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

**ABSTRACT**

The present investigation was carried out during *rabi* season of 2021-22 on a sandy clay loam soil at the Agricultural College Farm, Bapatla to study the effect of various rice crop residue management techniques and nitrogen levels on soil physico chemical properties and rhizosphere biotaof sorghum. 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 physicochemical 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 succeeding sorghum

1. **INTRODUCTION**

 Sorghum (*Sorghum bicolor* L. Moench), popularly called as jowar, is an important staple food crop in the world. India is the second largest producer of sorghum in the world, it occupies an area of 5.13 m ha with a production of 4.37 mt and productivity of 852 kg / ha (Directorate of Economics and Statistics, 2021). Rice - pulse sequence was a dominant cropping sequence in Krishna agro-climatic zone of Andhra Pradesh. The area under this sequence has declined due to late planting of rice in consequence of delay in onset of monsoon and severe incidence of yellow mosaic virus on pulse crop. In the changed scenario, farmers are now growing sorghum in rice-fallows as an alternative to pulses. Rice crop residues include any biomass left in the field after grains and other economic components have been harvested.

 With the advent of mechanized harvesting, farmers have been burning *in-situ* large quantities of crop residues left in the field as which interfere with tillage and succeeding operations for the subsequent crop, causing loss of nutrients and soil organic matter. Burning of residues leads to loss of nutrients i.e. 80% of N, 25% of P, 21% of K and up to 60% of S (Mandal *et al.,* 2004) and also caused emission of 18 per cent black carbon which is second largest contributor in global warming (Ramanathan and Carmichael, 2008).

 The rice straw comprises majority of the cellulose (36-37%) and hemicellulose (23-24%) encrusted by lignin (15-16%) along with a small quantity of protein, thereby making it high in the ratio of C:N and hence is resistant to the decomposition of microbes compared to the straws of wheat and barley (Sangwan and Deswal, 2021). To alleviate such problems, lignocellulolytic microbes are utilized effectively to make the process economically viable and sustainably efficient. 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).

 Decomposition and N release from crop residues depend on autochthonous soil microbes, length of decomposition period, and soil and environmental conditions. Fungi are an important component of soil micro-biota in soil constituting more of the soil biomass (Ainsworth and Bisby 1995) than bacteria, depending on depth and nutrient conditions of soil. Fungi play an important role in the degradation of agricultural wastes such as wheat straw, rice straw, maize stover and sugarcane residue.

 Microbial decomposition enhances nutrient content by nitrogen fixing, phosphorous solubilization and cellulose decomposition of decomposed final product. There are a variety of bio-decomposers such as bacteria, fungi, protozoa, etc. and they are capable to degrade cellulose by depolymerizing cellulases which hydrolyze lignocelluloses. Most commonly known bio-decomposers are fungi which include Humicola, Trichoderma, Penicillium and aspergillus. The market sale value of soil microbes is increasing nowadays. Indian government is working for food self-sufficiency and environmental sustainability. Due to the high market value, the production of soil microbial-based decomposer product would be expected to increase in coming year. Further, the application of nitrogen even in balanced form may not sustain fertility under continuous cropping.

 A need-based crop residue and nitrogen management plan should be developed duly considering quantity of crop residues being produced, availability of infrastructure and equipment for management of crop residue. Thus, the present investigation was therefore undertaken to study the effect of various rice crop residue management techniques and nitrogen levels on soil physicochemical properties and rhizosphere biota of sorghum.

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. During the crop growth period, the weekly mean maximum temperature ranged from 29.7 to 33.3°C with an average of 31.7°C. The weekly mean minimum temperature ranged from 20.0 to 21.2°C with an average of 19.8°C. A total rainfall of 60.3 mm was received during the crop growth period. 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 as per 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.

 After harvest of rice panicles, residues of the rice crop were retained. Rice residues were added as per treatment in the four main plots. In residue removal plots, the residues were completely removed after harvest of the crop. Twenty-five days were allowed for decomposition of crop residues with the application of ANGRAU decomposer during the year of experimentation. The data soil physicochemical properties and rhizosphere biota were recorded as per standard procedures. 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. Effect of rice crop residue management techniques and nitrogen levels on soil physicochemical 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. **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. **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 probably due to the fact that addition of carbonaceous substances in soil which on decomposition added organic matter and increased organic C. Decomposition of residue took its time and finally improved organic carbon content in the soil due to treatment manipulations made by applying *Trichoderma* for residue. These results are similar with the findings 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 influenced 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).

 Incorporation of crop residues lead to build up of soil available N, P and K as reported by Mandal *et al.* (2004) and Kumar *et al*. (2004). The increase in available N was due to application of nutrient with crop residues and *Trichoderma* as reported by Jat *et al*. (2013) and Khare *et al*. (2014). Residue incorporation exerted positive influence on soil available N as reported by Kalpana (2016). Increase in soil available N content may be the outcome of mineralization of added residues by the soil microbes. Similar findings were also reported 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). This might be due to increased application of fertilizers that leave residual nutrients in soil besides nutrient uptake by crop. Similar results were also observed by Arunakumari and Prasad (2016). 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 findings were in accordance with Kumar *et al.* (2004) who reported that available N, P and K got enriched by the incorporation of residue. Incorporation of crop residues contributed towards significantly positive buildup of soil available potassium (K) and this might be due to release of nonexchangeable K on account of addition of crop residue as reported by Kalpana (2016). The K content increased in soil was due to early release of K from residues as reported by Mukesh (2019) and also reported that treated plots with residue showed highest available K in soil.

Among nitrogen levels, the highest available potassium (325.7 kg ha-1) was obtained with application of 20 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 influenced 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. **Effect 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 nonsignificant 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 might be due to returning straw to the soil can enhance soil structure, increase organic matter content, and provide a healthy habitat for microorganism development and reproduction, as well as sufficient carbon and nitrogen supplies and energy, resulting in an increase in the species, quantity, and activity of soil microorganisms as reported by 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 nonsignificant results. 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).

Significant actinomycetes population increase in the residue incorporated treatment might be due to the reason that, actinomycetes inhabit the rhizosphere of crops where they increase soil fertility through the recycling of organic matter and solubilizing phosphate (Shukla *et al.,* 2020).

**Table 3. Soil rhizosphere biota (Bacteria, fungi and actinomycetes) after harvest of sorghum as influenced 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 and discussion, 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 physicochemical 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.

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