GIS-based Fertility Assessment and Mapping for Agricultural Research Station, Tandur, Telangana, India

ABSTRACT

This study was conducted to determine the soil fertility status of the Agricultural Research Station, Tandur of Professor Jayashankar Telangana State Agricultural University (PJTSAU), Vikarabad District, Telangana. To identify the soil sampling points, GPS device was used and collected total of 60 soil samples on grid-based method at a depth of 0–15 cm. The collected samples were analyzed for pH, EC, OC, N, P_2O_5, K_2O, Zn, Cu, Fe and Mn status by following standard methods in the laboratory of Regional Agricultural Research Station, Palem, PJTSAU, Nagarkurnool District of Telangana, and Arc-GIS software was used further to prepare soil fertility maps. Around 37.5% of samples fall in neutral pH, whereas 62.5% samples were found as moderately alkaline reactions and entire farm soils were non-saline. Among the analyzed soil samples, 37.29% samples were in low organic carbon content, and rest of the samples *i.e.,*62.71% have medium organic carbon content and total samples were low in available N content (< 280 kg ha^{-1}). The analyzed farm samples were medium to high in available phosphorus and potassium (28.67 & 71.33 % of P_2O_5 and 16.96 & 83.04 % of K_2O respectively) content. In contrast, the micronutrients (Zn, Cu, Fe & Mn) exceeded their sufficiency level and suggested for amelioration measures to enhance research efficacy in the farm and to build future research strategies based on the determined soil fertility status.

Keywords: *GPS-GIS, soil properties, Arc-Gis, fertility maps and nutrient management*

1. INTRODUCTION

In India, agriculture is the mainstay of majority population, which has been highly dependent on natural resources for centuries (Amsalu *et al.,* 2007) for production, and a major driver for the national economy. To feed burgeoning human population, we are harvesting higher yields from multiple crops on the same piece of land per season by degrading natural resources in the country, which causes serious threatening to sustainable agriculture and food security (Tsegaye and Bekele, 2010). Continual cropping and inadequate replacement of essential nutrients removed in harvested materials, leaching, and erosion have been the major cause for the decline of soil fertility status (Matson *et al.,* 1998). To tackle these drawbacks, central and state governments of the country initiated the Soil Health Card Scheme under “National Mission for Sustainable Agriculture (NMSA) and led to a decline of 8-10% in use of chemical fertilizers and raised the productivity of 5-6% as per the study conducted by the National Productivity Council (NPC) as reported by Ministry of Agriculture & Farmers Welfare, (2020).

More than 90% of the Indian soils are deficient in available nitrogen (N), and deficiencies of phosphorus (P), potassium (K), sulphur (S), zinc (Zn), boron (B), iron (Fe) and manganese (Mn) being 80, 50, 41, 36, 23, 13 and 7%, respectively. A decline in fertilizer response ratio from 12.1 kg grain per kg NPK in 1960-69 to 5.1 kg grain per kg NPK in 2010-17 reflects on the deterioration of soil fertility, due to low nutrient use efficiencies of 30-50% for N, 15-25% for P, 50-60% for K, 8-12% for S, and 2- 5% for micronutrients (Satish Chander, 2020). Among the Indian states, Telangana and Andhra Pradesh were the most vulnerable in terms of soil erosion and occupied second and third places accounting for nearly 40 and 42% of the total geographical area being eroded by water (Maji *et al.,* 2010). Further, it was noticed that more than two-thirds of the total geographical area of these states are also affected by soil erosion (Biswas *et al.,* 2015).

Soil tests are commonly used to assess the sufficiency or deficiency of essential plant nutrients, which provide information about a soil's ability to supply plant-available nutrients to evaluate the nutritional sufficiency or deficiency of soil-plant system further to design corrective treatments (Gary, 1998). Therefore, this study was initiated with the objective to identify nutrient limitations through soil analysis to know nutrient status at Agricultural Research Station (ARS), Tandur, ProfessorJayashankar Telangana State Agricultural University (PJTSAU) of Telangana, India. Furthermore, the results of this study serve in making suggestions on improving fertilization and soil management to achieve efficient breeding programs for sustainable crop production.

2. MATERIAL AND METHODS

Agricultural Research Station, Tandur was established in the year 1989 under ProfessorJayashankar Telangana State AgriculturalUniversity (PJTSAU), Vikarabad District of Telangana, India. The farm is located at 17°17´N latitude and 77° 30´ Elongitude which comes under Southern Telangana Zone and the zone is characterized by hot and dry with an average rainfall of 905 mm annually received mostly from the south-west monsoon. The district has 51 percent of black soils with varying depths, while red soils occupy 27%, and laterite soils present to an extent of 17 percent. A total of 60 geo-referenced surface soil samples(0-15 cm depth) were collected after harvest of *rabi* crops during 2018 on-grid basis according to operational guidelines given by Department of Agriculture and Cooperation, Government of India for rainfed areas (DoAC, 2014). The samples were properly labeled, air-dried, and processed for further analysis of various soil parameters. The physico-chemical properties (pH and EC) were determined by standard procedures given by Jackson (1973), whereas organic carbon content was estimated by wet-oxidation method (Walkley and Black, 1934). The plant-available nitrogen (N) content was estimated by alkaline permanganate method as per the procedure of Subbaiah and Asija, (1956). Available phosphorus (P_2O_5) was determined by using sodium bicarbonate (0.5NNaHCO3) extractant at pH 8.5 by Olsen *et al.,* (1954) and available potassium (K_2O) was extracted by neutral normal ammonium acetate and measured with flame photometer (Muhr *et al.,*1965). As well as available micronutrients (Zn, Cu, Fe, and Mn) were extracted by DTPAextractantat 7.3 pH as per the operational procedures of Lindsay and Norvell (1978), and determined with AtomicAbsorption Spectrophotometer (AAS).

Further, Nutrient Index Value (NIV) was calculated by Ramamoorthy and Bajaj's (1969) index method, after classifying soil samples based on their soil test values of various nutrients categorized as low, medium, and high fertility classes, then calculated using the following equation.NIV = (NL × 1 + NM × 2 + NH × 3) / Total no. of samples where, NL, NM and NH are the number of samples in low, medium and high fertility classes of nutrient status, and NT is the total number of samples. The index values are rated into three categories *viz*., low (<1.67), medium(1.67-2.33) and high (>2.33) for OC, available N, P and K. Further, the available micronutrients were rated into six classes as very low (< 1.33), low(1.33-1.66), marginal (1.66-2.00), adequate(2.00-2.33), high (2.33-2.66) and very high (>2.66). Database on soil nutrient status was imported into GIS environment, further generated soil fertility maps by krigging method using Arc-GIS software by categorizing the fertility status as 'Low', 'Medium' and 'High' with appropriate legends.

3. RESULTS AND DISCUSSION

3.1 pH and Electrical Conductivity

The soil pH ranged from 7.04 to 8.46 with an overall mean of 7.60 (Fig. 1). In some fields, higher soil pH noticed due to soluble and exchangeable sodium ions along with bicarbonate ions, which further precipitate as calcium and magnesium carbonate during evaporation (Rajamani *et al.,* 2020). Among the analyzed samples, 37.5% of farm soils were found in neutral range of pH, while 62.5% of soil samples had a pH reaction of alkalinity and none of the samples were noticed with soil acidity(Bhatt and Singh, 2017). EC of the soil samples varied from 0.11 to 0.30 $dSm^{-1}$with an overall mean of 0.17 dSm^{-1} (Fig. 2). Further, it was observed that entire study area samples were non-saline, which indicates that entire research blocks were normal and suitable for all crops to grow to reach the research station mandate.

Similar results were also reported by Raj *et al.,* (2020) at Regional Agricultural Research Station, Jagtial district of the same state.

3.2 Organic Carbon (%)

The organic carbon (OC) status of the research farm varied from 0.39 to 0.64 % with a mean value of 0.50 % (Fig.3). Among the analyzed soil samples, 37.29% samples were low in organic carbon content, and rest of the samples *i.e.,*62.71% registered medium status of organic carbon content. This might be due to the cultivation of red gram, chickpea, and green gram crops instead of rice, which facilitated nitrogen fixation of leguminous crops to improve organic carbon status, and further governs physico-chemical properties of the soil for sustainable crop growth and to better respond to applied nitrogenous fertilizers (Rajamani *et al.,* 2020).

3.3 Available Major (N, P and K) Nutrient Status in kg ha^{-1}

The surface soils' available nitrogen (N) content varied between 163.07 to 250.88 kg ha^{-1} with a mean value of 197.33 kg ha^{-1} and presented in Fig.4. The entire farm soils were low (< 280 kg available nitrogen ha^{-1}), among them 45.83% of samples have >200 kg available nitrogen ha^{-1}, and followed same trend of organic carbon content (Khaledian *et al.,* 2017 and Khadka *et al.,* 2018). One of the characteristic features of a tropical environment is its high temperature which leads to rapid loss of soil organic matter due to volatilization (Shinde *et al.,* 2017). The nutrient index value registered as 1.08 which indicates the overall fertility rating for available nitrogen status was low and it signifies the full dose (100%) of recommended nitrogen fertilizers required for adequate supply of nitrogen for crops in the research farm. Certainly, it is one of the most deficient elements in the tropics for crop production, in addition to the aforementioned factors applied nitrogenous fertilizer would have resulted in a low amount of available N in the study area.

The available phosphorus (P_2O_5) ranged from 52.47 to 96.19kg ha^{-1} with a mean value of 67.94 kg ha^{-1} (Fig.5), indicating a very high availability phosphorus status in the farm soils. Among the samples analyzed, 28.67% of the soils were in medium range, and 71.33% of research plots pose high phosphorus, which has immobile nature in the soil system. The farm soils registered a nutrient index value of 2.91 for available phosphorus status by specifying higher category. The continuous use of phosphatic fertilizer without knowing its availability in the soil might be the reason for high phosphorus content in the alkaline soils (Rajamani *et al.,* 2013) and suggested reducing the P application as 30% during *kharif* season (Kumar *et al.,* 2017).

The available potassium (K_2O) content ranged from 279.55 to 403.36 kg ha^{-1} with a mean value of 361.95 kg ha^{-1} and revealed that farm soils were medium to high in available potassium content (Fig. 6), as well as the nutrient index value registered as 3.09, where the element exists in the crop-lands as K^+ forms to involve in physiological processes of plant metabolism. Around 83.04% of soil samples were in high status of available K_2O content, and rest of 16.96% soil samples fall in the medium category of available potassium content as 145 to 340 kg ha^{-1}, which suggested 30% of recommended potassium dose sufficient for farm soils where the available potassium determined as high, and other research blocks should apply recommended dose of potassium fertilizers to accelerate the nutrient catalytic function in various crops grown in research fields (Singh *et al*., 2016).

3.3 Available Micronutrients (Zn, Cu, Fe and Mn) Status

The available zinc (Zn) content ranged from 0.78 to 2.91 mg kg^{-1} with a mean value of 1.08 mg kg^{-1} as represented in Fig.(7). The analyzed farm soils had more than 0.60 mg kg^{-1} of available zinc content critical level, which indicates the sufficiency status of available zinc for plant growth. Zinc plays an essential role in plants for several biochemical processes such as cytochrome and nucleotide synthesis, auxin metabolism, chlorophyll production, enzyme activation, and the maintenance of membrane integrity (Havlin *et al.,* 2010). The nutrient index of available zinc was noticed as 3.05, and the tested soil samples also revealed that entire farm soils have sufficient status of available Zn due to regular application of organic sources with zinc-based fertilizers according to the crop requirement. Furthermore, the applied organic sources play an important role in the availability of zinc by forming soluble organo-metal complexes and stable metalo-organic complexes to enhance concentration of soluble zinc complexes in soil solution through dissolution of sparingly soluble and chelated zinc compounds (Ganeshamurthy *et al.,* 2019).

The available copper (Cu) in the farm soils varied from 1.91 to 3.11 mg kg^{-1} with an average value of 2.47 mg kg^{-1} as presented in Fig.(8). Copper is an important micronutrient, required for lignin synthesis and acts as a constituent of ascorbic acid, oxidase, phenolase and plastocyanin in plants (Mahashabde and Patel, 2012). The entire farm soils registered > 0.20 mg kg^{-1} of available copper content, which indicates entire analyzed soil samples were high status of available copper and nutrient index registered as 3.05. The high content of available copper may show their toxicity stress for plant growth. Therefore, it is important to decrease copper-based molecules to control pests and diseases and plan further better soil amelioration measures to reduce the toxicity stress of copper (Husak, 2015).

The available iron (Fe) content in the farm was ranged from 6.46 to 13.32 mg kg^{-1} with an average of 8.78 mg kg^{-1}as depicted in Fig.(9). The research farm soils recorded > 4.00 mg kg^{-1} of available Fe content of its critical level and showed sufficiency of available iron content, which plays a critical role in metabolic processes such as DNA synthesis, respiration, and photosynthesis (Singh *et al.,* 2013). The nutrient index found as 3.05, and this excess sufficiency of the nutrient might be due to the cultivation of crops in alkaline & calcareous soils with various sources of organic and inorganic materials, which have the potential to maintain soluble Fe, and the capacity of roots to assimilate Fe from applied compounds (Ahmed *et al.,* 2014).

The available manganese (Mn) content of the farm soils ranged from 6.77 to 22.90 mg kg^{-1} with an average of 11.69 mg kg^{-1} as presented in Fig.(10). Manganese is an important micronutrient, which serves as a cofactor, activating numerous enzymes involved in the catalysis of oxidation-reduction, decarboxylation and hydrolytic reactions in plants (Katkar and Patil, 2010). The entire farm soils registered > 2.00 mg kg^{-1} of available Mn content of its critical level and showed excess content in the soil. The higher nutrient index value observed as 3.05, and this high content of available manganese may show toxicity stress on crop growth, therefore amelioration of farm soils is a prerequisite to reducing manganese toxicity stress (Mousavi *et al*., 2011).

4. CONCLUSION

Soils of Agricultural Research Station, Tandur soils are neutral to moderately alkaline in reaction, owing to alkalinity of the farm soils may impede nutrient availability and microbial diversity suggests amelioration measures for sustainable soil management to reduce negative impact on crop growth. The analyzed soils were non-saline, and low to medium in organic carbon (%) content, advocated to adopt the crop residue incorporation, crop rotation and cover cropping. Furthermore, fertilizers should apply for various research as well breeding trials based on determined nutrient status of the research farm, because plants may suffer deficiency stress of low nutrient availability or toxicity stress of very high status of nutrients. To tackle these constraints specific care should be taken to deal with such nutrients in the research farm to enhance research efficacy and to build up future research strategies based on the determined fertility status of the farm.

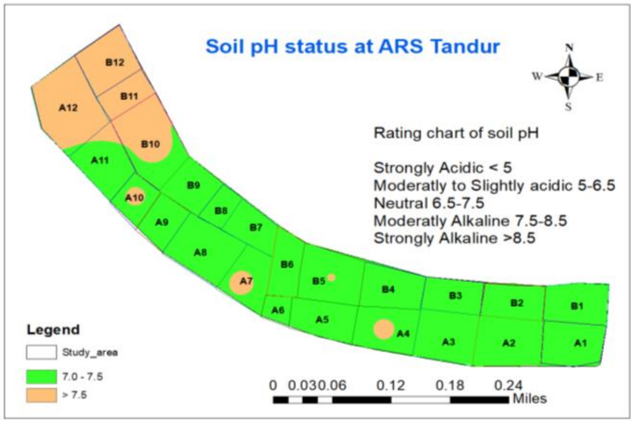

Fig 1: Soil pH of Agricultural Research Station, Tandur

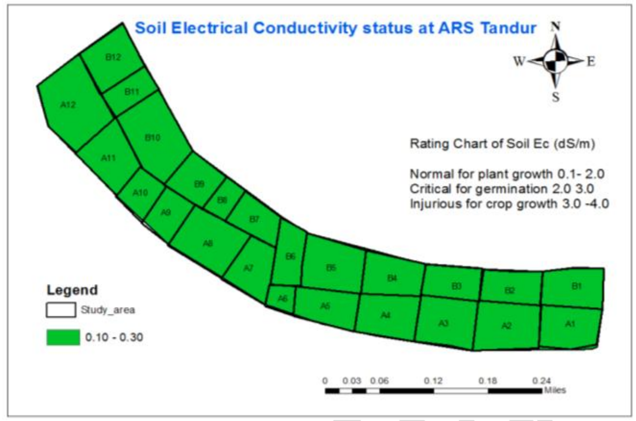

Fig 2: Soil EC of Agricultural Research Station, Tandur

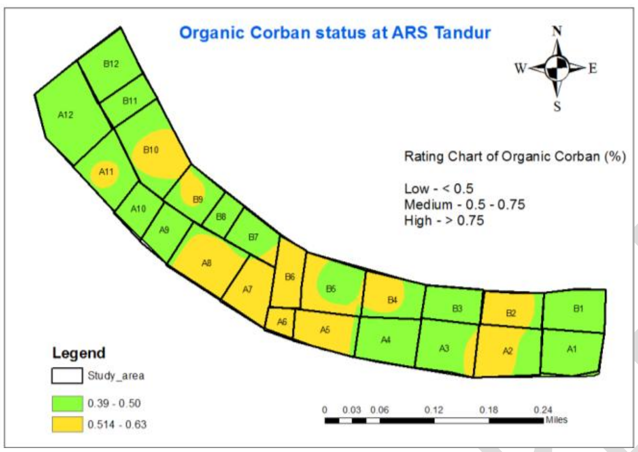

Fig 3: Soil OC (%) of Agricultural Research Station, Tandur

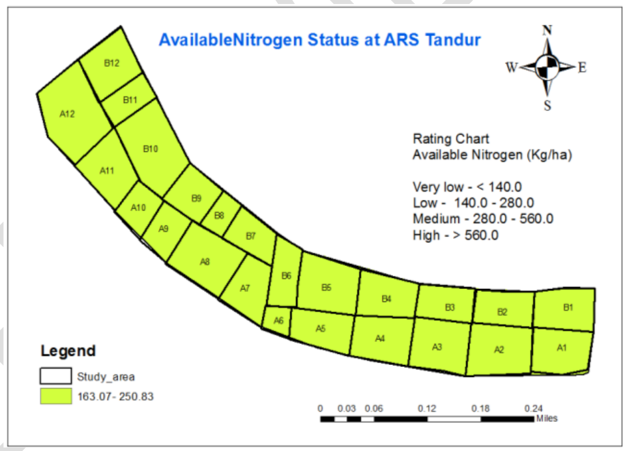

Fig 4: Available soil N (kg ha^{-1}) status of Agricultural Research Station, Tandur

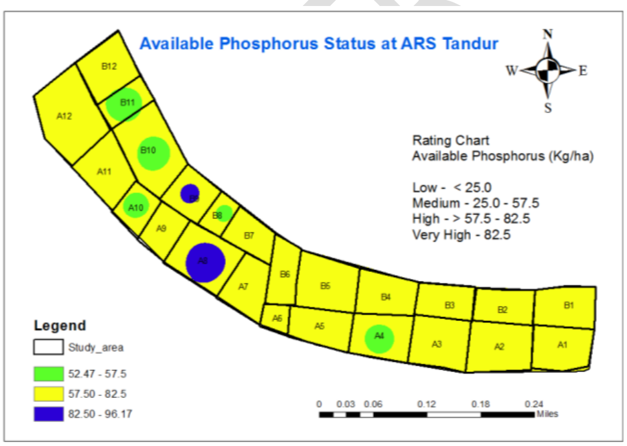

Fig 5: Available soil P_2O_5 (kg ha^{-1}) status of Agricultural Research Station, Tandur

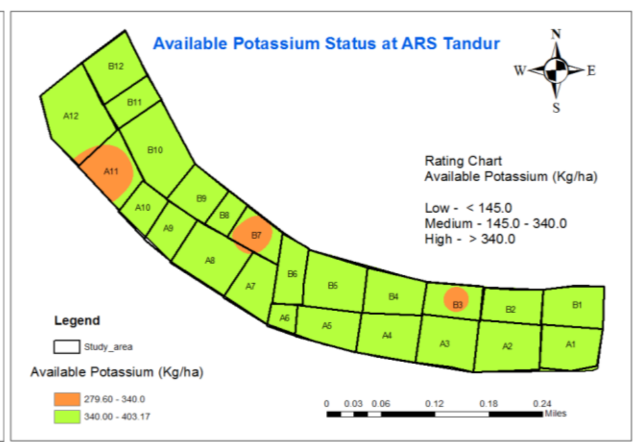

Fig 6: Available soil K_2O (kg ha^{-1}) status of Agricultural Research Station, Tandur

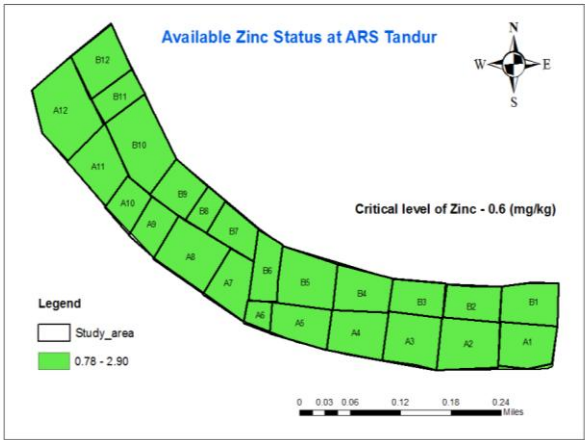

Fig 7: Sufficiency status of zinc (mg kg^{-1}) at Agricultural Research Station, Tandur

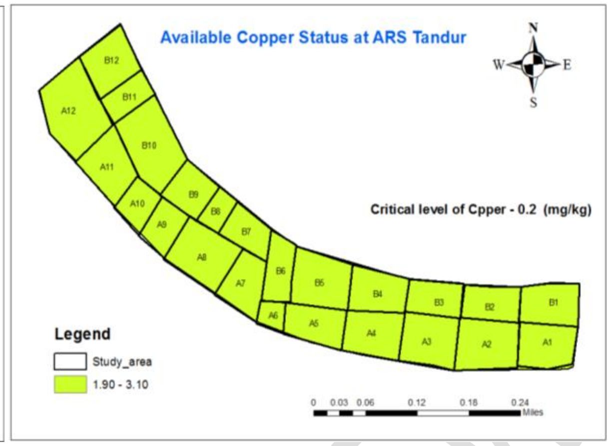

Fig 8: Sufficiency status of copper (mg kg^{-1}) at Agricultural Research Station, Tandur

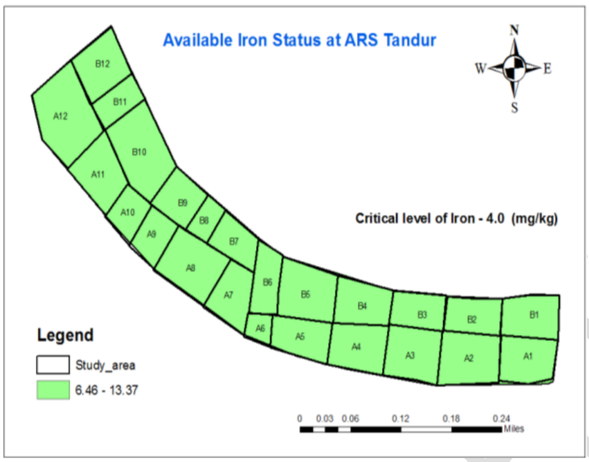

Fig 9: Sufficiency status of Iron (mg kg^{-1}) at Agricultural Research Station, Tandur

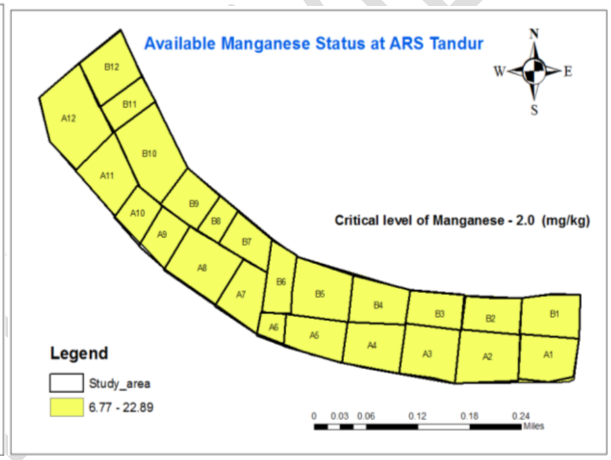

Fig 10: Sufficiency status of Iron (mg kg^{-1}) at Agricultural Research Station, Tandur

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