Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(4): 1352-1357
Received: 19-05-2019
Accepted: 21-06-2019

P Venkata Subbaiah
Assistant Professor,
Department of Soil Science & Agricultural Chemistry,
Agricultural College, Bapatla, Andhra Pradesh, India

Correspondence
P Venkata Subbaiah
Assistant Professor,
Department of Soil Science & Agricultural Chemistry,
Agricultural College, Bapatla, Andhra Pradesh, India

Effect of inorganic and organic sources of nutrients and their conjuctive use on soil helath

P Venkata Subbaiah

Abstract
Soil health is an appropriate function of soil within ecosystem boundaries. Soil health is assessed in terms of soil physicochemical, physical, chemical and biological properties of soil. Soil health indices like Bulk density, hydraulic conductivity, water holding capacity, porosity and aggregate stability, organic carbon, available major and (N,P & K) micronutrients(Fe, Mn, Cu & Zn), nitrogen fractions (NH_4^+ & NO_3^- N), P-fractions (Al-P, Fe-p, Ca-P, Olsen P and Saloid –P), activity of soil enzymes (urease, dehydrogenase, acid and alkaline phosphatase) increases with conjuctive use of organic and inorganic nutrients rather individual application in crop production.

Keywords: Organic nutrients, inorganic nutrients and soil health

Introduction
Fertilizer application is an indispensable operation and is an integral part of modern crop production. However, the imbalanced and continuous use of chemical fertilizers in intensive cropping systems led to the stagnation/ reduction in crop yields and caused adverse effects on physical, chemical and biological properties of soil, especially of the plough layer. Soil is most basic and vital resource on which agricultural production depends. Maintenance of soil health is a real key to achieve sustainability in agriculture. It is high time to transform the Indian agriculture scenario to meet the food demand for the growing population and simultaneously conserve the soil ecological environment (Anonymous, 2016) [1]. This call for special effort to manage natural resources of agriculture and the need for sustainable agriculture. Different sources of organic nutrients are available but optimum amount utilization become a question mark. The complementary effect of manures along with fertilizers improves soil properties towards sustaining soil productivity and soil health.

Soil physical properties
Physical properties of soils, perhaps, play more important role than chemical properties in determining the adaptability of soils to cultivation of food, fodder, fibre crops and timber *etc*. Adverse soil physical conditions restrict the full expression of genetic potential of the plants by affecting the root growth, nutrient availability and uptake and hence greater emphasis is now being given to the soil physical properties which otherwise are becoming limiting factors of crop production. Phosphatic fertilizers are known to improve soil structure by promoting aggregation in normal soils while inorganic nitrogenous fertilizers have shown depressing effects on soil physical properties.

Bulk density is a simple index for soil structure. It is defined as the ratio of mass of oven dry soil to its bulk volume. It is expressed as g cm^{-3} or Mg m^{-3}. In general it ranges from 1.1 to 1.4 Mg m^{-3} in fine textured soils and 1.5 to 1.8 Mg m^{-3} in coarse textured soils. Reduction in the bulk density of soils due to the addition of organic material has been well documented in several studies

Bellaki *et al.* (1998) observed that the addition of paddy straw to meet 50% N requirement of the recommended level of 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1} to a clayey soil at Dharwad in Karnataka reduced the bulk density from 1.35 to 1.26 Mg m^{-3}. Substantial reduction in the bulk density of a *Vertic Haplustepts* was also reported by Selvi *et al.* (2005) [30] by the application of FYM at 10 t ha^{-1} along with the recommended level of fertilizers at Coimbatore. Sheeba and Chellamuthu (1996) [31] reported that the application of FYM along with recommended level of fertilizers in calcareous black clay loam soil reduced the bulk density substantially.

Hydraulic conductivity of a soil may be defined as the ability or capacity of the soil to transmit or transfer the water from higher pressure points to lower pressure points.

The hydraulic conductivity of various textured soils vary from 0.001 cm h^{-1}in fine textured to 25 cm h^{-1} in coarse textured soils.

Improvement in the transmission of water was confirmed by the combined application of FYM along with fertilizers by Sheeba and Chellamuthu (1996) [31] and Selvi *et al.* (2005) [30]. Similar responses were obtained by the addition of paddy straw by Bellaki *et al.* (1998) and maize straw by Mathan (2000) [21] by integrating their supply with the fertilizers.

When all the pores of soils are filled with water, the soil is said to be at its maximum water holding capacity. Water serves as a carrier of plant nutrients in soil. Hence, optimum moisture content in the soil during the crop growth period is essential for successful crop production. In general, the amount of water held by the soil depends on texture, the amount and nature of organic and inorganic colloidal materials present in the soil. The WHC and the amount of available water in sandy and loamy soils increase with the application of organic matter.

Substantial improvement in the WHC of different textured soils was reported by Sheeba and Chellamuthu (1996) [31] and Santhy *et al.* (1999) [29] and Selvi *et al.* (2005) [30] by the application of FYM along with recommended level of fertilizers.

Singh *et al*. (2018) [37] reported that, addition of Muncipal Solid Wate (MSW) @ 10 t ha^{-1} with reduced dose of gypsum @ 25% Gypsum requirement in sodic soil reduced bulk density and increased infiltration rate significantly over the only use of gypsum or phosphogypsum @ 50% gypsum requirement in degraded sodic soils.

Arindam Sarkar *et al*. (2018) [2] reported that, there was improvement in soil hydraulic & structural parameters under FYM & vermicompost incorporation as evident from higher values of soil organic carbon, saturated hydraulic conductivity, per cent water stable aggregates, mean weight diameter, aggregate stability and soil porosity. Application of 100% NPK+ FYM in loam soils of Delhi showed higher stability of aggregates and lower dispersible clay and highest particulate organic carbon in soils (Paulson Thomas *et al.* 2018) [24].

Soil physico – chemical properties

Organic materials when added to soils undergo microbial decomposition. During the course of decomposition several changes occur in the soil environment. The production of organic acids, release and uptake of ions and change in organic matter status bring about changes in physico-chemical properties of soil.

Several studies confirmed an improvement in the organic carbon content of the soil due to the application of organic sources of nutrients along with the fertilizers.

Venkatesh *et al.* (2002) [40], Karki *et al.* (2005) [14] and Gayatri Verma and Mathur (2009) [9] reported a positive influence on application of FYM along with the fertilizers. The improvement in soil organic carbon content by the application of vermicompost was also reported by Jayprakash *et al.* (2004) [11], Ramesh *et al.* (2008) [25] and Singh and Nepalia (2009) [36]. Singh *et al*. (2018) [37] reported that, addition of Muncipal Solid Wate(MSW) @ 10 t ha^{-1} with reduced dose of gypsum @ 25% Gypsum requirement in sodic soil rduced soil pH, Electrical conductivity and Exchangeable Sodium Percentage and increased about 169 per cent organic carbon over the only use of gypsum or phosphogypsum @ 50% gypsum requirement. Application of 25 per cent substitution of nitrogen through vermicompost decreased soil pH (8.05) over initial pH of 8.3 in vertici Haplustepts of Maharastra (Kamble *et al*, 2018) [13].

Soil chemical properties

Available nutrients

The available nutrients in the soil are greatly influenced by the nature and age of crops, microbial activity, enzymatic transformation and application of organic manures and inorganic fertilizers. Under the intensive system of agriculture, marked changes in the soil fertility are likely to occur due to high cropping intensity with high yielding varieties and high levels of nutrient input.

Use of chemical fertilizers alone may not keep pace with time in maintenance of soil health for sustaining the productivity. Addition of organic manures in any form helps in maintaining the organic matter and fertility levels in soils. The type of organic manures added and the soils involved influence considerably the rate of decomposition as well as consequent chemical changes broughtout in the soil. The superiority of an organic material used will be determined by its decomposability and mineralization pattern of nutrient elements contained therein.

Several research investigation showed that the application of FYM along with fertilizers increased the availability of N,P and K in the soil after harvest of maize (Santhy *et al.* 1998) [28]. Sheeba and Chellamuthu (1996) [31], Jamwal (2006) [10]. Increase in the availability of N and Zn was recorded by Khadtare (2006) [15] by substituting 25% of the recommended level of nitrogenous fertilizer with vermicompost. Application of FYM along with lime and half the dose of NPK to Rape seed and blackgram cropping system in an acid inceptisols of Assam increased the soil organic carbon and available N, P, K, S and exchangeable Ca and Mg (Basumatary, 2018) [3]. This was also reported with 25 per cent N substitution through vermicompost by Kamble *et al*. (2018) [13]. significant buildup of DTPA-Zn is observed in soil with the application of 25% N through vermin compost and sewage sludge and sesbania as green manure in rice –wheat cropping system (Singh *et al*. 2018) [37]. Application of 100% NPK + 15 t FYM ha^{-1} in soybean-wheat cropping system under vertisols increased available N(329 kg ha^{-1}), P (40.5 kg ha^{-1}), K(312 kg ha^{-1}) and S(48.6 kg ha^{-1}) and organic carbon (9.4 g kg^{-1}) over the rest of the treatments. The soil microbial biomass carbon, soil microbial biomass nitrogen, activity of dehydrogenase, acid and alkaline phosphatase also increased significantly, the same also lowered the C:N ratio of soil (Gajendra Patel *et al.* 2018) [8]. Highest activity of bacteria, fungi and actinomycetes was observed with the substitution of organic manures by Mitali Mandal *et al*. (2018) [22].

Nutrient fractions in soil

Nitrogen and phosphorus are present in different forms in soil. A greater amount of nitrogen occurs in organic form while that of phosphorus is in inorganic form (Tisdale *et al.,* 1995) [38].

N fractions

The inorganic forms of N in soils are NH_4^+-N, NO_3^--N and NO_2^--N. Plant roots take up nitrogen from the soil mostly as NO_3^- and to some extent as NH_4^+-N. The NO_2^- form is unstable and is usually present in soil in lesser extent.

Santhy *et al.* (1998) [28] analysed the status of nutrient fractions in a long term experiment in the *vertic ustropept* at Coimbatore. They recorded relatively larger proportion of NH_4^+ – N than the NO_3^- - N fraction in different treatments.

The soil receiving no external input of nutrients through any source recorded least quality of 3.5 mg NO_3^- - N and 3.7 mg NH_4^+ –N kg^{-1} soil. The application of fertilizers increased these fractions with increase in the level of their application. The NO_3^- - N increased to 6.6 and the NH_4^+ – N to 7.8 mg kg^{-1} soil in response to the application of NPK fertilizers at 150% of their recommendation. Larger quantities of these fractions were recovered by the application 10 t of FYM along with the recommended dose of fertilizers. The NO_3^- - N was 7.4 mg and NH_4^+ - N was 8.3 mg kg^{-1} soil due to this integration of organic and inorganic nutrient supplements. Duraisami *et al.* (2001) [7] also confirmed an increase in the level of both NH_4^+ – N and NO_3^- –N with increase in the level of fertilizer nitrogen. The supplement of organic source of nutrients i.e., biofertilizer and coirpith vermicompost to the inorganic fertilizer led to further build up of both the fractions. The results of these investigations highlight the possible role of organic source of nutrients along with the inorganics in enhancing the plant utilizable nitrogen fractions during its growth period and also the NH_4^+ -N which is to be mineralized and transformed to the useful NO_3^- - N fractions.

P fractions

Phosphorus like any other plant nutrient is present in the soil in two major components *i.e.*, organic and inorganic. Organic P, is mainly confined to the surface layer. It is mineralized into inorganic forms and the plants mainly depend upon inorganic P forms for this nutrient requirement. Soil inorganic phosphates are categorized into active - Al-P, Fe-P and Ca-P, less active reductant soluble-P and occluded-P and inactive residual-P, P fractions based on their chemical nature and contribution towards available P pool. Among active forms, Ca-P usually predominates the Al-P and Fe-P in alkaline soils whereas reverse is true in acidic soil. The specific surface area activity and solubility of Al-P and Fe-P is higher compared to Ca-P. Therefore, these two forms are the major contributors to P availability both in acidic and alkaline soils and also to P uptake by many crops (Tiwari, 2002) [39]. Information on P fractions are important for evaluation of their status on soil and understanding its chemistry that has influence on soil productivity and soil health (Manju Khabla and Dixit, 2017) [19].

Most of the water soluble P added to the soil is transformed into relatively insoluble inorganic compounds of Al and Fe and thereby reduce its availability for the plant use. However, after a time when intensity factor of the soil solution goes down, these inorganic P fractions may contribute to the P nutrition of crops. The information on the status of various P fractions in different soils and extent of transformation of added P into various inorganic fractions as influenced by fertilizers and organic manures is compiled for sound understanding of the results.

Verma *et al.* (1991) [41] analysed the inorganic P-fractions and reported that the Al-P fraction was most abundant with a mean of 87.1 in the Karail soil groups, Ca-P was most abundant in alluvial soils. It had 113.3 while the Fe-P fraction was the most abundant in the red soil having 60.5 of this constituent. The contribution of Olsen –P was least. It ranged from 8.5 to 12.0 in these soils. Mathan (1998) [20] studied the relationship of P-fraction to soil properties in the *Alfisols* and *Entisols* in Coimbatore. He reported that the saloid-P constituted 0.5-0.6% of the total P. It was observed to decrease with increase in the clay content. It recorded significant positive correlation with pH but negative association with active Al. One unit increase in pH was reported to have increased the saloid-P by 0.07 mg kg^{-1}. The Bray-I P ranged from 5.6-10.9 kg ha^{-1}. The Al-P ranged from 12.5 to 34.2 mg kg^{-1} contributing 5.2-15.6% of the total P in the soil. The Ca-P was the predominant fraction. It ranged from 23.6 to 23.3% of the total P in the soil. The organic P-ranged from 10.9 to 26.4% of the total P in the soil.

Rokima and Prasad (1991) [27] studied the influence of integrated nutrient management treatments to rice on the transformation of applied P into inorganic P-fractions at Pusa, Samasthipur in Bihar. It was observed that the water soluble, saloid-P, Al-P, Fe-P, Ca-P, labile-P and the total-P increased with increase in the level of fertilizer application to the recommended dose. The influence of FYM or blue green algae was relatively less in increasing these fractions. The integration of these organics with the fertilizers enhanced the buildup of all the forms of inorganic-P. The earlier investigation of Singh *et al.* (1979) [35] also showed that the saloid-P, Al-P, Fe-P and Olsen-P were increased by the application of FYM and phosphatic fertilizer. However, they observed that this integrated nutrient management treatment had more effect on the Ca-P. They observed that the Ca-P was the predominant fraction in the calcareous soil ranging from 41 to 45% of the total-P. The labile-P ranged from 3.6 to 5.3% and the other fractions were very small. Singaram and Kodandaraman (1994) [34] studied the residual effect of applied phosphorus in finger millet – maize-black gram cropping system for efficient P- management at Coimbaotre in *Vertic Ustropept*. They observed that the Ca-P was the predominant fraction ranging from 308 to 336 ppm. The reductant soluble-P accounted for 139-144 ppm, Fe-P 105-117 ppm and Al-P 129-143 ppm. The saloid constituted least proportion ranging from 22-25 ppm. The increasing level of applied phosphorus from 0 to 95 kg P_2O_5 ha^{-1} did not show significant difference amongst any of these fractions. The application of high level of 90 kg P_2O_5 ha^{-1} to finger millet had a substantial residual effect. The Al-P, Fe-P and reductant soluble-P fractions were more after the harvest of unfertilized maize their buildup increased further after the harvest of black gram preceded by high dose of 90 kg P_2O_5 ha^{-1} to finger millet and maize. That the saloid-P did not show a substantial difference due to different levels of P-application. Santhy *et al.* (1998) [28] reported that the *Vertic Ustropept* soil at Coimbatore had less than 1% saloid bound-P due to the high P-fixation nature of soil. The Ca-P accounted for 62%of the total inorganic P. The concentration of Fe-P was less than the Al-P due to higher activity of Ca-P and Al-P. The saloid-P, Al-P, Fe-P, Ca-P, total -P and Olsen-P increased with increase in the level of fertilizer application up to 150% NPK. The Olsen-P increased further by the application of FYM along with the recommended level of fertilizers. But rest of the fractions were significantly less than those due to the influence of fertilizer application @ 150% NPK to fingermillet – maize – cowpea cropping sequence. Application of FYM @ 5 t ha^{-1} along with target 35 q ha^{-1} wheat productivity NPK recommendation under acid alfisol recorded highest H_2O –P(15.0 ppm), $NaHCO_3$ inorganic P(67.7 ppm), $NaHCO_3$ organic P(57.3 ppm), NaOH inorganic P(95.7ppm), NaOH organic P(156 ppm), HCl-P(58.0 ppm) and Residual –P(421 ppm), this might be due to application of FYM over a long period of might influence forms and availability of P due to release of organic acids and other microbial products which modify soil pH during decomposition (Manju Khabla and Dixit, 2017) [19].

Soil enzymatic activity

The biological condition of a soil can serve as a marker of the soil status and is closely linked to its natural fertility. The enzymes in soil originate from animal, plant and microbial sources. Crop plants contribute to enzymes in soil both directly and indirectly. Among the plant parts, roots are the most important sources of soil enzymes. Enzymes in soil are biologically significant as they are involved in the transformation, cycling of mineral elements and influence their availability to plants. The activity of soil enzymes is influenced by the nature, age of crop and addition of fertilizers and manures. The enzyme activity is considered as an index of microbial activity. Interest in soil enzyme activity has increased recently since it is believed to reflect the potential capacity of a soil to perform nutrient transformations.

Enzyme activities are very much influenced by the addition of organic manures due to increase in soil microbial activity. Available NPK and organic carbon content have a strong positive relationship with all the enzymes. Higher rates of NPK fertilization enhanced the activities of soil enzymes and the effect was more pronounced with organic manures in combination with fertilizers. (Kamalakumari and Singaram, 1995, Singaram and Kamalakumari, 1995 and Reddy, 2002) [12, 32, 26].

Pallab *et al*. (1990) [23] reported that several biochemical changes involving plant nutrient transformations and organic matter decomposition are catalysed chiefly by enzymes which are extracellular and are of plant origin. The microorganisms present in the soil contribute maximum to the enzyme pool in addition to this soil macrofauna, plant roots, debris and organic matter under decomposition also contribute the same. They further observed that several biochemical changes were involved in plant nutrient transformation and organic matter decomposition.

Dotaniya *et al.* (2018) [6] observed that, Long term application of sewage water increases soil organic carbon, carbon sequestration, microbial population and dehydrogenase and alkaline phosphatase activity of soil. This was also reported by Latare *et al*. (2018) [18] with Sewage sludge application to soil.

The enzyme urease (urea amidohydrolase) is an important microbial extracellular enzyme which influence the availability of plant utilizable forms of nitrogen in soils. Urease is an unique enzyme because it catalyses the hydrolysis of urea to ammonia (NH_3) which is subsequently transformed to ammonium (NH_4^+) and nitrate (NO_3^-) ions. It is important in the process of rapid urea hydrolysis leading to appreciable losses of fertilizer N through ammonia volatilization. As nitrogen fertilizer use efficiency is influenced by the activity of this enzyme, the determination of urease activity in soils provides a good index about the ability of soil to hydrolyze urea. In general, the urease activity increase with increase in organic carbon in soils.

The enzyme dehydrogenase transfers electrons from one substance to the other and is involved in degradation of carbohydrates and lipids etc. The measurement of the soil dehydrogenase activity provides an index of the activity of soil micro organisms which in turn bring about the transformation and availability of nutrients to crop plants by acting on organic matter (Pallab *et al*., 1990) [23]. Klein *et al.* (1971) [16] reported that the dehydrogenase activity can be taken as an index of metabolic activity of the microbial population.

The enzyme phosphatase breaks hemicellulose compounds of organic materials. By involving water, it breaks "humus – O – P $(OH)_2$" bond to produce "humus – OH" and H_3PO_4 making phosphorus available to plants. The optimum pH for acid and alkaline phosphatase enzymes are 6.5 and 11.0, respectively.

The urease in the soil has a microbial extracellular enzyme (Paulson and Kurtz, 1969) [24], it accumulates through release from living and dead microbial cells or plants. The soil urease is increased by urea concentration and organic matter, decrease by water level and has no effect with O_2 (Zantua *et al*., 1977) [43]. Singaram and Kamalakumari (1995) [32] reported that the continuous application of increasing level of fertilizers up to 150% recommended level of NPK ha^{-1} to maize over a period of 20 years increased the urease and dehydrogenase activity considerably which was recorded at knee height, tasseling and harvest stage. However the phosphatase activity reduced by increasing the level of NPK fertilizers from 50-150% recommended dose but the response was spectacular for these enzymes by the application of 10 t ha^{-1} FYM along with the recommended level of NPK through fertilizers. They also stated that the continuous addition of inorganic fertilizers over 20 years did not cause any detrimental effect on enzyme dynamics of the crop.

Singaram and Kamalakumari (2000) [33] reported that the continuous application of inorganic fertilizers to maize increased the urease and dehydrogenase activities but reduced the phosphatase activity with increase in the level of NPK from 50 to 150% of the recommendation. These enzymes accumulated in larger quantities by the application of FYM with recommended level of NPK. This positive response was attributed to the role of FYM as source to increase the microbial activity. Reddy (2002) [26] studied the relationship of urease activity in 15 soils of different locations in northern Telangana zone of Andhra Pradesh. The results established that the urease activity increased with increase in organic carbon content due to the presence of extracellular urease adsorbed on fine components of organic matter. It was also reported that the higher drymatter content in the soil stimulates the ureolytic microorganisms that serves as a source of carbon, energy and other nutrients essential for microbial growth and multiplication.

Chhonkar and Tarfadar (1984) [5] carried out enzyme assay from 27 soil samples differing in their physical and chemical properties. The results showed that the total phosphatase, acid phosphatase, neutral phosphatase and alkaline phosphatase had positive and significant correlation with the organic carbon content. The clay was not related with the total phosphatase activity or its different fractions. The organic carbon was thus found to be the most dominant factor determining the accumulation of phosphatases. Kuprevich and Scherbokova (1971) [17] reported that the phosphatases are the adoptive enzymes and are most likely to be affected by the availability of the substrate. Application of 100 % NPK + FYM @ 15 t ha^{-1} recorded significantly higher activity of soil urease(79.2 mg $NH4^+$-N kg^{-1} soil 2 h^{-1}), dehydrogenase (246.1 mg TPF kg^{-1} soil 24 h^{-1}), acid phosphatase (452 mg PNP kg^{-1} soil h^{-1}) (Mitali Mandal, 2018) [22].

Conclusion

Several research findings revealed that, application of organic manures and their conjuctive use along with other nutrient sources significantly influenced the soil health in terms of Physico chemical, physical, chemical and biological activites of soil under different climatic situations of India.

References

1. Anonymous. Progress report of All India Coordinated Wheat and Barley improvement Project 2015-16, Director's Report. Ed.G.P. Singh, ICAR-Indian Institute of Wheat and Barley Research, Karnal, India, 2016, 96.
2. Arindam Sarkar, Prasanta Kumar, Bandyopadhyay. Effect of Incubation Duration of Incorporated Organics on Saturated Hydraulic Conductivity, Aggregate Stability and Sorptivity of Alluvial and Red –laterite soils. Journal of the Indian Society of Soil Science. 2018; 66(4):370-380.
3. Basumatary A. Integrated Sulphur Management in Rapeseed (*Brassica camprestis*)-Blackgram (*Vigna mungo*) sequence in an inceptisol of Assam. Journal of the Indian Society of Soil Science. 2018; 66(4):425-431.
4. Bellakki MA, Badanur VP, Setty RA. Long term effect of INM on properties of a Vertisol. Journal of the Indian Society of Soil Science. 1998; 46(2):176-180.
5. Chhonkar PK, Tarafdar JC. Accumulation of phosphatases in soils. Journal of the Indian Society of Soil Science. 1984; 32:266-272.
6. Dotaniya ML, Meena VD, Rajendiran S, Vasanda Coumar M, Asha Sahu, Saha JK *et al*. Journal of the Indian Society of Soil Science. 2018; 66(3):310-317
7. Duraisami VP, Rani Perumal, Mani AK. Changes in organic carbon, available nitrogen and inorganic N fractions under integrated nitrogen management of sorghum in a black soil. Journal of Indian Society of Soil Science. 2001; 89(3):435-439.
8. Gajendra Patel, Dwivedi BS, Dwivedi AK, Risikesh Thakur, Muneswar Singh. Long-term Effect of Nutrient Management on Soil Biochemical Properties in Vertisol under Soybean –Wheat Cropping Sequence. Journal of the Indian Society of Soil Science. 2018; 66(2):215-221
9. Gayatri Verma, Mathur AK. Effect of integrated nutrient management on active pools of soil organic matter under maize-wheat system of a typic haplustept. Journal of the Indian Society of Soil Science. 2009; 57(3):317-322.
10. Jamwal JS. Effect of INM in maize (*Zea mays* L.) on succeeding winter crops under rainfed conditions. Indian Journal of Agronomy. 2006; 51(1):14-16.
11. Jayaprakash TC, Nagalikar VP, Pujari BT, Setty RA. Effect of organics and inorganics on soil properties and available nutrient status of soil after harvest of maize crop under irrigation. Karnataka Journal of Agricultural Sciences. 2004; 17(2):311-314.
12. Kamalakumari K, Singaram P. Relationship among soil chemical, biochemical properties and enzyme activities. The Madras Agricultural Journal. 1995; 82(1):69-70.
13. Kamble BM, Kathmale DK, Rathod SD. Soil Nutrient Status, Uptake and Economics of Groundnut –Wheat Cropping Sequence as influenced by Organic Sources and Fertilizers. Journal of the Indian Society of Soil Science. 2018; 66(1):66-75.
14. Karki TB, Ashok Kumar, Gautam RC. Influence of INM on growth, yield content and uptake of nutrients and soil fertility status in maize (*Zea mays* L.). The Indian Journal of Agricultural Sciences. 2005; 75(10):682-685.
15. Khadtare SV, Patel MV, Mokashi DD, Jadhav JD. Influence of vermicompost on quality parameters and soil fertility status of sweet corn. Journal of Soils and Crops. 2006; 16(2):384-389.
16. Klein DA, Loh TC, Goulding. A rapid procedure to evaluate the dehydrogenase activity of soils in an organic matter. Soil Biology and Biochemistry. 1971; 3:385-387.
17. Kuprevich VF, Scherbakova TA. Jn Soil Biochemistry, Marcel Dekker Inc., New York, 1971.
18. Latare AM, Singh SK, Omkar Kumar. Impact of Sewage Sludge Application on Soil Fertility, Microbial Population and Enzyme activities in Soil under Rice-Wheat System. Journal of the Indian Society of Soil Science. 2018; 66(3):300-309.
19. Manju Khabla, Dixit SP. Effect of Prescription –based fertilizer application on Different fractions of Phosphorus under wheat in an acid *Alfisol*. Journal of the Indian Society of Soil Science. 2017; 65(4):447-451.
20. Mathan KK. Phosphorus fractions in Alfisols and Entisols and their relation to soil properties. The Madras Agricultural Journal. 1998; 85(10-12):601-604.
21. Mathan KK. Impact of biological wastes on soil physical properties and yield of maize and finger millet. The Madras Agricultural Journal. 2000; 87(10-12):618-620.
22. Mitali Mandal, Kumba Karna Rout, Debasis Purohit, Pradipa Majhi, Muneswa Singh. Evaluation of Rice-Rice System on grain yield, Chemical and Biological Properties of an Acid Inceptisols. Journal of the Indian Society of Soil Science. 2018; 66(2):208-214.
23. Pallab De K, Arun Mishra K, De SK. Soil enzyme activities and agricultural importance. Indian Journal of Agricultural Chemistry. 1990; 29:223-227.
24. Paulson Thomas, Meena MC, Aggarwal BK, Shri Ram, Surjit Mondal, Mishra AK, Chakrborthy D. Strength and Stability of Aggregates as the key indicators for evaluating Soil Physical Conditions. Journal of the Indian Society of Soil Science. 2018; 66(2):268-274.
25. Ramesh P, Panwar NR, Singh AB, Ramana S. Effect of organic manures on productivity, nutrient uptake and soil fertility of maize (*Zea mays*) – linseed (*Linum usitatissinum*) cropping system. Indian Journal of Agricultural Sciences. 2008; 78(4):351-354.
26. Reddy MS. Relationship between organic carbon and soil enzymes. The Journal of Research ANGRAU. 2002; 30(2):143-146.
27. Rokima J, Prasad B. Integrated Nutrient Management-II. Transformation of applied P into inorganic P fractions in relation to its availability and uptake in calcareous soil. Journal of the Indian Society of Soil Science. 1991; 39:703-709.
28. Santhy P, Jayasree Sankar S, Muthuvel P, Selvi D. Long-term fertilizer experiments - Status of N, P and K fractions in soil. Journal of the Indian Society of Soil Science. 1998; 46(3):395-398.
29. Santhy P, Velusamy MS, Murugappan V, Selvi D. Effect of inorganic fertilizers and fertilizer-manure combination on soil physico-chemical properties and dynamics of microbial biomass in an Inceptisol. Journal of the Indian Society of Soil Science. 1999; 47(3):479-482.
30. Selvi D, Santhy P, Dhakshinamoorthy M. Effect of inorganics alone in combination with farmyard manure on physical properties and productivity of vertic haplustepts under long-term fertilization. Journal of the Indian Society of Soil Science. 2005; 53(3):302-307.
31. Sheeba S, Chellamuthu S. Impact of fertilization and intensive cropping on physical properties of vertic ustropept soil. Madras Agricultural Journal. 1996; 83(10):652-655.
32. Singaram P, Kamalakumari K. Long term effect of FYM and fertilizers on enzyme dynamics of soil. Journal of the Indian Society of Soil Science. 1995; 43(3):378-381.

33. Singaram P, Kamalakumari K. Effect of continuous application of different levels of fertilizers with FYM on enzyme dynamics of soil. The Madras Agricultural Journal. 2000; 87(4-6):364-365.
34. Singaram P, Kothandaraman GV. Interrelationship between different phosphorus fractions in a cropping sequence treated with different phosphorus sources. The Madras Agricultural Journal. 1994; 81(6):305-308.
35. Singh B, Bhumbla DR, Randhawa NS. Bulletin of Indian Society of Soil Science. 1979; 12:131.
36. Singh D, Nepalia. Influence of integrated nutrient management on quality protein maize (*Zea mays*) productivity and soils of southern Rajasthan. The Indian Journal of Agricultural Sciences. 2009; 79(2):1020-1022.
37. Singh SK, Maneesh Kumar, Singh RP, Bohra JS, Srivastava JP, Singh SP *et al*. Conjoint application of organic and inorganic sources of nutrients on Yield, Nutrient uptake and Soil fertility under Rice (*Oryaza sativa*)- wheat(*Triticum aestivum*) System. Journal of the Indian Society of Soil Science. 2018; 66(3):287-294.
38. Tisdale SN, Nelson WL, Beeton JD, Havlin JL. Soil fertility Fertilizers, 5th edition, Prentice Hall, India Private Limited, New Delhi, 1995.
39. Tiwari TN. Fundamentals of soil science. Indian Society of Soil Science, New Delhi, 2002.
40. Venkatesh MS, Majumdar B, Kailash Kumar, Patiram. Effect of phosphorus, FYM and lime on yield, P uptake by maize and forms of soil acidity in Typic Hapludalf of Meghalaya. Journal of the Indian Society of Soil Science. 2002; 50(3):254-258.
41. Verma LP, Singh AP, Srivastava MK. Relationship between Olsen’s P and Inorganic P fractions in soils. Journal of the Indian Society of Soil Science. 1991; 39:361-362.
42. Yash Pal Singh, Sanjay Arora, Vinay Kumar Mishra, Himanshu Dixit, Ravindra Kumar Gupta. Conjoint Use of Chemical Amendments and Municipal Solid Waste compost for amelioration of Degraded Sodic soils. Journal of the Indian Society of Soil Science. 2018; 66(4):392-398.
43. Zantua MI, Dumenil LC, Bremner JM. Relationship between soil urease activity and other soil properties. Soil Science Society of America Journal. 1977; 41:350-35.