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Influence of Long Term Fertilization on Soil Fertility – A Review.

S Hemalatha*, K Radhika, S Maragatham, and S Praveena Katharine

Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore – 3, Tamil Nadu, India.

Review Article

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***For Correspondence**

Deaprtment of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore – 3, Tamil Nadu, India.

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ABSTRACT

Long term fertilizer experiments play an important role in understanding the complex interactions involving soils, plants, climate and management practices and their effects on crop productivity. It is well recognized that long term fertilizer experiments are repositories of valuable information regarding the sustainability of intensive agriculture. The LTFE serves as an important tool to understand the changes in soil properties due to intensive cropping and continuous fertilization. Consistent use of chemical fertilizers and manures in soil alters the physico-chemical and biological properties of the soil.

Effects of long-term fertilization on soil chemical properties

Soil reaction – Ph

Long-term application of fertilizers and manures to soil is expected to affect changes in the soil reaction depending upon the nature of the soil and the composition of manure-fertilizer schedules adopted in the particular cropping system.

From a study in *Haplustalfs* with soybean-wheat cropping sequence, it was found that the continued cropping and fertilization over 21 years resulted in the decrease of soil pH by 0.1 to 0.2 units and the maximum fall in the pH was due to the application of N alone either as urea or ammonium sulphate source and the acid-producing nature of these fertilizers was attributed as reason for the decrease in pH. With an increase in the levels of NPK from 50 to 150 per cent of optimal dose, there was corresponding decrease in the soil pH [34].

Sheeba and Chellamuthu, [42] observed that the continued application of varying quantities of inorganic fertilizers and their combinations with FYM over 22 years did not alter the pH appreciably.

The results of the LTFE on fixed plot with sorghum-sunflower sequence at Parbhani, indicated significant decrease in pH values in those treatments where 50 per cent N was applied through organic source viz., green manure, FYM, pressmud compost, wheat straw and at 100 per cent N through organic sources [18].

Soil salinity – EC

A study in a Permanent Manurial Experiment (PME) on *Aridisols* showed an increase in soil EC value from 0.67 dSm^{-1} to 0.80 dSm^{-1} due to the continued application of fertilizers for over 30 years. The increase in the EC of the soil with continued application of fertilizers was due to the addition of salts through fertilizers and solubilisation of native minerals due to the reduction in the pH of the [17]. Mairan *et al.* [18] concluded that there was decline in values of soil EC of *Vertisol* with crop residue incorporation over fertilizer application in LTFE on fixed plot with sorghum-sunflower sequence.

Cation exchange capacity (CEC)

Bellakki *et al.* [5] stated that the combined application of organic and inorganic sources of nutrients resulted in significant increase in CEC over control. Increase in fertilizer levels from 50 to 125 per cent gradually increased the CEC of soil due to addition of organic matter through plant roots. The CEC of soil was found to be significantly increased by the application of higher rates of FYM and the best treatment was application of 7.5 t FYM ha^{-1} with half dose of N and P fertilizers [35].

Soil Organic carbon content

In the long-term field experiments, at Ludhiana (*Ustochrepts*), Hyderabad and Bhubaneswar (*Tropaquept*) and Palampur (*Hapludalfs*) cultivation for 15 years increased soil organic carbon. The increase was most distinct with laterite soils of Bhubaneswar [34]. Long-term experiments are the primary source of information to determine the effect of cropping system, soil management, and fertilizer usage and residue utilization on changes in soil organic carbon (SOC) and to determine agricultural sustainability [4]. Suresh *et al.* [48] found that the FYM had profound effect on the organic carbon content (5.9 g kg^{-1}) of soil. The organic matter content was 2.09 per cent with FYM application (NPK + FYM + Zn), which was significantly higher than all the other treatments. The addition of FYM helped in maintaining the organic matter status of 2.1 per cent as observed when the experiment trail was initiated during 1984 [44].

Alok Tiwari et al. [1] reported from the experiment conducted on Typic Haplustalf; that the continued application of fertilizers alone also helped in increasing the organic carbon content of soil, which could be attributed to higher contribution of biomass to soil in the form of crop stubbles and residues.

In *Vertisols*, the organic carbon content of both surface and sub-surface soils increased significantly with the incorporation of FYM either alone or in combination with recommended doses of fertilizers. This could be attributed to better root growth and more plant residues incorporation into the soil. The organic carbon and nitrogen contents of soil under 33 years of cropping decreased with increasing frequency of fallow than under continuous cultivation [52].

Fan *et al.* [11] observed that the combination of organic and inorganic fertilization enhanced the accumulation of soil organic carbon and maintained the highest productivity .Organic carbon content of soil was higher when higher rate of FYM was added [35]. Kuntal *et al.* [16] stated that the balanced application of inorganic fertilizer and organic amendments greatly influenced the accumulation of organic matter in soil.

Effect of long-term fertilization on soil nutrient status

The cultivation of crops without application of manures or fertilizers caused a drastic exhaustion of the native pool of nutrients from the soil under the present agro - climatic condition (dry land *Vertisol*). The combined application of organic source such as FYM (50 per cent of the requirement) with nitrogenous fertilizers N i.e., urea (50 per cent of the requirement) + sustained the higher availability of N, P and K[48].

Available nitrogen

Application of major nutrients especially N plays a key role in determining the yields of crops [10]. Among the major nutrients, nitrogen is universally deficient and most vulnerable to losses especially under tropical climate. Its regular supply during crop growth period is possible through release of nitrogen from organic manures [53].

Nitrogen accumulation was higher when manure or straw was added along with NP fertilizers. This might have been partially due to a slow release of N from manure and straw, resulting in reduced losses of N [11]. Similar result was also reported by Bhandari *et al.* [6].

In the red loam soils of the old and new permanent manurial experiments at Coimbatore, the available nitrogen content was found to be enhanced due to continuous incorporation of organic manures [24]. Continuous addition of potassium had decreased the available N status of the soil due to the blocking up of adsorbed NH_4 by added potassium preventing its release [13]. The results of the long-term fertilizer experiments were reviewed by Nambiar [25] and reported that there was a decline in the available N status of the soil in plots where N had not been applied for many years. Subramanian and Kumaraswamy [46], stated that the soil available N status in the long - term fertilizer experiment conducted on *Inceptisol* was the highest under100 per cent optimum NPK + FYM treatment while under cropped but unmanured treatment it was the lowest as against the initial status.

A comparison of available N status of the fallow plots with control clearly revealed that cultivation without any addition of fertilizers or manures drastically reduced the soil N availability. Increasing the NPK dose from 50 to 150 per cent increased the available N content of the soils and the highest available N was noticed under FYM treated plots [7]. The results of Long - Term

Manurial Experiment showed that the N availability was not altered by the levels of phosphorus or potassium application, but their application without FYM caused depletion of available N [36].

Any increase in the rate of FYM applied would increase the available N status of the soil [19]. The available N content of the soil increased over the initial value under 100 per cent NPK + FYM treatment and was due to higher organic carbon content in *Inceptisol* [39]. Continued cropping without fertilization depleted the available N status from the initial value in plots receiving only FYM. However, it increased significantly with regular dressing of N fertilizers. The increase in available N status due to organic manure application would be due to the multiplication of soil microbes leading to enhanced conversion of organically bound N into inorganic forms [29].

Legume cropping increased the N status of the soil, which may be attributed to the litter fall and atmospheric N-fixation by legume crops [51]. There was decline in availability of N in all the treatments when compared to the initial values in *Vertisol* at LTFE, MAU, Parbhani. Continuous manuring helped to increase the available nitrogen of soil [18].

Available phosphorus

A build up in the available P status of the soil over the initial value recorded in 1972, occurred in 100 per cent NPK + FYM and also in 150 per cent NPK treatments. The results of LTFEs all over the country have revealed that the use of N alone leads to accelerated depletion of soil P [26]. Reviewing the results of long-term fertilizer experiments, Nambiar [25] reported a considerable build-up in the available P status of alluvial, red loam and submontane soils of Punjab, Ranchi and Palampur due to the application of increasing rates of P. Similar trends were also reported in the medium black soils of Coimbatore by Subramanian and Kumaraswamy [46] and Muthusamy *et al.* A marked rise in the available P status of the soil with the application of lime and FYM might be due to the inactivation of iron, aluminium and hydroxyl Al ions thereby reducing the P fixation in soil [32]. Bahl and Avtar Singh [3], stated that an increase in the available P status with the application of organics and the increased availability was a consequence of decrease in P adsorption and phosphate potential of soil. A balance sheet of P under different fertilizer treatments was worked out in LTFE of soil type *Typic Ustrochrept*. The mean uptake of P in unfertilized plots was the lowest (14.9 kg ha^{-1}) followed by those receiving 100 per cent N alone (26.6 kg ha^{-1}) and 50 per cent NPK (28.0 kg ha^{-1}). The highest annual gain of 66.6 kg ha^{-1} was noted in 150 per cent optimum NPK treatment and the lowest (7.0) in suboptimal dose [43].

Graded levels of P application were accompanied by a corresponding increase in the amount of available P owing to higher rates of P application in the amount exceeding crop uptake [39]. The available P status of soil after 10 years of rice - wheat cropping was minimum in control whereas the maximum available P was found in NPK + FYM + Zn treatment. The NPK + FYM + Zn and NPK + FYM treatments nearly maintained P availability as that of the initial value whereas in other treatments noticeable depletion in available P was seen [44].

Jayasree Sankar *et al.* [15] stated that the continued application of phosphatic fertilizer to a rice-wheat crop rotation over the years resulted in an increased available soil P status .The combined application of organic manure and inorganic fertilizer increased the available P status of the soil. The increased release of P may be due to the fact that organic anions compete with the phosphate ions for binding sites on soil particles thereby reducing the P fixation [28].

A build-up of P in P- receiving plots and depletion in N and K treated plots was observed [12]. In calcareous soil, CO_2 produced during the decomposition of organic matter plays an important role in increasing the phosphate availability. Organic matter enhanced the labile P in soil through complexation of cations like Ca and Mg when it is applied in combination with inorganic fertilizers [52]. Among the treatments, 100 per cent NPK + FYM recorded the highest level of P availability in the surface layer of soil in LTFE (*Inceptisol*). Also the addition of 150 per cent of NPK had shown a beneficial effect. Phosphorus availability was found to increase with increase in the amounts of applied NPK in the 0-15 and 15-30 cm layers [38]. The availability of P was significantly increased in the treatments where 50 per cent or 100 per cent of N was applied through organic source or where 150 per cent NPK was applied [18].

Slope of the trend lines for soil available P indicated declines of about 0.20 mg kg^{-1} y^{-1} for the unfertilized and N only treatments, but increases of 0.19, 0.25, 0.38 and 0.67 mg kg^{-1} y^{-1} for the manure, NP, SNP and MNP treatments respectively [11]. In Allophanic *Andisol,* the cultivated soils (Chemical fertilizer plot, chemical fertilizers + compost plot, chemical fertilizers + compost +lime plot) contained a higher amount of phosphate than the uncultivated soils, as the phosphate applied to Andisols is specially sorbed on soil and accumulates in the Ap horizons [27,49].

Available potassium

Decline in available K status was observed in the plot receiving only fertilizer N but the significant increase in available K content has been noted in the plot receiving either FYM or GM along with fertilizer N. This suggests that FYM and GM helped to maintain the supply of K by releasing the K from reserve source [21]. Intensive cropping with high yielding crop varieties led to depletion of K from soil which was evident from a number of long term field experiments conducted across the country under AICRP programme of ICAR [2].

The application of zinc and sulphur fertilizers along with 100 per cent optimal NPK increased the available K status of *Vertisol*, compared to the application of 100 per cent NPK alone [37]. The effects of the long- term intensive cropping and fertilizers on available potassium status in a *Haplustert* soil was that the available soil K declined over the 29 years of intensive cropping and fertilizer application even at 150 per cent NPKS [50].

The status of available K in soil was found to decrease in all the treatments but the decrease was of lower magnitude in 100% NPK + FYM and 150% NPK treatments indicating the need to raise the level of K fertilizer application to meet the demand of the crops [1]. The long- term effect of application of micronutrients on the available K status of the soil was studied and it revealed that the application of micronutrients alone decreased the available K status of the soil whereas the application of these nutrients along with FYM increased its availability [54].

The beneficial effects of FYM on the availability of K may be ascribed to the reduction in K fixation and release of K due to the interaction of organic matter with clay [52].

Declined rate of 2.06, 2.44 and 2.45 mg kg^{-1} y^{-1} for the control, N and NP treatments, respectively was found. In contrast, available K levels increased with time at rates ranging from 0.98 to 1.18 mg kg^{-1} y^{-1} for plots receiving manure or straw. Inputs of K with organic materials resulted in a build-up of soil available K because manure or straw generally contains high amount of K [11]. Available potassium contents were higher when higher rate of FYM was added to the soil [35].

Secondary nutrients

Calcium, magnesium and sulphur are required in relatively larger amounts for good crop growth. Sulphur and magnesium are needed by plants in about the same quantities as phosphorus, and for many plant species, the calcium requirement is greater than that of phosphorus. In a multiple cropping system with higher fertilizer levels, use of high-analysis fertilizers like urea without secondary and micronutrients would decrease the availability of secondary nutrients like calcium, magnesium and sulphur in soil and cause imbalance of nutrients.

Exchangeable calcium and magnesium

In a multiple cropping system, higher fertilizer levels decreased the availability of calcium and magnesium while the application of FYM increased the levels of exchangeable Ca and Mg [31]. In the Old Permanent Manurial Experiment at the TNAU, the Ca content was lower in plots receiving continued application of nitrogen, which may be due to the increased uptake of Ca by crops, induced by nitrogen treatment [23].

A decrease in the exchangeable Ca and Mg contents of the soil was detected where ammonium sulphate had been used as the source of nitrogen. This decrease was more during the first seven years but the decreasing rate lessened subsequently due to the reduction in yield with less removal of nutrients. In the case of FYM application, there was first a decrease followed by an increase due to slow mineralization of organic manures [47]. An increase in the Ca and Mg status of the soil was found due to the continued application of manure while the addition of N in soil tended to decrease it [30]. The exchangeable Ca and Mg status of continuously fertilized acid soil increased due to the application of lime and FYM [32]. The long-term Integrated Nutrient Management on soil fertility status leads to increased content of both Ca and Mg due to the incorporation of FYM along with fertilizers. The FYM has a positive effect on Ca and Mg content in soil because it is having high adsorptive capacity that might have adsorbed Ca and Mg which would otherwise be leached [5]. The cultivated soils with the application of fertilizer + compost + lime contained a large amount of exchangeable Ca associated with fertilization and liming [49].

Available micronutrients

The enhancement in the DTPA- Fe due to the addition of organic substances may be ascribed to their ability to form stable water- soluble complexes preventing the reaction with other soil constituents and also increasing the Fe content by releasing it from the native reserves [14]. Addition of lime along with the NPK increased the availability of micronutrients in soil, which might be due to the higher organic matter content of these soils supporting enhanced microbial activity and consequent release of organic complexing substances, which would make micronutrient cations labile [47].

Lowest amounts of available micronutrients were observed in the unmanured control which was due to the continued exhaustion of micronutrients. The availability of micronutrients in the soil was suppressed due to lime application in acid soils, which might be due to the change in pH and physical adsorption on the finer particles of $CaCO_3$ rendering them unavailable to plants [33]. A study was conducted on the effect of the continued manuring on the extractable micronutrients in an *Alfisol.* DTPA-extractable Zn content was found to be higher in 100 per cent NPK + Zn treatment and 100 per cent NPK + FYM treatment. The increase in Zn content due to the application of FYM was due to the mineralization of organically bound forms of Zn in the FYM and possible addition of Zn through super phosphate [9].

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A study on alluvial soil recorded the decrease in available Zn content of the soil due to the application of higher levels of N and P and also the available Cu content was found to be higher in N alone treatment compared to N applied in combination with P and K indicating that the P and K have adverse effects on available copper content [45]. The available Mn status increased with the addition of FYM. This may be due to the release of Mn^{2+} bound to organic ligands in the organic matter and acceleration of the reduction of Mn^{4+} to Mn^{2+} [41]. In the study on Chromusterts, it was reported that a substantial increase in available Mn status occurred by the increased dose of NPK [8].

The depletion rate of DTPA- extractable micronutrients was higher in soils treated with chemical fertilizers alone as compared to the plots that received both fertilizers and organic manures after completion of 12 cycles of rice- wheat sequence in an *Inceptisol* [55]. The DTPA - Mn content in soil showed statistically significant positive effect of all balanced fertilizer treatments [44]. The DTPA - Zn content of N, NK and NPK treatments were observed to be higher than that of control. The DTPA - Zn level in NPK + Zn treatment was higher (2.75 mg kg^{-1}) due to continuous application of Zn in the soil.

The balanced or imbalanced fertilizer treatment increased the DTPA - Cu over control. The DTPA - Cu level was high in NPK + FYM and NPK + FYM + Zn treatments [44]. The application of balanced fertilizer treatments either alone or with FYM (NPK + FYM and NPK + FYM + Zn) showed significantly higher DTPA - Fe content than other treatments after 10 years of rice - wheat cropping sequence. Further significant increase in DTPA - Fe with SSP was also noticed [44]. The cationic micronutrients in the soil showed a build up with the application of FYM. The increased availability may be due to the chelation process [40]. Cu was more soluble in soil with a high pH. The soil pH influences the degree of complexation of Cu in the soil solution. Under high pH conditions, while free Cu^{2+} solubility is exceedingly low, the soluble complexes of Cu increase the total copper solubility in soil [20,49].

CONCLUSION

Thus, from reviewing the above literatures, the importance of long term fertilizer experiment was felt in aspects of sustained crop and soil health. The limelight falls on sustainable maintenance of soil fertility in intensive cultivation of crops. The need of the hour is the production of more grain per unit area per unit time per unit input without detrimental effect on soil environment and soil health. There is a necessity for continuous monitoring of changes in nutrient dynamics. So, LTFE provide a resource of soil and plant material to further scientific research into soil and plant processes that control soil fertility, plant productivity, water, soil, and air quality.

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