means were tested for significance using an F-test at a 5% level of significance. The critical difference (C.D.) among treatment means and standard errors of means were calculated to interpret the results accurately.

Result and Discussion

Per cent of Nutrient uptake of Nitrogen, Phosphorous and Potassium by strawberry plant influenced by different organic manures was recorded and it is furnished in the Table 1. The results show that the application of organic manures significantly affected the nutrient uptake of strawberry.

The treatment with the highest N uptake was T6 (50% N equivalent through vermicompost + 50% N equivalent through poultry manure) and T9 (50% N equivalent vermicompost + 50% N equivalent through sheep manure) with 283.39 kilograms per hectare and 283.42 kilograms per hectare respectively. T8 (50% N equivalent through FYM + 50% N equivalent through poultry manure) and T5 (100% N equivalent through sheep manure) are on par with 250.81 kilograms per hectare and 250.01 kilograms per hectare respectively. The control treatment had the lowest N uptake (137.7 kg ha^{-1}).

The treatment with the highest P uptake was T6 (50% N equivalent through vermicompost + 50 % N equivalent through poultry manure) (43.98 kg ha^{-1}), followed by T9 (50 % N equivalent vermicompost + 50 % N equivalent through sheep manure) (32.91 kg ha^{-1}). T8 (50% N equivalent through FYM + 50% N equivalent through poultry manure) and T5 (100% N equivalent through sheep manure) are on par with 24.02 kilograms per hectare and 21.85 kilograms per hectare respectively. The control treatment had the lowest P uptake (16.06 kg ha^{-1}).

The treatment with the highest K uptake was T6 (50% N equivalent through vermicompost + 50 % N equivalent through poultry manure) (186.04 kg ha^{-1}), followed by T9 (50% N equivalent vermicompost + 50% N equivalent through sheep manure) (174.99 kg ha^{-1}). The control treatment had the lowest K uptake (99.84 kg ha^{-1}).

Poultry manure promotes plant growth and development, while vermicompost provides essential nutrients and improves soil fertility. The synergistic effect of these organic amendments enhances the nutrient uptake and metabolism in strawberry plants, leading to increased ascorbic acid production (El-Hamid *et al.*, 2006).

Table 2: Impact of different organic manures on soil pH, soil EC, soil organic carbon content, available nitrogen, available phosphorous and available potassium (kg ha^{-1}) in soil after harvest of strawberry.

Treatments	pH (1:2.5)	EC (dS m^{-1})	OC (g kg^{-1})	Available Nitrogen (kg ha^{-1})	Available Phosphorous (kg ha^{-1})	Available Potassium (kg ha^{-1})
T1 – Absolute control	6.24	0.18	0.23	120.92	9.02	52.65
T2 – 100 % N equivalent through FYM	6.26	0.33	0.40	123.42	9.02	73.20
T3 – 100 % N equivalent through PM	6.44	0.44	0.49	176.11	41.05	109.52
T4 – 100 % N equivalent through VC	6.28	0.35	0.43	127.19	14.12	84.64
T5 – 100 % N equivalent through SM	6.53	0.45	0.51	148.38	32.10	106.03
T6 – 50 % N equivalent through VC + 50 % N equivalent through PM	6.83	0.80	0.61	134.71	24.90	93.96
T7 – 50 % N equivalent through VC + 50 % N equivalent through FYM	6.34	0.43	0.45	128.44	22.48	85.64
T8 – 50 % N equivalent through FYM + 50% N equivalent through PM	6.64	0.78	0.55	132.20	23.63	90.28
T9 – 50 % N equivalent VC + 50 % N equivalent through SM	6.74	0.79	0.59	144.75	29.52	101.32
'F' test	*	*	*	*	*	*
S. E. m±	**0.02**	**0.01**	**0.01**	**0.04**	**0.01**	**0.02**
C. D at 5 %	**0.05**	**0.02**	**0.02**	**0.13**	**0.04**	**0.06**

The findings indicated that the use of organic manures significantly influenced soil pH, electrical conductivity (EC) and organic carbon content in strawberry cultivation. The organic manures might have contributed to maintaining soil pH due to their buffering capacity. These manures potentially contained compounds capable of mitigating rapid pH fluctuations by releasing either acidic or alkaline ions as required. This stabilization effect likely balanced the soil pH, creating a favourable environment for nutrient availability and plant growth. The soil pH in the experimental plots ranged from 6.42 to 6.83, with all treatments involving organic manures exhibiting a slightly acidic nature.

The application of FYM significantly buffered soil pH due to its abundance of basic cations (Rajneesh, 2017), which contributed to maintaining soil pH. Prashanth *et al.*, (2020) also observed an increase in the pH of acidic soils following the addition of FYM, either alone or in combination with fertilizers. This buffering effect was attributed to the replacement or neutralization of acidic cations such as H+, Fe^{3}z and Al^{3}z by basic cations like Ca^{2}z and Mg^{2}z during the decomposition process (Agarwal *et al.*, 2014).

Table 2 shows a significant difference among all the treatments. An increase in electrical conductivity was observed in T6 (50% nitrogen equivalent from vermicompost + 50% nitrogen equivalent from poultry manure), which recorded 0.80 dS m^{-1}, in comparison to the absolute control, which showed 0.18 dS m^{-1}.

The use of organic manures was found to increase soil electrical conductivity (EC). This effect was likely attributed to the release of basic cations, such as calcium and magnesium, from the organic materials, along with the formation of soluble salts, primarily involving calcium. Similar results were documented by Katkar (2011), Srinivarrao *et al.*, (2014), and Sharma *et al.*, (2007). Organic manures appeared to play a role in stabilizing soil EC by improving soil structure and retaining moisture. The organic matter present in these manures likely enhanced the soils water-holding capacity, which helped prevent excessive mineral accumulation that might otherwise raise EC. This process contributed to maintaining optimal soil EC levels, fostering a conducive environment for plant growth.

The data presented in Table 2 shows a significant variation in the soil organic carbon content after the crop was harvested. Soil organic carbon content is increased due to application of organic manures (Liang *et al.*, 2014, Nicolas *et al.*, 2012; Ros *et al.*, 2006). The treatment T6 (50% N equivalent through vermicompost + 50% N equivalent through poultry manure) showed the highest organic carbon content (0.61 g kg^{-1}) in the soil after harvest, followed by T9 (50% N equivalent vermicompost + 50% N equivalent through sheep manure) with 0.59 g kg^{-1}. Conversely, the lowest organic carbon content (0.23 g kg^{-1}) was observed in the control treatment (T1).

The observed differences resulting from the application of vermicompost combined with poultry manure could be attributed to the lower nitrogen content in vermicompost compared to other organic manures. This likely resulted in a higher carbon-to-nitrogen (C:N) ratio, which may have contributed to an increased organic carbon content in the soil. Similarly, Kumari *et al.,* (2011) suggested that after removing the test plants, the soil samples exhibited enhanced levels of organic carbon, total nitrogen, total phosphorus and total potassium, particularly in areas treated with vermicompost.

The data presented in Table 2 revealed a significant variation in the nitrogen, phosphorus and potassium content of the soil after crop harvest. The treatment T3 (100% N equivalent through poultry manure) resulted in the highest nitrogen status of 176.11 kg ha^{-1}, while the lowest nitrogen status, 120.92 kg ha^{-1}, was observed in the control treatment (T1). Similarly, the highest phosphorus and potassium content, 41.05 kg ha^{-1} and 109.52 kg ha^{-1} respectively, were recorded in treatment T3. In contrast, the lowest phosphorus (9.02 kg ha^{-1}) and potassium (52.65 kg ha^{-1}) levels were found in the control treatment (T1).

The increased nitrogen availability in the soil was attributed to high nitrogen in poultry manure. This facilitated improved nitrogen mobilization, enhancing its accessibility to plants. Consequently, the elevated nitrogen availability supported better plant growth and increased productivity.

Application of organic manures to the soil leads to rapid increase in microbial biomass (Ghoshal and Singh 1995, Heinze *et al*., 2010) but in small fractions. However, this plays a direct role in increased nutrient cycling and plant nutrition, because of microbial fast turnover action (Jenkinson and Ladd, 1981). Enzymes present in the manures also have the synergistic effect on soil, which results in crop yield. Therefore, biological properties of soil, such as urease activity, dehydrogenase activity, acid phosphatase activity and alkaline phosphatase activity, has been studied and analysed to know the impact of enzyme activity on the yield of strawberry. Conclusions were derived from the observations, which are illustrated in Fig. 1. However, long-term application of organic manures increases lignin and lignin-like products, which appears to increase organic carbon content in soil organic matter (Lima *et al*., 2009).

Significant variations were observed in soil enzyme activity in the strawberry soil after harvest. The highest dehydrogenase activity was noted in treatment T6, which involved 50% nitrogen supplied through vermicompost and 50% through poultry manure, with a value of 16.10 µg TPF g^{-1} h^{-1}. This was followed by treatment T9, comprising 50% nitrogen from vermicompost and 50% from sheep manure, with an activity of 15.75 µg TPF g^{-1} h^{-1} (Fig. 1). The lowest dehydrogenase activity, recorded in the control, was attributed to the absence of organic matter, measuring 11.12 µg TPF g^{-1} h^{-1}.

The highest urease activity was observed in treatment T6, which included 50% nitrogen equivalent through vermicompost and 50% nitrogen equivalent through poultry manure, recording 35.50 µg NH_4-N g^{-1} h^{-1}. This was followed by treatment T9, comprising 50% nitrogen equivalent through vermicompost and 50% nitrogen equivalent through sheep manure, with a value of 33.75 µg NH_4-N g^{-1} h^{-1}. The lowest urease activity, 20.23 µg NH_4-N g^{-1} h^{-1}, was noted in the control treatment due to the absence of organic matter. Similar findings were reported by Tejada *et al.,* (2006).

The highest acid phosphatase activity was observed in treatment T6 (50% nitrogen equivalent through vermicompost + 50% nitrogen equivalent through poultry manure) at 27.430 µg PNP g^{-1} h^{-1}, followed by treatment T9 (50% nitrogen equivalent through vermicompost + 50% nitrogen equivalent through sheep manure) with 24.36 µg PNP g^{-1} h^{-1}. The control treatment exhibited the lowest acid phosphatase activity, measuring 15.23 µg PNP g^{-1} h^{-1}, due to the absence of organic matter.

Similarly, the highest alkaline phosphatase activity was recorded in treatment T9 (50% nitrogen equivalent through vermicompost + 50% nitrogen equivalent through sheep manure) at 15.98 µg PNP g^{-1} h^{-1}, followed closely by treatment T6 (50% nitrogen equivalent through vermicompost + 50% nitrogen equivalent through poultry manure) at 15.75 µg PNP g^{-1} h^{-1}. The control treatment again showed the lowest alkaline phosphatase activity, measuring 7.48 µg PNP g^{-1} h^{-1}, due to the lack of organic inputs.

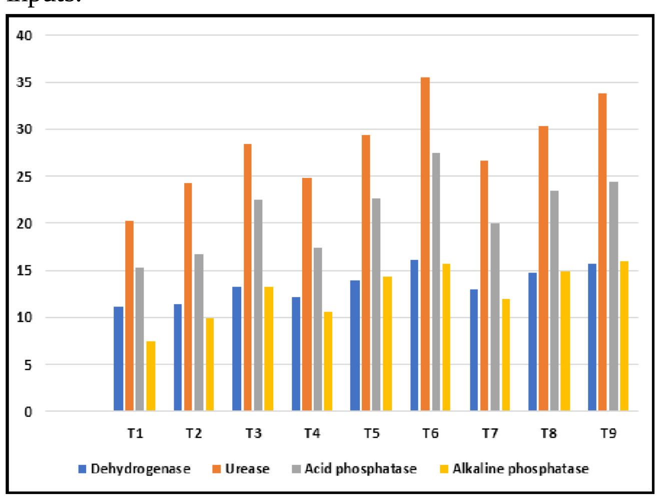

Fig. 1: Impact of different organic manures on enzyme activity.

The observed increase in dehydrogenase and urease enzyme activity in strawberries under the combined application of vermicompost and poultry manure was likely attributed to enhanced microbial activity. These organic amendments appeared to create a nutrient-rich environment that supported the proliferation of microorganisms responsible for dehydrogenase enzyme production. The interaction between the organic inputs and microbial communities seemed to stimulate greater enzyme activity, indicating a possible improvement in soil

Soil enzymes were crucial in facilitating the decomposition of organic matter and nutrient cycling (Nannipieri *et al.,* 2011). Treatments that included a combination of vermicompost and poultry manure significantly enhanced soil enzyme activity compared to those that received other organic manures or the control treatment.

Conclusion

The investigation was conducted to evaluate the effect of different organic manures on plant nutrient uptake, soil chemical and biological properties of strawberry under polyhouse condition. Among different treatment combinations used, plants grown using a manure combination of 50 per cent N equivalent through vermicompost and 50 per cent N equivalent through poultry manure has shown increased nutrient uptake by strawberry plant as compared to the control. This combination has also improved the soil properties by increasing the microbial activity, enzyme activity and nutrient availability to plants. As a result, there was also a positive impact on the strawberry growth, yield and quality. The same also performed best in terms of B:C ratio having highest ratio when compare to all other treatments.

Reference

Agarwal, B., Mahapatra P., Kumar A., Shahi D., Kumar R. and Karmakar S. (2014). Soil acidity and health of an Alfisol under Soybean-Wheat cropping system in an acid soil of Jharkhand. *Annals of Plant and Soil Research*, **16(4)**, 275-278.

Beer, K., Kumar S., Gupta A.K. and Syamal M.M. (2017). Effect of organic, inorganic and bio-fertilizer on growth, flowering, yield and quality of strawberry (*Fragaria*× *Ananassa* Duch.) cv. Chandler. *International journal of current microbiology and applied sciences*, **6(5)**, 2932-2939.

Bray, R.H. and Kurtz L.T. (1945). Determination of total, organic, and available forms of phosphorus in soils. *Soil science*, **59(1)**, 39-46.

Casida Jr, L.E., Klein D.A. and Santoro T. (1964). Soil dehydrogenase activity. *Soil science*, **98(6)**, 371-376.

El-Hamd, A.S.A.A., Abdou A.A., Mansour S.A.A. and El-Sayed A.A.A. (2006). Effect of some biofertilizers on the yield and fruit quality of strawberry.

Eivazi, F. and Tabatabai M.A. (1977). Phosphatases in soils. *Soil biology and biochemistry*, **9(3)**, 167-172.

Agegnehu, G., Nelson P.N. and Bird M.I. (2016). Crop yield, plant nutrient uptake and soil physicochemical properties under organic soil amendments and nitrogen fertilization on Nitisols. *Soil and Tillage Research*, **160**, 1-13.

Ghoshal, N. and Singh K.P. (1995). Effects of farmyard manure and inorganic fertilizer on the dynamics of soil microbial biomass in a tropical dryland agroecosystem. *Biology and Fertility of Soils*, **19**, 231-238.

Heinze, S., Raupp J. and Joergensen R.G. (2010). Effects of fertilizer and spatial heterogeneity in soil pH on microbial biomass indices in a long-term field trial of organic agriculture. *Plant and Soil*, **328**, 203-215.

Jackson, W.A., Flesher D. and Hageman R.H. (1973). Nitrate uptake by dark-grown corn seedlings: some characteristics of apparent induction. *Plant Physiology*, **51(1)**, 120-127.

Jenkinson, D.S. and Ladd J.N. (1981). Microbial biomass in soil: measurement and turnover. *Soil biochemistry*, **5(1)**, 415-471.

Katkar, R.N., Sonune B.A. and Kadu P.R. (2011). Long-term effect of fertilization on soil chemical and biological characteristics and productivity under sorghum (*Sorghum bicolor*)-wheat (*Triticum aestivum*) system in Vertisol. *Indian journal of agricultural sciences*, **81(8)**, 734.

Kumari, G., Mishra B., Kumar R., Agarwal B.K. and Singh B.P. (2011). Long-term effect of manure, fertilizer and lime application on active and passive pools of soil organic carbon under maize-wheat cropping system in an Alfisol. *Journal of the Indian Society of Soil Science*, **59(3)**, 245-250.

Liang, Q., Chen H., Gong Y., Yang H., Fan M. and Kuzyakov Y. (2014). Effects of 15 years of manure and mineral fertilizers on enzyme activities in particle-size fractions in a North China Plain soil. *European Journal of Soil Biology*, **60**, 112-119.

Lima, D.L., Santos S.M., Scherer H.W., Schneider R.J., Duarte A.C., Santos E.B. and Esteves V.I. (2009). Effects of organic and inorganic amendments on soil organic matter properties. *Geoderma*, **150(1-2)**, 38-45.

Nannipieri, P., Giagnoni L., Landi L. and Renella G. (2011). Role of phosphatase enzymes in soil. *Phosphorus in action: biological processes in soil phosphorus cycling*, 215-243.

Nicolás, C., Hernández T. and García C. (2012). Organic amendments as strategy to increase organic matter in particle-size fractions of a semi-arid soil. *Applied Soil Ecology*, **57**, 50-58.

DV, P., Krishnamurthy R. and Naveen D.V. (2020). Long-term effect of integrated nutrient management on soil nutrient status, content and uptake by finger millet crop in a typic kandiustalf of eastern dry zone of Karnataka. *Communications in Soil Science and Plant Analysis*, **51(2)**, 161-174.

Rajneesh, Sharma R.P., Sankhyan N.K. and Kumar R. (2017). Long-Term Effect of Fertilizers and Amendments on Depth-Wise Distribution of Available NPK, Micronutrient Cations, Productivity, and NPK Uptake by Maize-Wheat System in an Acid Alfisol of NorthWestern Himalayas. *Communications in Soil Science and Plant Analysis*, **48(18)**, 2193-2209.

Reganold, J.P., Andrews P.K., Reeve J.R., Carpenter-Boggs L., Schadt C.W., Alldredge J.R. and Zhou J. (2010). Fruit and soil quality of organic and conventional strawberry agroecosystems. *PloS one*, **5(9)**, e12346.

Ros, M., Pascual J.A., Garcia C., Hernandez M.T. and Insam H. (2006). Hydrolase activities, microbial biomass and bacterial community in a soil after long-term amendment with different composts. *Soil Biology and Biochemistry*, **38(12)**, 3443-3452.

Sharma, M., Mishra B. and Singh, R. (2007). Long-term effects of fertilizers and manure on physical and chemical properties of a mollisol. *Journal of the Indian Society of Soil Science*, **55(4)**, 523-524.

Srinivasarao, C.H., Ramachandrappa B.K., Jakkula V.S., Kundu S., Venkateswarlu B., Pharande A.L. and Venkanna K. (2014). Nutrient balance after thirteen years of organic and chemical nutrient management and yield sustainability of groundnut-fingermillet rotation in rainfed alfisols of semi-arid India. *Journal of the Indian Society of Soil Science*, **62(3)**, 235-247.

Subbiah, B.V. and Asija G.L. (1956). A rapid procedure for the estimation of available nitrogen in soils.

Walkley, A. and Black I.A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil science*, **37(1)**, 29-38.