Original Research Article

Evaluation of Soil Particle Distribution and Primary Nutrients Status Across the Rice Productive Regions of Mahabubnagar, Telangana

Abstract

The current research involved a thorough field survey to assess particle size distribution and the availability of primary nutrients in *rabi*-grown rice soils (2022-2023) across three productivity regions: high (5923-6052 kg ha^{-1}), medium (5793-5923 kg ha^{-1}), and low (<5793 kg ha^{-1}) in Mahabubnagar district, Telangana. A total of 225 surface soil samples (0 - 15 cm depth), with 75 samples from each productivity region, were collected before the transplanting of *rabi* rice crop using a stratified random sampling method and are further processed and analysed for soil texture, available nitrogen (N) phosphorus (P) and potassium (K). The sand, silt and clay content in high, medium and low productivity regions averaged 52.37%, 55.75%, 57.41%; 17.77%, 15.47%, 16.96% and 29.86%, 28.79%, 25.63% respectively. The respective available N, P and K showed mean values of 257.88 kg ha^{-1}, 253.61 kg ha^{-1} and 240.13 kg ha^{-1}; 59.13 kg ha^{-1}, 55.40 kg ha^{-1}, 54.49 kg ha^{-1} and 304.96 kg ha^{-1}, 301.25 kg ha^{-1}, 300.19 kg ha^{-1} in high, medium and low productivity regions. Low productivity areas had the highest mean sand content, impacting soil particle aggregation. Silt content varied notably, especially in medium and low productivity regions, while clay content varied most in high productivity regions. Available N declined from high to medium and medium to low productivity regions. Fluctuations in available P and K showed wide distribution within each category, indicated by large standard deviation and coefficient of variation values across productivity regions, particularly in case of potassium emphasizing the inclusion of diverse soil conditions and factors influencing potassium availability when devising fertilization strategies.

***Key words:** Productivity, Particle size analysis, Primary Nutrients, Available Nitrogen, Available Phosphorus and Available Potassium.*

1. INTRODUCTION

One of the most vital natural resources is soil, which is a part of the terrestrial ecosystem and serves for variety of purposes, including supporting plant growth (Nwachokor *et al*., 2009) [13]. Understanding its characteristics is essential for effective land use planning to maximize agricultural production (Kumar *et al.,* 2013) [6]. Soil's physical, chemical and biological properties significantly impact its functions, such as in providing as a medium for plant growth, regulating water supply, recycling raw materials, and serving as a habitat for soil organisms (Vasu *et al.,* 2016b) [21]. The quality of agricultural soil, influenced by its physical attributes, which refer primarily to the soil's strength and storage characteristics in the crop root zone (Mohanty *et al*., 2007) [10], directly affects crop

Commented [ks1]: Delete the reference, write only the reference number in full manuscript performance and environmental sustainability. Soil texture, a stable property, serves as a valuable indicator of various factors determining soil's agricultural potential, including water retention, infiltration rate, aeration, fertility, tillage ease, and susceptibility to erosion (Nath, 2014) [12]. The physical characteristics of the soil have deteriorated even more as a result of overfertilization and poor management, endangering the potential for soil productivity (Kumar *et al.,* 2018) [7].

In addition to physical characteristics, soil fertility plays a significant role in determining plant growth influenced by the concentrations of water, micronutrients, organic and inorganic materials, available nitrogen (N), phosphorus (P), and potassium (K). An important indication of crop productivity, quality, and yield that distinguishes between balanced and imbalanced fertilization is NPK ratio. Thus, for a high crop production, balanced fertilizer application is crucial (Tale and Ingole, 2015). Soil chemical fertility, particularly nutrient deficiency, is a major contributor to soil degradation and is a constraint on soil productivity, stability, and sustainability (Hartemink, 2010). Nutrient cycling in the soil, influenced by various inputs and losses, maintains the balance of organic and inorganic constituents. Long-term fertilizer trials (Ladha *et al*., 2003) [8] showed decreasing yields when chemical fertilizers are applied continuously; attributing to reduced nutrient supplying power and soil fertility that affects the growing food needs of the people globally (Shahid *et al.,* 2013) [17] which is very crucial for sustainable agricultural production. However, intensive agrochemical uses because of industrialization and agricultural development poses risks such as soil degradation and negative effects on agricultural production (Narkhede *et al*., 2011) [11].

Rice is a major global crop, with India being the second largest producer after China. Telangana, the rice hub of Southern India witnessed a significant expansion in paddy cultivation, with acreage grown from 1.31 crore acres to 2.20 crore acres, and production increased from 0.68 crore tonnes to 2.70 crore tonnes from 2014 to 2023 (https://www.business-standard.com/economy/news/total-cultivated-area-in-telangana-up-from-13-mn-to-22-mn-acres-since-2014-123081400274_1.html) [4]. But the rice soil's fertility and quality were being depleted as a result of continuous cropping in areas like Telangana due to prolonged improper management practices that led to the destruction of soil properties because of monoculture, uneven application of inorganic fertilizer, and excessive reclamation (Ladha *et al*., 2003) [8] making it challenging to maintain rice productivity. Achieving increased crop productivity, implementing effective soil conservation measures, and fostering sustainable agriculture management require a comprehensive understanding and examination of soil conditions. Therefore, considering the importance of above soil properties and their influence to identify the differences between rice soils with varying productivity, this study has been undertaken to uncover variations in soil properties that help in development of sustainable land use management and the improvement of grain yield in rice cultivation.

2. MATERIAL AND METHODS

2.1 Location of study site

Mahabubnagar district is positioned between latitudes 15° 55′ and 17° 29′ N and longitudes 77° 15′ and 79° 15′ E of Telangana state with the borders of the districts Ranga Reddy to the north, while the Nagarkurnool to the east, Raichur and Gulbarga districts of Karnataka State to the west, and the districts of Wanaparthy and Jogulamba-Gadwal of Telangana to the south (https://mahabubnagar.telangana.gov.in/about-district/) [3]. The study site of rice soil regions of Mahabubnagar district, Telangana, India, are illustrated in Figure 1.

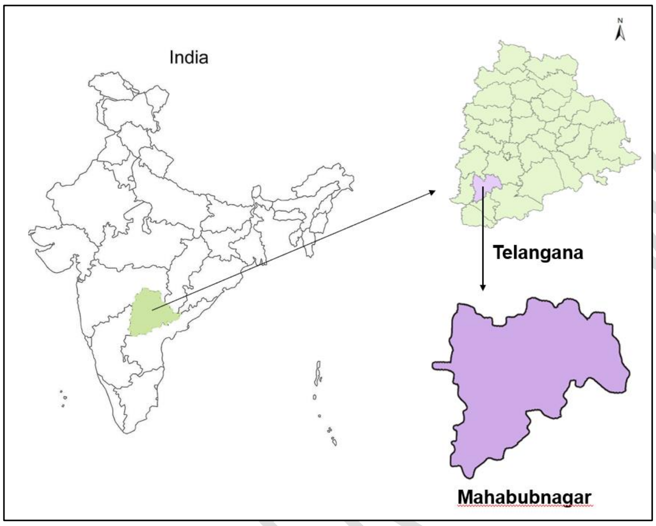

Figure 1. Location of the Study Site

2.2 Soil sample collection

The present study involved the survey and collection of soil samples from the study area where *rabi* paddy was cultivated by dividing the mandals of the district into low (<5793 kg ha^{-1}), medium (5793-5923 kg ha^{-1}) and high (5923-6052 kg ha^{-1}) productive regions based on the area and yield data gathered from the District Agriculture office, Mahabubnagar. A total of 225 samples were collected, specifically 75 from each productive region from the topsoil layer (0 – 15 cm deep) before the transplanting of the *rabi* crop, 2022-2023 by stratified random sampling method. These samples were then air-dried, crushed to pass through 2 mm sieve, stored in plastic bags and subjected to further laboratory analysis.

2.3 Laboratory Analysis

The collected soil samples were analysed for the parameters *i.e.,* soil texture by Bouyoucos hydrometer method that elucidates the particles size distribution as described by Piper, 1966 [15]. The analysis for available nitrogen was carried out by alkaline permanganate method (Subbaiah and Asija, 1956) [18], available phosphorus by Olsen's method using colorimeter at 660 nm (Olsen *et al*., 1954) [14] and available potassium by extraction with neutral normal ammonium acetate using flame photometer (Jackson, 1973) [5] that aimed to explore the relation between soil characteristics and rice productivity in the three regions of Mahabubnagar district.

3. RESULTS AND DISCUSSION

3.1 Computation of Particle size analysis in the three productivity regions

In the view of soil physical characteristics, Table 1 and figure 2 details the particle size distribution of soils, characterized as clay loamy, sandy loamy, sandy clay loam, and sandy clay that revealed the diversity of the soils of the study area. In regions with high productivity, the sand content fluctuated between 31.54% and 79.68%, averaging at 52.37% with a standard deviation of 12.65 and 24.16% coefficient of variation. In medium productivity areas, the range was from 37.54% to 79.68%, averaging at 55.75% with a standard deviation of 12.48 and 22.39% coefficient of variation. Low productivity regions saw a range of 31.54% to 79.68%, with an average of 57.41%, a standard deviation of 13.72 and a 23.89% coefficient of variation.

Turning to silt content, high productivity regions spanned 2.00 % to 32.00 %, averaging at 17.77 % with a standard deviation of 9.30 and 52.34 % coefficient of variation. In medium productivity areas, the range was from 2.00 % to 28.00 %, averaging at 15.47 % with a standard deviation of 9.06 and coefficient of variation of 58.55 %. Low productivity regions exhibited a range of 2.00 % to 42.00 %, with an average of 16.96 %, a standard deviation of 9.93, and a rich coefficient of variation at 58.54 %.

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On the examination of clay content, high productivity regions showcased a range of 18.32 % to 42.60 %, averaging at 29.86 % with a standard deviation of 5.96 and a 19.97 % coefficient of variation. In medium productivity areas, the range was 18.32 % to 40.32 %, averaging at 28.79 % with a standard deviation of 6.00 and a 20.85 % coefficient of variation. Low productivity regions displayed a range of 8.32 % to 28.46 %, with an average of 25.63 %, standard deviation of 6.24, and a 24.35 % coefficient of variation. Figure 2 provides a graphical representation of distribution of soil particles in three productive regions.

Thus, it can be inferred that soils of three regions contributed to their unique composition. Sand content varied across productivity regions, with the highest mean observed in low productivity areas. Silt content varied significantly, with the highest coefficient of variation observed in medium and low productivity regions. Clay content displays variations, with the highest mean observed in high productivity regions and a notable coefficient of variation in low productivity areas. High productivity regions tend to have lower mean sand and high silt, clay contents compared to the other two, favouring the aggregation of soil particles. The similar trend was observed in high, medium and low productive paddy soils of Liu *et al*., 2014 [9]. Particle size distribution that helps in the determination of soil texture, which in turn shows its impact on root production and, consequently, water and nutrient uptake. Notably, clay soil proves advantageous for higher grain yield due to its ability to retain water and nutrients, resulting in increased tillers, heavier seeds, and improved grain filling compared to sandy soil (Dou *et al*., 2016) [1]. The variability in particle size distribution across different productivity levels emphasizes the importance of soil aggregation in the effective agricultural management.

Table 1. Descriptive statistics of particle size analysis among the three rice productivity regions

HIGH PRODUCTIVITY REGIONS (n = 75)					
Soil Property	**Minimum**	**Maximum**	**Mean**	**SD**	**CV**
Sand (%)	31.54	79.68	52.37	12.65	24.16
Silt (%)	2.00	32.00	17.77	9.30	52.34
Clay (%)	18.32	42.60	29.86	5.96	19.97
MEDIUM PRODUCTIVITY REGIONS (n = 75)					
Soil Property	**Minimum**	**Maximum**	**Mean**	**SD**	**CV**
Sand (%)	37.54	79.68	55.75	12.48	22.39
Silt (%)	2.00	28.00	15.47	9.06	58.55
Clay (%)	18.32	40.32	28.79	6.00	20.85
LOW PRODUCTIVITY REGIONS (n = 75)					
Soil Property	**Minimum**	**Maximum**	**Mean**	**SD**	**CV**
Sand (%)	31.54	79.68	57.41	13.72	23.89
Silt (%)	2.00	42.00	16.96	9.93	58.54
Clay (%)	8.32	38.46	25.63	6.24	24.35

**SD – Standard deviation, CV – Coefficient of Variation*

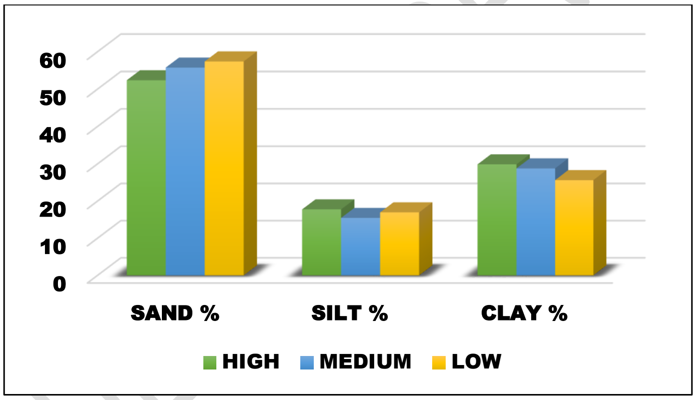

Figure 2. Particle size distribution among the three productivity rice regions

3.2 Computation of Primary Nutrients in the three productivity regions

3.2.1 Available Nitrogen

Nitrogen is a crucial plant nutrient, constituting 1 – 5 % of a plant's dry weight. It is a vital component of proteins, playing a key role in plant metabolism. In soil, organic nitrogen seems inaccessible to plants, while available nitrogen exists in mineral forms, primarily as ammonium and nitrate in the soil solution, supporting plant growth.

In high productivity regions, the available nitrogen (N) in the current study (Table 2) ranged from 191.00 to 361.05 kg ha^{-1}, with a mean of 257.88 kg ha^{-1}, standard deviation of 44.40, and 17.22 % coefficient of variation. Whereas, the range followed to be from 194.00 to 363.00 kg ha^{-1} in medium productivity regions with a mean of 253.61 kg ha^{-1}, having standard deviation and coefficient of variation of 44.78, 17.66 % respectively, and from 191.17 to 361.04 kg ha^{-1} with a mean of 240.13 kg ha^{-1}, having standard deviation of 36.64 and coefficient of variation 15.26 % in low productivity regions. The mean available N value followed a decreasing trend from high to medium and medium to low productivity regions whereas the standard deviation and coefficient of variation values indicated a moderate level of variability in N levels across the three productivity regions, with the highest variability in high and medium productivity areas. The categorization suggests a low to medium level of nitrogen availability in the soils across the studied regions.

Table 2 Descriptive statistics of primary nutrients among the three rice productivity regions

HIGH PRODUCTIVITY REGIONS (n = 75)					
Soil Property	**Minimum**	**Maximum**	**Mean**	**SD**	**CV**
Available Nitrogen (kg ha^{-1})	191.00	361.05	257.88	44.40	17.22
Available Phosphorus (kg ha^{-1})	29.00	84.00	59.13	15.62	26.42
Available Potassium (kg ha^{-1})	129.00	426.00	304.96	84.85	27.82
MEDIUM PRODUCTIVITY REGIONS (n = 75)					
Soil Property	**Minimum**	**Maximum**	**Mean**	**SD**	**CV**
Available Nitrogen (kg ha^{-1})	194.00	363.00	253.61	44.78	17.66
Available Phosphorus (kg ha^{-1})	23.00	94.00	55.40	19.06	34.40
Available Potassium (kg ha^{-1})	144.00	405.00	301.25	77.37	25.68
LOW PRODUCTIVITY REGIONS (n = 75)					
Soil Property	**Minimum**	**Maximum**	**Mean**	**SD**	**CV**
Available Nitrogen (kg ha^{-1})	191.17	361.04	240.13	36.64	15.26
Available Phosphorus (kg ha^{-1})	25.00	84.00	54.49	17.17	31.52
Available Potassium (kg ha^{-1})	137.00	415.00	300.19	86.20	28.72

**SD – Standard deviation, CV – Coefficient of Variation*

3.2.2 Available Phosphorus

Phosphorus, being one of the macronutrients, is essential for the transformation of sugars and starches, photosynthesis, energy transfer, and nutrient flow inside plants. The current study's available phosphorus (P) in high productivity regions ranged from 29.00 to 84.00 kg ha^{-1}, with a mean of 59.13 kg ha^{-1}, a standard deviation of 15.62, and a coefficient of variation of 26.42 %. AP in medium productivity regions showed a wider range from 23.00 to 94.00 kg ha^{-1} with a mean of 55.40 kg ha^{-1}, having standard deviation of 19.06 and coefficient of variation 34.40 %. In low productivity regions, the range fluctuated between 25.00 to 84.00 kg ha^{-1} with a mean of 54.49 kg ha^{-1}, having standard deviation of 17.17 and coefficient of variation 31.52 %, respectively (Table 2). These outcomes are in line with the findings of Sannidi *et al*., 2022 [16]. This observed variability in available P levels emphasizes the importance of agricultural management practices based on the specific phosphorus dynamics within each productivity category.

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3.2.3 Available Potassium

Potassium, an indispensable constituent of soil minerals, poses a challenge for plant assimilation as it is not readily available for the absorption. Plants can access only a limited quantity of soil potassium, present in exchangeable forms and the soil solution. This accessibility is influenced by variations in soil parent materials and the impact of weathering processes.

The available potassium (K) content in soils in high productivity regions, varied from 129.07 to 426.08 kg ha^{-1}, with a mean of 304.96 kg $ha^{-1,}$ having standard deviation and coefficient of variation of 84.85 and 27.82 % respectively. Medium productivity regions displayed available K levels ranging from 144.01 to 405.07 kg ha^{-1}, with a mean of 301.25 kg ha^{-1} having standard deviation of 77.37 and 25.68 % coefficient of variation. Similarly, low productivity regions showcased K levels ranging from 137.04 to 415.02 kg ha^{-1}, with a mean of 300.19 kg ha^{-1} having standard deviation and coefficient of variation of 86.20 and 28.72 % respectively (Table 2) and are categorised from medium to high similar to the findings reported by Vasu *et al*., 2016a [20]. The figure 3 provides a graphical representation of values of primary nutrients in the three productive regions. The high standard deviation and coefficient of variation values across the productivity regions suggest a wide dispersion of K levels within each category. This variability may be attributed to factors such as soil composition, weathering, and other environmental influences. Farmers and agronomists should consider the diverse soil conditions and factors influencing potassium availability when implementing fertilization strategies.

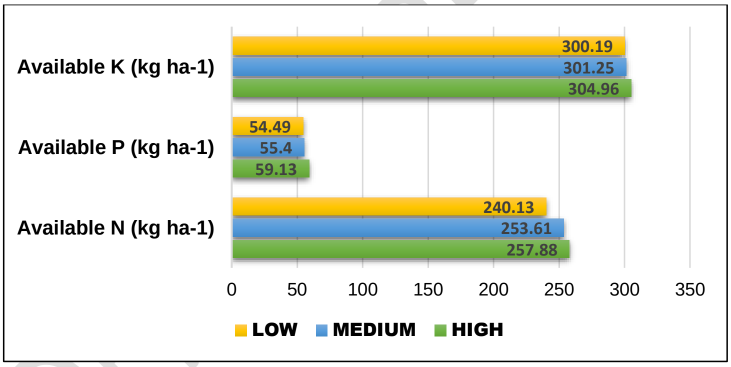

Figure 3. Depiction of Essential Nutrients Across Three Rice Productivity Regions (correct the per ha in figure)

4. CONCLUSION

The study unveils significant variability in sand, silt, and clay content, delineating the unique soil compositions contributing to each productivity region's distinct character. Notably, low productivity areas exhibited the highest mean in sand content, impacting soil particle aggregation and, consequently, crop yield. Silt content displayed pronounced variations, particularly in medium and low productivity regions, while clay content showed variations, with the highest mean in high productivity areas, favouring soil particle aggregation. A low to medium level of nitrogen availability in the soils in the study area showed a declining trend from high to medium and medium to low productivity regions. The observed fluctuations in the quantities of available phosphorus highlight the significance of agricultural management strategies that take into account the phosphorus dynamics within each productivity category. Within each category, potassium levels appear to be widely distributed, as indicated by the large values of the standard deviation and coefficient of variation throughout the productivity regions. When adopting fertilization strategies, farmers and agronomists should take into account a variety of soil conditions and factors that influence the availability of potassium. Particle size distribution that helps in the determination of soil texture affects the water and nutrient uptake, thereby shows its impact on root production and therefore yield.

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