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Review Article

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Influence of Integrated Nutrient Management Strategies on Soil Fertility

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A B S T R A C T

Soil fertility management by integrated nutrient management is getting support to overcome the problems faced by chemical fertilizers, like soil pollution, nutrient leaching, and over dependent of costly external inputs. An organic fertilizer improves physical and microbiological properties of soil but they have comparatively low in nutrient content, so larger quantity is required for plant growth. However, inorganic fertilizers are usually immediately and fast containing all necessary macro and micro nutrients that are directly accessible for plants. But continuous use of chemical fertilizers alone causes soil organic matter degradation, soil acidity and environment pollution. So, replacement of a part of chemical fertilizers by organic manure through a simple technique of using minimum effective dose of sufficient and balanced quantities of organic and inorganic fertilizers in combination with specific microorganisms called integrated nutrient management has a bright solution in this area. Eco-friendly approach integrated nutrient management occurring a balance between fertilizers input and crop nutrient requirement and maintain the soil fertility is reviewed with regard to sustainable agriculture.

Keywords
- Integrated nutrient management
- Soil Fertility
- Strategy

Introduction

Global food production needs to be increased at least by 70% over the current level by 2050 to meet the increase in food demand, which rapidly increases as a result of over pollution. To achieve this challenging target, agriculture must grow significantly, in consideration of the factors that contribute to increase the yield production, which are already reduced or tend to reduce, since they are placing unprecedented pressure on the natural resources. Intensive cropping system with high yielding varieties for boosting food production caused marked depletion of inherent nutrient reserves in soil. Consequently along with deficiency of N, P and K the deficiency of secondary and micronutrients are frequently reported. Presently, the major concern in agriculture is to arrest any further decline in crop productivity and soil quality. Although high
yielding nutrient responsive crop varieties resulted in higher productivity, it led to the over explanation soil reserves and other resources. In general, Indian soils are poor in fertility, as these have been consistently depleted of their finite nutrient resources due to continuous cultivation for centuries, adoption of modern agricultural technology and imbalanced use of fertilizers and poor use efficiency of fertilizers.

Currently, our goal of interest need to be modified in managing nutrient programme to provide a safe food supply free from pollutants or at least which contains a minimum level of agrochemicals contaminants further more guaranteeing an environment with pollution. Therefore, the great challenges have been to optimizes the nutrient supplies to maintain high nutrient use efficiency, refine the natural resources, modify the agricultural practices to achieve more grain yield per unit area, without jeopardizing the soil and natural resources and improve the water use efficiency to provide more crop per drop. All of these are the most important goals, which can be achieved by the implementation of integrated nutrient management programme not only at the present time but also in the near future. The objective of the present review is to assess the effect of integrated nutrient management strategies and their contribution to soil fertility.

Results of the integrated nutrient management on soil fertility

Soil organic carbon

Continuous cropping without the application of organic manure caused a decrease in organic carbon (Nambiar, 1985). Singh et al., (1999) working on mollisols at Pantnagar reported that 10 years of continuous intensive rice-wheat cropping under various fertilizers and manure treatment recorded drastic reduction in organic matter except in lot receiving single super phosphate and FYM. Beri et al., (1995) reported that maximum increase in soil organic carbon content was observed with integrated use of inorganic fertilizers (N+P+K) and organic manures. Continuous application of fertilizers alone or in combination with graded level of FYM for soybean based cropping system was studied by Babhublkar et al., (2000) and reported that highest organic carbon status due to application of higher rate of FYM with half dose of N and P fertilizers.

Organic carbon content increased significantly (6-80 g kg⁻¹) in cultivated soil over uncultivated soil (5-19 g kg⁻¹) under the long term of different cropping system (Sharma and Bali, 2000). Singh and Swarup (2000) assess the result of long term fertilizers experiment in various agro-ecological regions of India and observed a decline in organic carbon as a result of the continuous application of N fertilizers a alone while the balanced use of chemical fertilizers along with organic manure improved organic carbon. Focusing on role of soil organic carbon in maintaining soil fertility and productivity. Yaduvanshi (2001) reported that continuous use of inorganic fertilizers reduced the organic carbon content of soil.

The addition of FYM and integrated use of FYM with chemical fertilizers resulted in significantly higher organic carbon accumulation over inorganic fertilizers alone after harvest of maize in an alfisols (Kumari et al., 2013). Ravankar et al., (2005) reported that the maximum amount of organic carbon was found in the plot receiving inorganic fertilizer in combination with organics. Working on use of organic manures and fertilizers in rice-wheat cropping system. Kumar and Yadav (2003) noted an increase in organic matter content and it was attributed to
the direct incorporation of organic matter, better root growth and more plant residue addition.

The effect of integrated use of chemical fertilizers and FYM in long term fertilizers experiment in all the treatments, the organic carbon content increased however, a marginal decrease was registered in the 100% N and control plot Sharma and Subehia (2003). Highest organic carbon content in FYM and green manure plots than in the control plots under rice-wheat cropping system in Haryana was also reported by Phogat et al., (2004). Gathala et al., (2007) assess the effect of integrated nutrient management in soil properties in the long term fertilizers experiment noted an increase in organic matter content. Singh and Nepalia (2009) conducted an experiment at Rajasthan college of Agriculture, Udaipur, Rajasthan and concluded that application of vermicompost @5 t ha\(^{-1}\) with 100% RDF on maize improved the organic carbon content of soil than control. Pandey et al., (2009) reported that addition of different organic materials increased the organic carbon of the soil.

Highest organic carbon content (0-88%) was observed in the treatment where 4 t ha\(^{-1}\) organic manure was applied along with recommended level of NPK and Zn at 0.5 kg ha\(^{-1}\) (Sur et al., 2010). The effects of different integrated nutrient management practices on soil organic carbon as well as the sustainability of the rice-wheat system were evaluated in long term experiment at different agro-climatic zone of IGP by Nayak and Mohan (2012). They reported that application of NPK either through inorganic fertilizers or through combination of inorganic fertilizers and organics such as FYM or crop residue or green manure improved the soil organic carbon content. Karmakar et al., (2011) reported that the application of 50% NPK, 23% N through FYM, green manure and blue green algae increased the organic carbon status of soil. Organic carbon wad recorded maximum in integrated nutrient management treatment including vermicompost and recommended dose of NPK (Lalith Kannan et al., 2013). Highest organic content with the application of RDF (120:60:40 NPK kg ha\(^{-1}\)) + FYM 10 t ha\(^{-1}\) was also reported by Pandey and Awasthi (2014). The result of the field experiment concluded by Sarkar et al., (2016) at Nadia West Bengal revealed that the amount of organic carbon in soil was found to maintain the highest fertility status in the treatment receiving NPK + FYM 10 t ha\(^{-1}\) + Zn 5 kg ha\(^{-1}\).

The treatment with organic nutrient management package registered significant increase in soil organic carbon (24.4 to 41.9%) and the build up was maximum in the soil applied with one third N each through FYM, green manuring and neem oil cake + Azospirillum + PSB to rice (Patra et al., 2017). Organic carbon content of soil after harvest of pearl millet increased significantly with 100% RDF + Azotobacter + PSB or 50% RDF + 5 t FYM + Azotobacter + PSB significantly Jakhar et al., (2018). Jadhao et al., (2019) also reported an improvement in the organic carbon status of the soil with conjoint use of organics and fertilizers. Ravankar et al., (2005) reported that the maximum amount of organic carbon was found in the plot receiving inorganic fertilizers in combination with organics. In spite of regular application of organics in the vertisols of semi arid areas the organic carbon increase is gradual, therefore offers a great challenge for the substance of soil quality (Singh and Wanjari, 2007). Organic carbon content in soil increased significantly by supplementing fertilizers with organic sources (Singh et al., 2018). Report a field experiment conducted on a sandy loam soil at Varanasi, Uttar Pradesh. Integrated use of recommended level of NPK to pearl millet
and mustard with organic manure and bio fertilizers improved the soil status of N and P by 83.0 and 26.3 kg ha\(^{-1}\) over the initial value (Tomar et al., 2018).

Integrated use of bio-organics and inorganic fertilizers can improve crop productivity and sustain soil health & fertility and soil organic carbon. Irrespective of treatments soil health status with respect to soil organic carbon, N, P and K has been improved in organic, inorganic and biological treated combined application to sole inorganic sources (Roy et al., 2017).

The improved organic matter content of soil in the treatment receiving organic material with chemical fertilizers might be owing to direct addition of organic substances in soil, better root growth and more plant residue recycled in soil (Sharma et al., 2000). The subsequent decomposition of these roots has resulted in increase organic carbon content soil (Tolanur and Badnur, 2003). The important in nutrient status of soil may be ascribed to more biomass (leaves and roots etc.) added by the pigeon pea (Shivran and Ahlawat, 2000). Application of organic nutrient sources with inorganic fertilizers over 31 years resulted in a significant income in SOC contents the initial status.

The maximum build up of SOC was observed in treatment applied with 50% RDF through fertilizers + 50% N as azola (Mishra et al., 2017). The increase in SOC due to integrated use of inorganic and organics can be attributed to higher contribution of biomass to the soil in the form of better root growth, crop residue and the added organic sources (Upadhyay and Vishwakarma, 2014). The higher build up of SOC in the organic sources applied plot may be attributed to slower breakdown rate and increased above and below ground organic residue due to enhanced crop growth (Moharana et al., 2012).

### Macro nutrients

#### Available nitrogen

Incorporation of FYM along with fertilizers enhanced the available N content in post harvest soil as compared to control. Increase in available N may be attributed to mineralization of FYM (Chandel et al., 2014). There was a significant build up of available N in soil receiving 100% NPK along with FYM @ 10 t ha\(^{-1}\) over other treatment. This may be due to optimal fertilizers input (Chesti et al., 2015). Verma et al., (2012) reported that the balanced use of fertilizers alone or conjoint use of inorganics with organics resulted in a significant build up of available N over three decades leading to sustained soil fertility. The favourable soil conditions under organic manure application might have helped the mineralization of soil N leading to build up of higher available N (Walia et al., 2010).

Sharma et al., (2013) observed that availability N content in soil increased with the use of recommended dose of fertilizer in combination with manure. Pandey et al., (2009) reported that there was a build up of available N with conjoint use of chemical fertilizers with compost and crop residue incorporation in soil.

A significant improvement in available N status of soil with addition of crop residue and FYM was also reported by Sharma et al., 2000. Bajpai et al., (2006) observed that available N status of soil differ significantly with in situ incorporation of *Sesbania aculeate*, FYM and rice straw combined with chemical fertilizers over control. The build up of available N in soil due to application of NPK with or without organic manure may be ascribed to the residual effect of applied fertilizers and the mineralization of FYM (Bharambe et al., 2004).
Application of crop residues along with FYM and green manure significantly increased the available N content of soil over 100% NPK alone (Kumar et al., 2008). Such an increase in the content of available N due to addition of organic material and chemical fertilizers has also been reported by Jagtap et al., 2007. Improvement of soil physic-chemical properties with the application of organic manure along with chemical fertilizers leads to build up of soil available N status (Karmakar et al., 2011). Application of organic nutrient sources with organic fertilizers over 31 years resulted in a significant increase in soil available N over the initial status. The maximum build up of N was observed in treatment applied with 50% RDF through fertilizers + 50% N as azolla (Mishra et al., 2017). The results of the field experiment conducted at Water Management Research Station, Begopara, Nadia, West Bengal, India revealed that the available N content in soil was found to maintain the highest fertility status in the treatment receiving NPK + FYM 10 t ha\(^{-1}\) + Zn 5 kg ha\(^{-1}\) (Sarkar et al., 2016).

Ahmad et al., (2018) reported that application of recommended dose of fertilizers + PSB + Rhizobium + FYM @ 3 t ha\(^{-1}\) + Harit- Varden @ 5 t ha\(^{-1}\) recorded significantly build up of available N content over RDF alone. Improvement in the availability of soil N with the conjoint use of organic and inorganic fertilizer was also reported by Jadhao et al., 2019. Conjoint use of chemical fertilizers along with FYM increased the available N status (317 kg ha\(^{-1}\)). The favourable soil condition provided by FYM addition might have helped in mineralization of additional soil N leading to build up of higher available N (Santhy et al., 1998). Sarin et al., (1991) also reported that mineralization of N was higher with the addition of FYM. The plant biomass produced is a source of C and N in due course of time can be converted into plant available forms through the process of mineralization (Glendining and Powlson, 1995). Sharma and Gupta (1998) also reported that supplementing organics with inorganic N fertilizers enhanced the available N content of the soil due to hastened mineralization, one the requirement of N by microbes is met through inorganic N. Available N increased in treatments receiving varying combination of FYM, paddy straw and azolla with RDF and the enhancement was from 254.2 kg ha\(^{-1}\) (initial) to 285.8 kg ha\(^{-1}\). Increase in available N with organics is attributed to its direct addition through organics which has released on mineralization with time (Sharma and Subehia, 2014). Increase in available N with organics was due to increase in SOC and slow release of N from organics (Yadav et al., 2000).

Available phosphorus

Swarup and Yaduvanshi (2000) reported that there was significant improvement in available phosphorus status of soil with addition of crop residue and FYM. The build up of available phosphorus in the soil due to application of 100% NPK with or without FYM application may be ascribed to the residual effect of applied fertilizers and the mineralization of FYM (Bharambe and Tomar, 2004). Similar observations were also reported by Bajpai et al., 2006. Kumar et al., 2008 reported that the available P status of soil was higher under 100% NPK + FYM which was on par with 100% NPK + green manure and 50% NPK + FYM treatment. Long term fertilizers experiment under rice-wheat system observed that fertilizers treatment had significant influence on available soil phosphorus (Bhatt, 2012).

The integrated nutrient management treatment 50% N through FYM + 50% NPK through fertilizers recorded the highest available P content in soil (Sharma et al., 2014). Chesti et
al., (2015) reported that incorporation of FYM along with 100% NPK recorded significantly higher available P as compared to all other treatments. The increased availability of available P with organics could be ascribed their solubilising effect on the native insoluble P fractions through release of various organic acid, thus resulting into a significant improvement in available P status of soil (Urkurkar et al., 2010). Kundu et al., (2016) reported that long term manure application along with chemical fertilizers led to significantly higher value of soil available P compared to other fertilization treatment. It has been noticed that in calcareous soil CO2 production play a dominant role in entraining the phosphorus availability (Singh and Wanjari, 2007).

Kakraliya et al., (2017) reported that application of recommended dose of NPK along with vermi compost, FYM and Azotobacter significantly increased the available phosphorus status of soil. Integrated use of recommended level of NPK to pearl millet and mustard with organic manure and bio fertilizers improved the soil status of P by 26.3 kg ha\(^{-1}\) over the initial value (Tomar et al., 2018). Jadhao et al., (2019) also opined that the availability of phosphorus was improved with conjoint use of organic and fertilizer. The application of NPK along with FYM maintained P reserve fairly at high level which was 77.8% more optimal NPK. The FYM could have solubilised the native P in the soil through the release of various organic acid (Jadhao et al., 2019). It has been noticed that in calcareous soil CO2 production play a dominant role in enhancing the P availability (Singh and Wanjari, 2007). Organic matter forms a protective cover on sesquioxide and this facilitate reduction in P-fixing capacity of soil (Tandon, 1987). The P build up under 100% NPK + 5 t FYM was higher which may be due to the influence of organic manure in increasing the labile pool in soil through completion of cations like Ca\(^{2+}\) and Mg\(^{2+}\) which as mainly responsible for the fixation of P in calcareous soil (Yashpal et al., 1993). Enhanced available pool of soil P with the application of inorganic fertilizers in conjunction with organics might be due to release of organic acid during decomposition which in turn helped in releasing P through solubilising native P in soil (Subehia and Sepehya, 2012).

**Available potassium**

There was a build up of available potassium in soil with conjoint use of chemical fertilizers with organics (Pandey and Kumar, 2018). Higher value of available K in the treatment receiving chemical fertilizers, crop residue and compost may be due to higher organic matter content which retained available K\(^+\) on exchange site (Kumari et al., 2017). The status of available K declined in almost all the treatments except 100% NPK + FYM @ 10 t ha\(^{-1}\) as compared to initial status. The increase in available potassium under irrigated treatment might be due to addition of organic matter that reduce K fixation and released K due to interaction of organic matter with clay (Chesti et al., 2015).

Singh et al., (2006) reported that available K status of soil increased with the application of organic manure viz., FYM, rice straw, dhaincha and chemical fertilizer individually or in combination by 180-660 kg ha\(^{-1}\) after rice and 25.1-78.4 kg ha\(^{-1}\) after wheat. Kumar et al., (2008) reported that the crop residue incorporation along with 100% NPK increased the available K status by 10.6% over its initial status of 123 kg ha\(^{-1}\). Significantly higher potassium content was recorded in the FYM and 100% RDF treated plot over five year (Sushma et al., 2007). Sur et al., (2010) conducted a field experiment in a Haplaquept soil to study the effect of integrated nutrient management on
availability of potassium in soil and reported that in general the adoption of integrated nutrient management practices helped to build up soil potassium status.

Enhancement of K content in soil with the adoption of integrated nutrient management has also been reported by Singh et al., 2011. Increase availability of K with 100% NPK + FYM application might be due to the direct addition of K to the available pool of the soil, mineralization of organic sources and solubilization from native source during the decomposition (Subehia and Sepehya, 2012). Kundu et al., 2016 reported that long term manure application along with chemical fertilizers led to significant higher values of soil available potassium. Improvement in available K status of soil with the integrated use of organics and inorganics fertilizers was also reported by Jadhao et al., 2019.

The increase in the status of available K with the combined use of organic and inorganic fertilizer at compared to even optimal or super optimal dose of NPK may be due to the addition organic minerals which supplies nutrient to the soil (Verma and Ram, 1994). Highest amount of available K in the FYM treated plots may be due to the fact FYM addition could increase the CEC of soil, which is responsible for holding more amount of exchangeable K and helped in the release of exchangeable K from non-exchangeable K pool (Kher and Minhas, 1991). This may also ascribed to the reduction in the K fixation and release of K from non-exchangeable site of the reserve held in the clay inter layers. The highest status of available K in 150% NPK over rest of the treatments may be due to higher rate (Sood et al., 2008). Application of inorganic fertilizer alone or in combination with organic nutrient sources recorded an increase in available K of the soil over control (Mishra et al., 2017). Highest available K under integrated treatments compared to inorganics might be due to addition of organic matter that reduced K-fixation and released K due to interaction of organic matter with clay, besides the direct K addition to the pools of soil (Urkurkar et al., 2010).

**Available sulphur, calcium and magnesium**

The studies on long term influence of four fertility levels and organic & inorganic sulphur under rice-wheat cropping system on soil fertility build up revealed a significant increase in available sulphur content in soil (Kumar et al., 2011). Maximum available (35-39 mg kg\(^{-1}\)) was noticed when 150% NPK of the recommended dose was applied in conjunction with compost and crop residue and the might be due to addition of S through SSP and mineralization of organic S (Pandey and Kumar, 2018). Chandel et al., (2014) reported that under wheat-maize cropping sequence combined application of 150 kg N + 10 t FYM ha\(^{-1}\) was found to be beneficial in increasing the productivity of the crop and improving available S status of the soil as compared to sole application of fertilizers. Adoption of integrated nutrient practices helped to build up Fe, Mn and Cu content.

Sushma et al., (2007) reported that sulphur content was significantly higher in coir pith based compost with pressmud and 100% RDF treated plots. The effect of crop residues on S availability in soil was enhanced in the presence of FYM or green manure (Kumar et al., 2008). The improvement in the status of available sulphur with application of NPK (where SSP was used) + 5 t FYM is obvious apparently due to supply of S through chemical fertilizers and organic sources (Jadhao et al., 2019). The available calcium and magnesium was found superior when applied with organic and inorganic fertilizers. The highest value was recorded in the treatment receiving vermicompost @ 5 t ha\(^{-1}\) with 75% RDF and it was followed by
application of sewage sludge @ 2 t ha⁻¹ with 75% RDF and green manure @ 12.5 t ha⁻¹ with 75% RDF (Sanjivkumar, 2014). The increase in available S was due to use of single superphosphate (SSP) as a source of P, which contains appreciable amount of S. The improvement in the status of available S with the application of NPK (where SSP was used) + 5 t FYM is obvious apparently due to supply of S through chemical fertilizer and organic sources (Jadhao et al., 2019). Continuous cropping with 100% NPK (-S) resulted in drastic reduction in available S (10.86 mg S kg⁻¹) which may be attributed to continuous use of DAP as P source which resulted in S deficiency in 100% NPK (-S) treatment causing reduction in crop yield (Santhy et al., 1998). The available Ca and Mg were found superior when applied with organic and inorganic fertilizers. The highest value was recorded in the treatment receiving vermicompost @ 5 t ha⁻¹ with 75% RDF and green manure @ 12.5 t ha⁻¹ with 75% RDF. The increase in exchangeable Ca and Mg content of soil might be due to release of these nutrients from added organic sources (Sanjivkumar, 2014).

**Micronutrient**

**Zinc (Zn)**

Chandel et al., (2014) concluded that under wheat-maize cropping sequence combined application of 150 kg N + 10 t FYM ha⁻¹ was found to be beneficial in increasing the availability of Zn status in the soil by 0.12 mg kg⁻¹, respectively as compared to sole application of fertilizers. The reason of higher Zn content in the soil with FYM was that FYM improved the availability of both native and added Zn through transformation of solid phase to soluble metal complex (Latha et al., 2001). Report of a field experiment conducted on a sandy loam at Varanasi, Uttar Pradesh to study the direct effect of three sources of organic manure i.e. sewage, sludge, vermicompost and Sesbania green manure in combination with recommended dose of NPK, reveals a differential pattern of nutrient build up as Zn in post harvest soil (Singh et al., 2018). Zinc is known to form relatively stable chelates with organic legends which decrease the susceptibility to adsorption fixation and precipitation (Subehia et al., 2011).

Prasad et al., (1980) reported that continuous use of chemical fertilizers singly or in combination with FYM increased or maintained the initial status of micro nutrients. Bellaki et al., (1998) conducted a long term field experiment for 10 years and reported that the combined experimentation of organic and inorganic sources of nutrients increased the available micronutrients significantly in comparison to inorganic fertilizers alone. Sushma et al., (2007) reported that application of coir pith based compost (45 t ha⁻¹) and 100% RDF recorded the highest Zn content of 0.74 mg kg⁻¹. Addition of organic material might have enhance the microbial activity in the soil and the consequent release of complex organic substances would have presented micronutrients from precipitation, fixation and leaching. Incorporation of compost, crop residues either alone or in combination with chemical fertilizers increases the available Zn status of soil over control (Pandey and Kumar, 2018). Jadhao et al., (2019) also reported an enhancement of soil available Zn status with incorporation of organics in conjunction with inorganic fertilizers.

Continuous cropping with 100% NPK + Zn resulted in the build up of DTPA-Zn which is obvious, however, the increase in available Zn status with the application of NPK + 5 t FYM and FYM alone may be due to mineralization of organically bound form of Zn with organics (Jadhao et al., 2019).
Kakraliya et al., (2017) reported that application of recommended due to NPK along with vermicompost, FYM and Azotobacter significantly increased the available nitrogen, phosphorus and potash status of soil. Similar results were also confirmed by Singh et al., 2015 where NPK, FYM and bio fertilizer significantly increased the available N, P and K content over control. Pandey et al., (2009) also reported that addition of organic manure with fertilizers level significantly improved the organic carbon content as compared to chemical fertilizer alone.

Zinc is known to form relatively stable chelates with organic legends which decrease their susceptibility to adsorption fixation and precipitation (Subehia et al., 2011). Amount of nutrient added, reaction time in soil, rate of extraction by roots, nature and amounts of clay minerals, organic matter content are the governing factors affecting the transformation of Zn in soil. (Jat et al., 2014).

**Boron (B)**

Chander et al., (2007) reported that incorporation of FYM in the experimental soil, maintained a higher availability of boron. The availability of B decrease significantly with increasing levels of chemical fertilizers and incorporation of compost and crop residue alone or in combination significantly increased the soil available B and the effectiveness followed the order compost + crop residue > compost > crop residue > control (Pandey and Kumar, 2018).

Parmer (2014) reported that the increased the status of available B with addition of boron fertilizers may be due to the increased availability of B in the soil. The formation of chelates with organic legends due to addition of FYM resulting higher B availability in soil. The amount of all cationic micronutrients (Fe, Mn, Cu and Zn) was progressively higher with the crop growth period suggesting a build up of these micronutrients in soil resulting from the adoption of integrated nutrient management system. Such build up of micronutrient might be partially owing to release of native soil micronutrient resulting from the dissolution action of organic manure (Sur et al., 2010).

**Copper (Cu)**

Numerically highest copper content was observed in the treatment having FYM @ 10 t ha$^{-1}$ + 100% RDF followed by treatment receiving FYM @ 10 t ha$^{-1}$ + 50% RDF (Prashanath et al., 2019). Sur et al., (2010) reported that integrated nutrient management system has positive effect in build up of soil available Cu status. Use of FYM, wheat straw and green manure along with chemical fertilizers significantly superior over alone and or recommended dose of chemical fertilizer application (Kumari et al., 2017).

**Iron (Fe)**

Among the long term fertilizers treatment receiving FYM @ 10 t ha$^{-1}$ + 100% RDF numerically recorded higher iron content Prashanath et al., (2019). Chaudhary and Narwal (2005) reported that the application of FYM significantly increased the DTPA extractable Fe status of soil. Under long term fertilization the available iron content increased even through land was continuously cropped indicated that considerable quantity of iron being added to the soil every year through application of fertilizers or due to increase the H$^+$ activity on fertilizers application (Sarkar, 1990). Sur et al., (2010) reported that build up of available Fe through integrated nutrient management system might be due to release of soil native Fe. Kumari et al., (2017) reported that highest DTPA
extractable content was recorded in the treatment with the application of 50% mineral fertilizers supplemented with 50% N through FYM as compared to control.

**Manganese (Mn)**

The treatment receiving FYM @ 10 t ha\(^{-1}\) + 100% RDF recorded highest manganese content of 18.50 and 18.53 mg kg\(^{-1}\) (before sowing and at harvest, respectively) in soil. The DTPA extractable Mn declined from their respective initial values as a result of continuous cropping and fertilizers application in control and also with imbalanced fertilization (Prashanath et al., 2019). This is essential to the continuous uptake by the crops over the year in addition to their non-replenishment in the form of fertilizers (Sanjib et al., 2009). Chaudhary and Narwal (2005) reported that application of FYM significantly increased the DTPA extractable Mn. The amount of Mn was progressively higher with the crop growth period suggesting a build up of this micronutrient in soil, resulting from the adoption of integrated nutrient management system (Sur et al., 2010). Significantly, higher available micronutrient values were recorded in the treatment receiving FYM along with balanced fertilizers compared to no FYM treatment (Hemalatha and Chellamuthu, 2012). Enhancement of Mn status of soil with the application of FYM, wheat straw and green manure with RDF is also reported by Kumari et al., 2017.

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