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Research Article

ASSESSMENT OF SOIL QUALITY PARAMETERS AS INFLUENCED BY CONTINUOUS ADOPTION OF NUTRIENT MANAGEMENT IN AN ALFISOIL

MITHILADEVI K.[1], MALARKODI M.*[1], SELVI D.[1], BALACHANDAR D.[1] AND GOKILA B.[2]
[1]Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore, 641003, Tamil Nadu, India
[2]Department of Agricultural Microbiology, Tamil Nadu Agricultural University, Coimbatore, 641003, Tamil Nadu, India
*Corresponding Author: Email - charmsmalar@gmail.com

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Abstract- The present investigation was carried out to evaluate the effect of continuous application of fertilizers and manures on soil quality parameters in the ongoing century-old Permanent Manurial Experiment of Tamil Nadu Agricultural University, Coimbatore during 2019. The post-harvest soil after harvest of 168th crop of sunflower was analyzed for physicochemical properties, chemical properties and enzyme activities. Results revealed that the application of inorganic fertilizers alone registered pH > 8.0 whereas the application of fertilizers and manures and application of manures alone registered pH < 8.0 in soil. Among the treatments, continuous application of NPK+FYM @ 12.5 t ha^{-1} improved the cation exchange capacity, organic carbon content and available nutrient status in the soil whereas unbalanced fertilization and unfertilized control decreased the most, resulted in degraded soil fertility. The enzyme activities were higher with NPK+FYM. The results indicated that the combined application of inorganic and organic fertilizers maintained higher soil quality.

Keywords- *Permanent Manurial Experiment, Inorganic fertilizers, FYM, Enzymes, SOC*

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Introduction

Applying an adequate amount of fertilizer is an important cultivation practice for the yield and quality of crops, environmental protection and soil sustainability [1]. Several long-term fertilizer studies have indicated that the prolonged use of chemical fertilizers accelerated degradation of soil and a decline in soil productivity [2]. These problems may partially be improved by applying organic amendments along with chemical fertilizers, which is a popular practice in crop production. An assessment of the soil productivity by using a soil quality index could provide key information to improve strategies and effective techniques for the future to achieve sustainable agriculture [3].

The physical, chemical and biological characteristics that enable soils to perform a wide range of functions are related to soil quality. Since the soil functions are not directly measurable, appropriate physical, chemical and biological properties, named soil quality indicators, are selected to indirectly measure how well each function is being performed. Many researchers have investigated and reported the significant effects of long-term fertilization on the physicochemical and chemical properties of soil [4-7]. The biological properties of soils usually respond more rapidly to changing soil conditions than the chemical or physical properties. Soil enzymatic activity has been used as an indicator of soil quality since it is the reflection of the effects of cultivation, fertilization, soil properties and pedological amendments [8,9]. Long-term experiments could be more useful for studying the changes in soil properties and processes over time and for obtaining information on the sustainability of agricultural systems for developing future strategies to maintain soil health [10]. The earliest long-term experiments called 'Rothamsted Classical Experiments' have yielded the most valuable information for the adoption of an efficient approach for managing the crops and cropping system. Based on the Rothamsted model, the Permanent Manurial Experiment (PME) of Tamil Nadu Agricultural University (TNAU) started during the year 1909 remains successful among a few permanent manurial experiments, which are being continued for more than 100 years in India and abroad. To evaluate the long-term effect of inorganic and organic manuring on crop productivity and soil health, the present study was carried out in the on-going PME with long-term nutrient management and continuous cropping in an Alfisol.

Materials and Methods

Experimental details

The present study was carried out during the year 2019, is a part of an on-going project of the century-old Permanent Manurial Experiment (PME) located in Tamil Nadu Agricultural University, Coimbatore, India to assess the effect of continuous nutrient management adoption on soil quality parameters after harvest of sunflower crop (168th crop). The experiment details and soil characteristics (analyzed in 1974) are given in [Table-1].

The treatments are T1, Control (unfertilized and unmanured); T2, 100% N; T3, 100% NK; T4, 100% NP; T5, 100% NPK; T6, 100% PK; T7, 100% K; T8, 100% P; T9, 100% NPK + Farmyard manure (FYM) @ 12.5 t ha^{-1}; T11, Farmers practice; T10, STCR-IPNS; T12, FYM @ 12.5 t ha^{-1}. The hybrid sunflower CO2 was raised during May 2019 and harvested during August 2019. The recommended dose of N, P_2O_5 and K_2O 60:90:60 kg ha^{-1} was applied to sunflower.

The sources of N, P and K used were urea, single super phosphate and muriate of potash, respectively for all the treatments. For treatments T9, T10 and T11, well-decomposed farmyard manure (FYM) at 12.5 t ha^{-1} (fresh-weight basis) with an average nutrient composition of 0.5% N, 0.23% P and 0.53% K was broadcasted 20 days before sowing and mixed with soil. For treatment T10, Soil Test Crop Response-Integrated Plant Nutrient Supply (STCR-IPNS), based on the soil test values and targeted yield of 30 q ha^{-1} the quantity of NPK was calculated and applied.

Table-1 *Experiment details and soil characteristics*

Details	PME, TNAU, Coimbatore
Year of establishment	1909
Location	Tamil Nadu Agricultural University, Coimbatore
Area	50 cents
Geographical coordinates	11°N, 77°E
Altitude	426.7 m
Max and Min temperature	34.3°C and 21.7°C
Annual rainfall	674.2 mm
Climate type	Semi-arid sub-tropical
Cropping sequence	Maize – Sunflower
Cropping situation	Irrigated
Soil texture	Sandy loam
Soil series	Palathurai
Soil classification	*Typic Haplustalfs*
Initial soil characteristics	
pH	8.30
Electrical conductivity (dS/m)	0.25
Soil organic carbon (g/kg)	1.80
Available N (kg/ha)	147
Available P (kg/ha)	3.58
Available K (kg/ha)	381

Soil Sampling and analysis

Soil samples were collected from the upper 15 cm soil depth in triplicate from each plot after the harvest of sunflower crop during 2019. In each plot, ten sub-samples were collected and pooled together as a composite sample. Soil pH and EC were determined in soil:water (1:2.5 ratio) extract by potentiometric and conductometry methods respectively [11]. Cation exchange capacity was estimated by the method as described by Piper [12]. Available soil N was determined by the alkaline-$KMnO_4$ method [13], available P by sodium bicarbonate (NaHCO3) extraction and subsequent colorimetric analysis [14], available K by using an ammonium acetate extraction followed by emission spectrometry [15], available S by turbidimetry method as outlined by Chesnin and Tien [16] and soil organic carbon was determined by chromic acid wet digestion method [17].

For enzyme analysis, soil samples were collected in triplicate after the harvest of sunflower. The dehydrogenase (DHA) was determined by the method of Casida *et al*. [18] and expressed as µg of triphenyl formazan released per gram soil per day (µg TPF g^{-1} day−1). Acid- and alkaline phosphatase were measured by the procedure as described by Tabatabai and Bremner [19] and expressed as µg p-nitrophenol per gram soil per h (µg PNP g^{-1} h^{-1}). Urease activity was measured using the method as outlined by Tabatabai and Bremner [20] and expressed in µg of NH_4 released per gram of soil per h.

Statistical analysis

The data were analyzed by using analysis of variance (ANOVA) and mean comparison by LSD as suggested by Panse and Sukhatme [21] at 5 percent significance level for concluding on the influence of various treatments.

Results and Discussion

Soil Physicochemical properties

Continuous fertilization and manuring significantly influenced the soil pH over the years. Continuous FYM addition recorded the lowest pH (7.69) as compared to other treatments [Table-2]. The treatments which received organic manures either alone or in combination with NPK viz., T9, T10 and T11 recorded lower pH (<8.0) compared to treatments that received only inorganic nutrients (>8.0). The decrease in pH in the former treatment may probably due to organic acids released during the decomposition of organic matter resulting in lower pH. The electrical conductivity of the soil was significantly influenced by the long-term addition of fertilizers or manures. The EC was higher in control (0.150 dS m^{-1}) and lower in FYM (0.120 dS m^{-1}), NPK+FYM (0.122 dS m^{-1}), STCR-IPNS (0.124 dS m^{-1}) treatments [Table-2]. Combined application of NPK+FYM had significantly higher CEC (28.1 Cmol (p+) kg^{-1}) followed by STCR-IPNS (25.5 Cmol (p+) kg^{-1}). This may be due to the colloidal nature of organic matter [22]. The lowest CEC was recorded under an unfertilized and unmanured plot (15.7 Cmol (p+) kg^{-1}) [Table-2].

Soil Organic Carbon

Soil organic carbon (SOC) content improved over the initial status, even in the control plots [Fig-1]. The gain in SOC content under the control plots of this study was due to the annual C addition from the biomass of both crops. The conjoint application of 100% inorganic fertilizer with FYM brought about a significant increase in the SOC content of soil than the unfertilized and unmanured control [Table-2]. Continuous adoption of NPK+FYM or STCR-IPNS enhanced the SOC content from 1.8 g ka^{-1} during 1974 to 8.45 g kg^{-1} in NPK+FYM and 8.23 g kg^{-1} in STCR-IPNS practice during 2019. Plot under NPK + FYM contained 30% and 203% higher SOC content than NPK and control plots, respectively most probably due to increased root biomass and plant residues, and the direct application of organic matter through FYM [23]. Balanced fertilization maintained soil organic carbon at more than 6 g kg^{-1}, whereas a buildup was noticed when FYM was integrated with NPK (>8 g kg^{-1}). Treatment received NPK (T5) alone had higher SOC (6.5 g kg^{-1}) than control (2.79 g kg^{-1}) which might be due to enhanced root residue addition to the soil under continuous cultivation [Table-2]. This confirms with the findings of Li *et al*. [24] who reported that balanced fertilization enhanced SOC content compared to unbalanced fertilization.

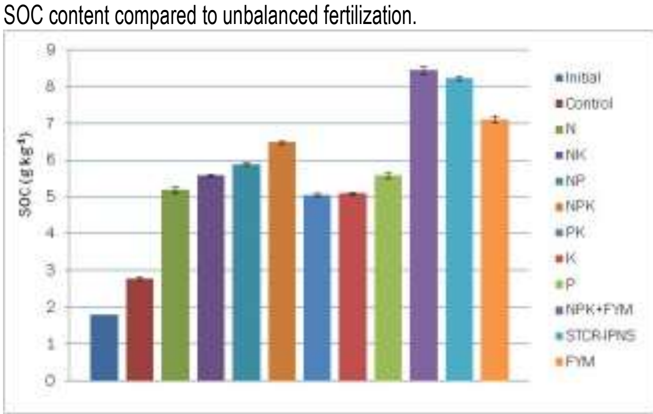

Fig-1 Effect of long-term fertilization on SOC content during 2019 over initial SOC content

(Data represent mean (n=3) and error bars indicate the standard error)

Available nutrient status

Available nutrient status was significantly altered by the continuous adoption of nutrients [Table-2]. The maximum available N content was recorded under NPK+FYM treated plot (218 kg ha^{-1}) followed by STCR-IPNS practice (207 kg ha^{-1}). The greater availability of N may be through direct addition of FYM, which might have helped in the multiplication of soil microbes, ultimately enhancing the conversion of organically bound N to mineral form.

The omission of N from the schedule drastically reduced N availability in the soil as compared to NPK. The availability of N was depleted in unfertilized control (T1) by 40% compared to NPK application (T5) might be due to continuous cropping without fertilization. There was a substantial build-up of available P content over the years [Table-2]. Available P recorded the highest (22.14 kg ha^{-1}) in the treatment that received NPK+FYM, which was on par with STCR-IPNS (21.82 kg ha^{-1}) practice. The addition of organic amendments may increase P availability through competition for phosphorus binding sites, solubilization of poorly soluble pools and increased solution pH [25]. Whereas, the omission of P and unfertilized control recorded lower available P status when compared to P received treatments might be due to exploitation of P from the soil by continuous cropping.

The highest value of available K (708 kg ha^{-1}) was observed in NPK+FYM treatment followed by STCR -IPNS (642 kg ha^{-1}) [Table-2]. The increase in the availability of P and K through the addition of FYM may be due to the decomposition of organic matter and the release of nutrients. The beneficial effect of FYM on the available K is also due to the reduction of K fixation and release of K due to the interaction of clay with organic matter. Unbalanced fertilization and skipping of K had lower K status may be attributed to the higher uptake of K by crops resulting in depletion of K in the absence of K addition. This finding was in corroboration with Arulmozhiselvan *et al*. [26]. Available S content was significantly higher in NPK+FYM treatment (49.1 kg ha^{-1}) followed by STCR-IPNS

Table-2 *Effect of long-term fertilization on physico chemical and chemical properties after sunflower (CO 2) in an alfisol*

Treatments	pH	EC (dS m^{-1})	SOC (g kg^{-1})	CEC [Cmol(p^{+}) kg^{-1}]	Available nutrients (kg ha^{-1})			
					N	P	K	S
Control	8.29	0.150	2.79	15.7	118	6.40	351	24.1
N	8.20	0.143	5.20	16.8	160	8.12	381	32.0
NK	8.19	0.140	5.60	17.5	162	8.54	515	35.2
NP	8.18	0.140	5.90	19.2	171	12.43	443	37.0
NPK	8.09	0.139	6.50	23.1	196	19.12	595	44.8
PK	8.11	0.137	5.07	21.8	129	11.98	555	40.8
K	8.14	0.141	5.10	20.2	128	7.41	580	33.6
P	8.17	0.139	5.60	22.6	129	14.54	346	39.0
NPK+FYM	7.90	0.122	8.45	28.1	218	22.14	708	49.1
STCR-IPNS	7.98	0.124	8.23	25.5	207	21.82	642	47.0
FYM	7.69	0.120	7.12	18.2	160	11.77	469	34.8
SEd	0.09	0.002	0.07	0.23	2	0.16	5	0.4
CD (0.05)	0.19	0.003	0.15	0.49	4	0.33	10	0.9

Table-3 *Effect of long-term fertilization on soil enzyme activities after sunflower (CO2) in an alfisol*

Treatments	Acid phosphatase (µg PNP g^{-1} h^{-1})	Alkaline phosphatase (µg PNP g^{-1} h^{-1})	Dehydro genase (µg TPF g^{-1} day^{-1})	Urease (µg of NH_4 released g^{-1} h^{-1})
Control	6.56	26.87	5.56	27.17
N	8.78	37.28	6.34	32.67
NK	9.65	34.77	7.20	37.17
NP	9.94	37.38	7.38	38.17
NPK	12.56	42.63	7.98	41.50
PK	9.74	31.40	6.95	39.16
K	8.70	32.59	6.06	33.83
P	8.69	35.20	6.10	36.16
NPK+FYM	15.89	53.18	9.49	53.55
STCR-IPNS	14.26	50.44	9.18	51.10
FYM	12.67	46.38	8.55	45.33
SEd	0.22	0.92	0.12	1.12
CD (0.05)	0.47	1.92	0.26	2.34

practice (47.0 kg ha^{-1}) indicating the continuous application of S through SSP in combination with FYM helped in the buildup of SO4-S in the soil over the years [Table-2]. The results of the present study are also in conformity with the findings of Lavanya *et al.* [27] who have recorded higher available sulphur content in the long-term fertilized soils under maize-wheat cropping system in treatment, which received SSP plus manure. The unfertilized control plot had the lower available S content. Overall, the combined application of inorganic and organic nutrients significantly enhanced the nutrients availability in soil as compared to inorganic alone and organic alone application.

Soil enzymes

The results revealed that the acid phosphatase activity varied from 6.56 in control to 15.89 µg PNP g^{-1} h^{-1} in NPK+FYM treatment. The activity was the highest in the treatment NPK+FYM (15.89 µg PNP g^{-1} h^{-1}) followed by STCR-IPNS (14.26 µg PNP g^{-1} h^{-1}) and FYM (12.67 µg PNP g^{-1} h^{-1}) treatments [Table-3].The highest phosphatase activity in the NPK+FYM treatment might be due to the improved microbial activity and perhaps multiplicity of phosphate solubilizing bacteria due to manure input over ten consecutive years [28]. The maximum alkaline phosphatase activity was obtained in NPK+FYM (53.18 µg PNP g^{-1} h^{-1}) followed by STCR-IPNS (50.44 µg PNP g^{-1} h^{-1}) and FYM (46.38 µg PNP g^{-1} h^{-1}) treatments and the lowest alkaline phosphatase activity was recorded in control (26.87 µg PNP g^{-1} h^{-1}). Application of NPK+FYM recorded an increase of 97.9 and 24.7% higher alkaline phosphatase activity over control and NPK respectively [Table-3]. The soil incorporated with organic manures expressed higher phosphatase activity which may be related to their microbial biomass production. The treatments received chemical fertilizers alone exhibited a reduction in alkaline phosphatase activity. The dehydrogenase activities ranged from 5.56 mg TPF g^{-1} day−1 in control treatment to 9.49 mg TPF g^{-1} day−1 in the NPK+FYM treatment. It is found that there is increased activity in NPK+FYM of about 70.7% over control and 18.9% over NPK alone treatment [Table-3]. The highest dehydrogenase activity in treatments applied with FYM may be attributed to FYM which might have provided a suitable environment for more accumulation of enzymes in soil matrix [29]. The urease activity was significantly higher in NPK+FYM (53.55 µg of NH_4 released g^{-1} of soil h^{-1}) followed by STCR-IPNS (51.10 µg of NH_4 released g^{-1} of soil h^{-1}) and least activity was found in control [Table-3]. The enhanced levels of urease in both FYM and NPK applied soils suggest that the continuous availability of substrates for the enzyme either in the form of organic sources or urea like inorganic sources. FYM alone amended soil recorded the highest urease activity (45.33 µg of NH_4 released g^{-1} of soil h^{-1}) compared to inorganic fertilization. Bhattacharyya *et al.* [30] reported that the addition of organic manures increased the urease activity over mineral N and control to a significant extent. Low level of urease activity in inorganic fertilizer treated soil indicated that mineral fertilization without a sufficient amount of available organic substrate may not have an impact on urease activity [31].

Conclusion

Thus, it may be concluded, from the present study, that the adoption of nutrient management in the maize-sunflower cropping sequence causes a remarkable influence on soil quality parameters such as physicochemical, chemical properties and enzyme activities. Application of NPK along with FYM and STCR-IPNS based fertilization improved the soil physicochemical, chemical properties and enzyme activities in comparison to the application of NPK fertilizers alone. The physico-chemical properties and enzyme activities play a vital role in the nutrient turn over and long-term productivity of the soil, which was enhanced by the balanced application of nutrients and manure. Integrated use of inorganic fertilizer and FYM improved the overall quality of soil whereas continuous cropping without fertilizers deteriorated the soil health.

Application of research: The Integrated Nutrient Management Technology: Combined application of recommended dose of NPK along with FYM @ 12.5 t ha^{-1} for sustaining the soil health.

Research Category: Soil fertility

Abbreviations: N: Nitrogen; P: Phosphorus; K: Potassium; FYM: Farmyard manure; kg: Kilogram; ha^{-1}: per hectare; t: ton; TNAU: Tamil Nadu Agricultural University; PME: Permanent Manurial Experiment; STCR-IPNS: Soil test crop response-integrated plant nutrient supply; EC: Electrical conductivity;

CEC: Cation exchange capacity; LSD: Least significant difference; SOC: Soil organic carbon

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Study area / Sample Collection: Sunflower

Cultivar / Variety / Breed name: Nil

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