**Soil physicochemical properties and rhizosphere biota of sorghum as influenced by rice crop residue management techniques and nitrogen levels**

**ABSTRACT**

The current investigation was conducted on a sandy clay loam soil at the Agricultural College Farm, Bapatla, during the *rabi* season of 2021–2022, to examine the impact of different nitrogen levels and rice crop residue management strategies on soil physicochemical properties and rhizosphere biotaof sorghum. Because the grain is frequently caught in constant rain, which causes grain molds to damage its quality, sorghum harvested during the rainy season is mostly used as feed and for other industrial purposes. But because of its high grain quality, post-rainy sorghum is mostly consumed as food. It is also a major source of stover, particularly in dry seasons. The area planted to sorghum has drastically decreased, particularly during the rainy season. However, post-rainy sorghum has remained relatively stable and is primarily grown in three districts of Karnataka (Bijapur, Gulbarga, and Raichur) and six districts of Maharashtra (Solapur, Ahmednagar, Pune, Beed, Osmanabad, and Aurangabad), in addition to portions of Andhra Pradesh and Tamil Nadu. The experiment was laid out in split-plot design with four rice crop residue management techniques (M1: No residue, M2: Burning of residue, M3: Incorporation of residue with rotovator without application of ANGRAU decomposer and M4: Incorporation of residue with rotovator after application of ANGRAU decomposer as main plot treatments and four nitrogen levels (Control, 40 kg ha−1, 80 kg ha−1and 120 kg ha−1) as sub plot treatments. Among soil physico chemical properties, pH, EC and available phosphorous did not differ significantly among the rice crop residue management techniques and nitrogen levels whereas the highest soil organic carbon, available nitrogen and available potassium were obtained with incorporation of residue with rotovator after application of ANGRAU decomposer (**M4**). Soil rhizosphere biota was significantly influenced by rice crop residue management techniques and was not influenced by nitrogen levels. Mean values for rice crop residue management techniques revealed that highest bacterial population was observed with incorporation of residue with rotovator after application of ANGRAU decomposer (**M4**) and lowest bacterial population was observed with burning of residue (**M2**). Highest fungal population was observed with incorporation of residue with rotovator after application of ANGRAU decomposer (**M4**) and lowest fungal population was observed with no residue (**M1**) which was on par with burning of residue (**M2**). Highest actinomycetes population was observed with incorporation of residue with rotovator after application of ANGRAU decomposer (**M4**) which was on par with incorporation of residue with rotovator without application of ANGRAU decomposer (**M3**) and lowest actinomycetes population was observed with burning of residue (**M2**) which was on par with no residue (**M1**).

**KEYWORDS:** Actinomycetes, Bacteria, Fungi, Nitrogen levels, Rice crop residue and ANGRAU decomposer.

1. **INTRODUCTION**

The fifth most significant coarse cereal crop farmed globally for fuel, fodder and food is sorghum. It is extensively cultivated in nations in Asia, Africa and America and is renowned for its broad tolerance of various soil types, weather patterns and environmental stressors like salinity, drought and extreme cold (Guitton, et al. 2018). “It is cultivated on an area of 41.55 million ha, with a grain production of 64.36 million tonnes. The United States ranked first in production (11.37 million tonnes) followed by Nigeria (6.73 million tonnes) and India” (United States Department of Agriculture (USDA), 2024). “In India, it is the second most dry land crop after pearl millet with an area of 4.10 million ha and production of 4.40 million tonnes and a net productivity of 1100  kg/ha” (USDA 2024). The predominant planting sequence in Andhra Pradesh's Krishna agroclimatic zone was rice-pulses (Mohan, 2017). Due to a major outbreak of yellow mosaic virus on pulse crops and delayed rice planting as a result of the delayed monsoon, the area under this sequence has shrunk (Ghosh *et al*., 2016). In the modified situation, farmers are now cultivating sorghum instead of pulses in rice-fallows (Chapke *et al*., 2017). Any biomass that remains in the field after grains and other valuable components have been collected is referred to as rice crop leftovers (Goswami *et al*., 2020).

“Farmers have been burning enormous amounts of crop residues that are left in the field since mechanised harvesting began because they obstruct tillage and following operations for the next crop, resulting in the loss of nutrients and soil organic matter” (Korav *et al*., 2022). Nutrient loss results from burning leftovers *i.e*. 80-90%of N, 25% of P, 20% of K and up to 50% of S and this also resulted in the release of black carbon, the second-biggest cause of global warming.

“The rice straw comprises majority of the cellulose (36-37%) and hemicellulose (23-24%) encrusted by lignin (15-16%) combined with a tiny amount of protein, making it high in the C:N ratio and therefore, resistant to microbial breakdown in contrast to wheat and barley straws”. (Sangwan and Deswal, 2021). The technique is made economically feasible and sustainably efficient by the appropriate use of lignocellulolytic bacteria to mitigate such issues. “The microbial consortium showed efficient degradation of rice straw, which cellulose, hemicelluloses and lignin lost 71.7%, 65.6% and 12.5% of its weight, respectively, in 20 days at 15 °C” (Zheng *et al.,* 2020). “The high silica (12-16%) and lignin content (6-7%) of rice residue with wide C:N ratio (80:1), slows down the in-situ decomposition process and leads to nitrogen immobilization under incorporation situations” (Singh *et al*., 2005).

 The length of the decomposition period, autochthonous soil bacteria and soil and environmental factors all affect the rate of decomposition and the release of nitrogen from crop leftovers (Ntonta *et al*., 2022). Depending on the depth and nutritional conditions of the soil, fungi make up a larger portion of the soil biomass than bacteria, making them an essential part of the soil microbiota (Rani, 2022). The breakdown of agricultural wastes like sugarcane residue, maize stover, rice straw, and wheat straw is significantly aided by fungi (Choudhary *et al*., 2016).

 “Microbial decomposition enhances nutrient content by nitrogen fixing, phosphorous solubilization and cellulose decomposition of decomposed final product” (Harindintwali *et al*., 2020). “By depolymerising cellulases, which hydrolyse lignocelluloses, a range of bio-decomposers, including bacteria, fungi, protozoa, and others, can break down cellulose” (Sista *et al*., 2019). Most commonly known bio-decomposers are fungi which include *Humicola*, *Trichoderma, Penicillium and aspergillus*. The value of soil microorganisms on the market is increasing these days. The Indian government is working towards food self-sufficiency and environmental sustainability. Because of their high market value, it is projected that the manufacturing of decomposer products based on soil microbes will increase in the coming year. Furthermore, even a balanced nitrogen application may not sustain fertility throughout continuous cropping.

Given the amount of crop residues produced, the availability of infrastructure and the equipment needed for crop residue management, a need-based strategy for managing nitrogen and crop residues should be created. In order to better understand how different methods of managing rice crop residue and nitrogen levels affect the physicochemical characteristics of soil and the rhizosphere biota of sorghum, the current study was conducted.

1. **Materials and Methods**

 An experiment was conducted during *rabi,* 2021–22 on sandy clay loam soils of Agricultural College Farm, Bapatla, with four rice crop residue management techniques M1: No residue, M2: Burning of residue, M3: Incorporation of residue with rotovator without application of ANGRAU decomposer and M4: Incorporation of residue with rotovator after application of ANGRAU decomposer as main plot treatments and four nitrogen levels (Control, 40 kg ha−1, 80 kg ha−1and 120 kg ha−1) as sub plot treatments which was replicated thrice. The soil was neutral in reaction, non saline, low in Organic Carbon, low in available Nitrogen, medium in available Phosphorus and medium in available Potassium. The test variety used for sowing was Mahalaxmi hybrid and crop was sown at 45 cm and 15 cm inter and intra row distance, respectively and adopted all the standard package of practices. Application of nutrients was done in accordance with the treatments in the form of urea, single super phosphate and muriate of potash respectively. Nitrogen was applied in two equal splits *viz*., at basal and knee-high stage. Entire recommended dose of phosphorus 60 kg P2O5 ha-1 and 40 kg K2Oha-1 was applied at basal in the form of single super phosphate and muriate of potash, respectively at the time of sowing.

Rice crop wastes were kept after the rice panicles were harvested. In the four major plots, rice residues were introduced according to treatment. Following crop harvest, the residues in residue removal plots were entirely eliminated. Throughout the experimentation year, 25 days were allotted for the decomposition of crop residues using the ANGRAU decomposer. According to conventional protocols, the rhizosphere biota and soil physicochemical characteristics were documented. Statistical analysis of all the data were carried out following the analysis of variance technique for split plot design as outlined by Panse and Sukhatame., 1978.

1. **Results and Discussion**

**3.1. Impact of rice crop residue management techniques and nitrogen levels on soil physic chemical properties**

**3.1.1. pH**

 pH did not differ significantly among the rice crop residue management techniques (Das *et al.,* 2001 and Mukesh, 2019) and nitrogen levels (Singh and Yadav, 2006) (Table 1).

* + 1. **Electrical conductivity (EC)**

 EC of soil did not differ significantly among the rice crop residue management techniques (Pandey *et al*., 2019) and nitrogen levels. These results are in conformity with the findings of Singh and Yadav (2006) (Table 1).

* + 1. **Organic carbon (OC)**

 Results of the analysis of data on organic carbon of sorghum with respect to rice crop residue management techniques indicated that, the highest soil organic carbon (0.50%) was obtained with incorporation of residue with rotovator after application of ANGRAU decomposer (M4) which was on par with incorporation of residue with rotovator without application of ANGRAU decomposer (M3) and the lowest organic carbon (0.41%) was obtained with burning of residue (M2) which was on par with no residue (M1) (Table 1).

It is most likely caused by the addition of carbonaceous materials to the soil, which, upon decomposition, increased organic C and added organic matter. After applying *Trichoderma* to the residue, treatment modifications led to a gradual increase in the organic carbon content of the soil. These findings are comparable to those of Verma et al. (2006) and Mukesh (2019).

 OC did not differ significantly among the nitrogen levels. However, interaction effect was also found to be non-significant (Table 1).

**Table 1. pH, EC and organic carbon of sorghum as affected by rice crop residue management techniques and nitrogen levels**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **pH** | **EC (dS m-1)** | **OC (%)** |
| **Rice residue management techniques** |
| M1 - No residue | 7.45 | 0.43 | 0.44 |
| M2 - Burning of residue | 7.40 | 0.46 | 0.41 |
| M3 - Incorporation of residue with rotovator without application of ANGRAU decomposer | 7.23 | 0.48 | 0.47 |
| M4 - Incorporation of residue with rotovator after application of ANGRAU decomposer | 7.20 | 0.51 | 0.50 |
| SEm (±) | 0.15 | 0.01 | 0.01 |
| CD (p=0.05) | NS | NS | 0.04 |
| CV (%) | 7.12 | 10.50 | 9.60 |
| **Nitrogen levels (kg ha-1)** |
| S1 - 0 | 7.30 | 0.44 | 0.43 |
| S2 - 40 | 7.31 | 0.45 | 0.46 |
| S3 - 80 | 7.32 | 0.47 | 0.46 |
| S4 - 120 | 7.34 | 0.50 | 0.48 |
| SEm (±) | 0.12 | 0.01 | 0.01 |
| CD (p=0.05) | NS | NS | NS |
| CV (%) | 5.98 | 10.11 | 9.78 |
| **Interaction** |
| SEm (±) | 0.25 | 0.03 | 0.02 |
| CD (P=0.05) | NS | NS | NS |

* + 1. **Available nitrogen**

Among the rice crop residue management techniques, the highest available nitrogen (229.3 kg ha-1) was obtained with incorporation of residue with rotovator after application of ANGRAU decomposer (M4) which was on par with incorporation of residue with rotovator without application of ANGRAU decomposer (M3) and M3 is on par with burning of residue (M2). Lowest available nitrogen (204.7 kg ha-1) was obtained with no residue (M1) which was on par with burning of residue (M2) (Table 2 and Fig 1). Crop residues increase the amount of accessible N, P and K in the soil, according to Mandal *et al.* (2004) and Kumar *et al*. (2004). The application of nutrients using crop residues and *Trichoderma* resulted in an increase in the amount of accessible N as reported by Jat *et al*. (2013) and Khare *et al* (2014). The addition of residue had a beneficial effect on the amount of N in the soil, according to Kalpana (2016). The mineralization of more wastes by the soil microbes may result in an increase in the amount of N that is available in the soil. Similar results were also published by Mukesh (2019).

Results of the analysis of data on available nitrogen in soil after harvest of sorghum with respect to nitrogen levels indicated that, significantly highest available nitrogen (240 kg ha-1) was obtained with application of 120 kg N ha-1 (S4) and the lowest available nitrogen (181.1 kg ha-1) was obtained with control (S1) (Table 2 and Fig 1). In addition to crop nutrient uptake, this could be because of increased fertiliser use, which leaves leftover nutrients in the soil. The findings of Arunakumari and Prasad (2016) were likewise comparable. Interaction effect was also found to be non-significant.

* + 1. **Available Phosphorous**

Available phosphorous in soil did not differ significantly among the rice crop residue management techniques and nitrogen levels. Interaction effect was also found to be non-significant (Table 2 and Fig 1).

* + 1. **Available Potassium**

Data pertaining to available potassium in soil after harvest of sorghum with respect to rice crop residue management techniques indicated that, significantly the highest available potassium (318.9 kg ha-1) was obtained with incorporation of residue with rotovator after application of ANGRAU decomposer (M4) which was on par with incorporation of residue with rotovator without application of ANGRAU decomposer (M3) and M3 was on par with burning of residue (M2) and the lowest available potassium (290.5 kg ha-1) was obtained with no residue (M1) which was on par with burning of residue (M2) (Table 2 and Fig 1). These results were consistent with those of Kumar *et al*. (2004), who found that the addition of residue enhanced the amount of accessible N, P, and K. According to Kalpana (2016), the addition of crop residues resulted in a significantly favourable build-up of soil accessible potassium (K). This could be because the addition of crop residues releases non-exchangeable K. According to Mukesh (2019), treated plots with residues had the greatest accessible K in the soil and the early release of K from residues was the cause of the soil's enhanced K content.

Among nitrogen levels, the highest available potassium (325.7 kg ha-1) was obtained with application of 120 kg N ha-1 (S4) which was on par with application of 80 kg N ha-1 (S3) and the lowest available potassium (285.5 kg ha-1) was obtained with control (S1) which was on par with application of 40 kg N ha-1 (S2). The maximum available K was observed with highest N level, compared to lower levels due to high available nutrients which might have left more residual nutrient status in the soil (Table 2 and Fig 1). These results are in complete agreement with the findings of Hussaini *et al*. (2008) and Kumar (2009).

**Table 2. Available N, P and K in soil after harvest of sorghum crop as affected by rice crop residue management techniques and nitrogen levels**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **Available N (kg ha-1)** | **Available P (kg ha-1)** | **Available K****(kg ha-1)** |
| **Rice residue management techniques** |
| M1 - No residue | 204.7 | 26.8 | 290.5 |
| M2 - Burning of residue | 207.9 | 27.5 | 294.6 |
| M3 - Incorporation of residue with rotovator without application of ANGRAU decomposer | 217.9 | 30.3 | 312.2 |
| M4 - Incorporation of residue with rotovator after application of ANGRAU decomposer | 229.3 | 31.1 | 318.9 |
| SEm (±) | 4.50 | 1.00 | 6.15 |
| CD (p=0.05) | 15.6 | NS | 21.3 |
| CV (%) | 7.3 | 10.1 | 7.0 |
| **Nitrogen levels (kg ha-1)** |
| S1 - 0 | 181.1 | 27.3 | 285.5 |
| S2 - 40 | 213.1 | 28.4 | 289.3 |
| S3 - 80 | 225.7 | 29.0 | 315.8 |
| S4 - 120 | 240.0 | 31.0 | 325.7 |
| SEm (±) | 3.25 | 1.05 | 5.78 |
| CD (p=0.05) | 9.5 | NS | 16.9 |
| CV (%) | 5.3 | 10.6 | 6.6 |
| **Interaction** |
| SEm (±) | 6.51 | 2.10 | 11.57 |
| CD (P=0.05) | NS | NS | NS |

**Fig 1. Available N, P and K (kg ha-1) in soil after harvest of sorghum**

* 1. **Impact of rice crop residue management techniques and nitrogen levels on soil rhizosphere biota**

**3.2.1. Bacterial population**

 Bacterial population did not differ significantly among the rice crop residue management techniques and N levels taken for study. However, interaction effect showed non significant results (Table 3).

 With respect to rice crop residue management techniques, highest bacterial population was observed with incorporation of residue with rotovator after application of ANGRAU decomposer (M4) and lowest bacterial population was observed with Burning of residue (M2) which may be because adding straw back to the soil can improve its structure, raise its organic matter content and give microorganisms a healthy place to grow and reproduce. It also provides enough carbon and nitrogen to the soil and energy, which increases the number, species and activity of soil microorganisms, according to Tilak (2004), Kalpana (2016) and Shukla *et al.* (2020).

* + 1. **Fungal population**

 Data pertaining to soil fungal population of sorghum at harvest wasa not affected by nitrogen levels. Interaction at harvest was found to be non-significant. A glance at the data indicates that highest fungal population was observed with incorporation of residue with rotovator after application of ANGRAU decomposer (M4) and lowest fungal population was observed with no residue (M1) which was on par with burning of residue (M2) (Table 3). Incorporating residues resulted in 1.5 to 11 times more fungal growth as reported by Beri *et al.* (1995). This might be due to increase in organic matter as the result of incorporation of crop residues. Maximum fungal forming units in residue incorporated treatment might due to higher moisture (high humidity) and congenial temperature for fungi.

* + 1. **Actinomycetes population**

Actinomycetes population did not differ significantly among the N levels taken for study and interaction effect also showed non significant results. But, among residue management practices, highest actinomycetes population was observed with incorporation of residue with rotovator after application of ANGRAU decomposer (M4) which was on par with incorporation of residue with rotovator without application of ANGRAU decomposer (M3) and lowest actinomycetes population was observed with burning of residue (M2) which was on par with no residue (M1) (Table 3). The reason for the notable increase in actinomycetes' population in the residue-incorporated treatment may be that these organisms live in the rhizosphere of crops, where they recycle organic matter and solubilise phosphate to improve soil fertility (Shukla *et al.,* 2020).

**Table 3. Soil rhizosphere biota (Bacteria, fungi and actinomycetes) after harvest of sorghum as affected by rice residue management techniques and nitrogen levels**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **Bacterial population****(X106 CFU g-1)** | **Fungal population****(X103 CFUg-1)** | **Actinomycetes population****(X 105 CFU g-1)** |
| **Rice residue management techniques** |
| M1 - No residue | 23.3 | 10.3 | 12.3 |
| M2 - Burning of residue | 20.6 | 11.3 | 11.3 |
| M3 - Incorporation of residue with rotovator without application of ANGRAU decomposer | 29.6 | 14.3 | 17.6 |
| M4 - Incorporation of residue with rotovator after application of ANGRAU decomposer | 35.3 | 17.6 | 19.4 |
| SEm (±) | 0.56 | 0.48 | 0.52 |
| CD (p=0.05) | 1.9 | 1.69 | 1.82 |
| CV (%) | 7.2 | 10.6 | 10.0 |
| **Nitrogen levels (kg ha-1)** |
| S1  - 0 | 26.7 | 12.9 | 14.4 |
| S2 - 40 | 26.9 | 13.1 | 14.9 |
| S3 - 80 | 27.1 | 13.2 | 15.3 |
| S4 - 120 | 28.1 | 14.3 | 16.1 |
| SEm (±) | 0.44 | 0.42 | 0.51 |
| CD (p=0.05) | NS | NS | NS |
| CV (%) | 5.6 | 10.1 | 10.8 |
| **Interaction** |
| SEm (±) | 0.88 | 0.85 | 1.03 |
| CD (P=0.05) | NS | NS | NS |

1. **Conclusion**

 Based on the above results, it can be concluded that incorporation of residue with rotovator after application of ANGRAU decomposer (M4) was found to be the most effective and sustainable approach to enhance the soil physico chemical properties and rhizosphere biota of succeeding sorghum.

1. **Future Scope**

By adding organic carbon, residue integration is essential for increasing the amount of SOM. Carbon sequestration, nitrogen cycling and structural enhancement are some of the long-term impacts. By changing soil microhabitats and supplying carbon sources, residue integration affects the organisation of microbial communities. Increased microbial biomass, changes in microbial composition, increased enzyme synthesis, better organic matter decomposition and nutrient mineralization, and improved soil health are some of the long-term impacts.

Although the ANGRAU decomposer is frequently employed for residue decomposition, environmental factors, residue makeup and soil microbial interactions can all affect how effective it is. Investigating alternate decomposers can increase decomposition rates in a variety of soil and climate situations, improve the dynamics of nutrient release for increased soil fertility, lessen reliance on a single strain of decomposer and support biodiversity. Pusa decomposers and naturally occurring or bioengineered microbial mixes for increased efficiency under certain soil and climate conditions are examples of potential substitute decomposers.

Reducing residue burning has several positive environmental effects, such as improved soil health, improved air quality, carbon sequestration, climate mitigation and biodiversity preservation.

It can be utilised as trustworthy work for future reference based on the research that has been done. The feasibility of large-scale adoption of residue management policies and incentives must be assessed in order to conduct research on long-term field studies, molecular techniques, residue quality effects, biotechnological advancements, integration with sustainable farming practices, long-term air quality monitoring, carbon budget analysis, sustainable residue management innovations and socioeconomic and policy research.

1. **Acknowledgements.**

I express gratitude to my Chairman Dr. S. Prathibhasree, Co-Chairman Dr. K. Anny Mrudhula and every faculty members of the Department of Agronomy for constant support and guidance to hold out the entire experimental research study.

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