**Nutrient uptake and economics of sorghum as influenced by rice crop residue management techniques and nitrogen levels in sorghum**

**ABSTRACT *(correct the major grammatical error present in whole manuscript)***

 The experiment 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 yield and nutrient uptake of 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. Mean values for rice crop residue management techniques revealed that nutrient uptake and economics were maximum with incorporation of residue with rotovator after application of ANGRAU decomposer (M4). Mean values for nitrogen levels revealed that highest values of nutrient uptake and economics of sorghum were recorded with 120 kg ha−1 (S4). Thus, Incorporation of residue with rotovator after application of ANGRAU decomposer (M4) and application of 120 kg ha−1 (S4) is an optimum and sustainable approach for getting better results in sorghum.

**Keywords:** Residue, Nutrient, Economics, Rotovator

1. **Introduction**

*“The* ***introduction lacks a clear research hypothesis*** *or explicitly stated objectives. While the study focus is evident, a more structured articulation of the* ***research gap*** *and* ***specific aims*** *would enhance clarity”.*

 A significant staple food crop worldwide is sorghum (*Sorghum bicolor* L. Moench), also known as jowar. With an area of 5.13 m ha, a production of 4.37 mt and a productivity of 852 kg/ha, India is the world's second-largest producer of sorghum (Directorate of Economics and Statistics, 2021). The predominant planting sequence in Andhra Pradesh's Krishna agroclimatic zone was rice-pulses. 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. As an alternative to pulses, farmers are increasingly cultivating sorghum in rice-fallows under the modified conditions. Any biomass that remains in the field following the harvest of grains and other valuable components is referred to as rice crop residues.

Since the introduction of mechanized harvesting, farmers have been burning enormous amounts of crop residues that are left in the field because they interfere with tillage and following operations for the next crop, resulting in the loss of soil organic matter and nutrients. In addition to causing the emission of 18% black carbon, the second largest contributor to global warming, burning leftovers results in the loss of nutrients, including 80% of N, 25% of P, 21% of K and up to 60% of S (Mandal *et al*., 2004), (Ramanathan and Carmichael, 2008).

Compared to wheat and barley straws, rice straw has a higher C:N ratio and is therefore more resistant to microbial breakdown because it contains a higher percentage of cellulose (36–37%) and hemicellulose (23–24%) coated in lignin (15–16%) and a smaller amount of protein (Sangwan and Deswal, 2021). The technique is made economically feasible and sustainably efficient by the appropriate use of lignocellulolytic bacteria to mitigate such issues. Rice straw was efficiently degraded by the microbial consortia; in 20 days at 15 °C, the cellulose, hemicelluloses, and lignin lost 71.7%, 65.6%, and 12.5% of their weight, respectively (Zheng *et al*., 2020). With a wide C:N ratio (80:1) and a high silica (12–16%) and lignin (6-7%) content, rice residue slows down in-situ breakdown and causes nitrogen immobilization in incorporation circumstances (Singh *et al*., 2005).

Crop residue decomposition and nitrogen release are influenced by autochthonous soil bacteria, the duration of the decomposition process and environmental and soil factors. 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 important part of the soil microbiota (Ainsworth and Bisby 1995). The breakdown of agricultural wastes like sugarcane residue, maize stover, rice straw, and wheat straw is significantly aided by fungi.

Through nitrogen fixing, phosposorous solubilization and cellulose breakdown of the decomposed end product, microbial decomposition increases the nutritional content. By depolymerising cellulases, which hydrolyse lignocelluloses, a range of bio-decomposers, including bacteria, fungi, protozoa and others, can break down cellulose. Fungi, such as *Aspergillus*, *Trichoderma*, *Penicillium* and *Humicola* are the most well-known biodecomposers. Soil microorganisms are becoming more and more valuable on the market these days. The Indian government is striving for environmental sustainability and food self-sufficiency. The production of soil microbial-based decomposer products is anticipated to rise in the upcoming year due to their high market value. Furthermore, during continuous cropping, nitrogen application even in a balanced form may not maintain fertility.

A need-based strategy for managing crop residue and nitrogen should be created, taking into account the amount of crop residue produced as well as the infrastructure and equipment available for crop residue management. Therefore, the current study was conducted to examine the impact of different rice crop residue management strategies and nitrogen levels on the nutrient uptake and economics of sorghum.

1. **Materials and Methods**

An experiment was conducted 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. It was carried out on sandy clay loam soils of Agricultural College Farm, Bapatla during *rabi,* 2021-22 and 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 28.60 C to 34.90 C with an average of 31.30C. The weekly mean minimum temperature ranged from 14.80 C to 25.60C with an average of 19.90C. A total rainfall of 243.5 mm was received during the crop growth period. The test variety used for sowing was Mahalaxmi hybrid (MLSH- 151) 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 on NPK uptake were recorded as per standard procedures. Statistical analysis of all the data are carried out following the analysis of variance technique for split plot design as outlined by Panse and Sukhatame, 1985.

1. **Results and Discussion**

*“While* ***Table 1 and Table 2*** *are informative,* ***visual aids (graphs, bar charts, or trend lines)*** *could better illustrate key findings, such as:*

* *The comparative effectiveness of different residue management techniques.*
* *The economic viability of different treatments in a clearer manner.”*

**3.1 Effect of rice crop residue management techniques and nitrogen levels on nitrogen uptake**

The calculated mean data related to nitrogen uptake of sorghum at harvest as affected by rice crop residue management techniques and nitrogen levels have been summarized and presented in Table 1 and Fig 1. The interaction effect of rice crop residue management techniques and nitrogen levels on nitrogen uptake was found to be non-significant.

 Nitrogen uptake by sorghum with respect to rice crop residue management techniques indicated that, highest N uptake by grain and straw were obtained with incorporation of residue with rotovator after application of ANGRAU decomposer (M4) and lowest values were obtained with no residue (M1). The increase in N uptake in above treatment was mainly due to cumulative impact of improved soil health, increased availability nutrients and better growth of plants development, which enhanced the crop yield as reported by Mukesh (2019).

With respect to N levels, significantly highest N uptake by grain was obtained with application of 120 kg N ha -1 (S4) and lowest uptake by grain was obtained with control (S1). Highest N uptake by straw was obtained with application of 120 kg N ha -1 (S4) and lowest uptake by straw was obtained with control (S1). This might be due to Nitrogen fertilization substantially increased the nutrient uptake by the sorghum grain (Mishra *et al*., 2013).

**3.2 Effect of rice crop residue management techniques and nitrogen levels on phosphorous uptake**

Data pertaining to phosphorous uptake of sorghum at harvest as affected by rice crop residue management techniques and nitrogen levels are presented in Table 1 and Fig 1. Interaction at harvest was found to be non-significant.

A glance at the data indicates that, among the rice crop residue management techniques, significantly highest P uptake by grain) was obtained with incorporation of residue with rotovator after application of ANGRAU decomposer (M4) and lowest P uptake by grain was obtained with no residue (M1). Highest P uptake by straw was obtained with incorporation of residue rotovator after application of ANGRAU decomposer (M4). Lowest P uptake by straw was obtained with no residue (M1). This might be due to improvement of physico-chemical properties of soil on account of incorporation of crop residues as reported by kalpana (2016). The increased concentration of grains and straw finally enhanced the uptake of phosphorus as reported by Mukesh (2019).

With respect to N levels, significantly highest P uptake by grain was obtained with application of 120 kg N ha -1 (S4) and lowest P uptake by grain was obtained with control (S1). Highest P uptake by straw was obtained with application of 120 kg N ha -1 (S4) and lowest P uptake by straw was obtained with control (S1). Nutrient uptake is a function of nutrient concentration and grain/stover yields. Increase in the level of nutrients application caused a corresponding increase in nutrient concentration in both grain and stover (Sujatamma *et al*., 2015).

**3.3 Effect of rice crop residue management techniques and nitrogen levels on potassium uptake**

Data pertaining to potassium uptake of sorghum at harvest as affected by rice crop residue management techniques and nitrogen levels are presented in Table 1 and Fig 1. Interaction at harvest was found to be non-significant.

Influence of rice crop residue management techniques on K uptake by sorghum indicated that, With respect to rice crop residue management techniques, significantly highest K uptake by grain was obtained with incorporation of residue with rotovator after application of ANGRAU decomposer (M4) and lowest K uptake by grain was obtained with no residue (M1). Highest K uptake by straw was obtained with incorporation of residue with rotovator after application of ANGRAU decomposer (M4) and lowest K uptake by straw was obtained with no residue (M1) .The application of nutrients and microbial consortium like *Trichoderma* might improve the structure of the soil, provide a better environment for root growth, thereby creating a more absorption surface for the uptake of potassium (Murali and Setti 2001 and Garai *et al*., 2014).

Results of the analysis of data on K uptake by sorghum with respect to N levels indicated that , significantly highest K uptake by grain was obtained with application of 120 kg N ha -1 (S4) and lowest K uptake by grain was obtained with control (S1). Highest K uptake by straw was obtained with application of 120 kg N ha -1 (S4) and lowest K uptake by straw was obtained with control (S1). Nutrient uptake is a function of nutrient concentration and grain/ stover yields. Increase in the level of nutrients application caused a corresponding increase in nutrient concentration in both grain and stover (Sujatamma *et al*., 2015).

**Table 1. NPK uptake (kg ha-1) of sorghum as influenced by rice crop residue management techniques and nitrogen levels.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **N uptake (kg ha-1)** | **P uptake (kg ha-1)** | **K uptake (kg ha-1)** |
| **Rice residue management techniques** | **Grain** | **Straw** | **Grain** | **Straw** | **Grain** | **Straw** |
| M1 - No residue | 53.59 | 39.43 | 14.73 | 10.08 | 17.57 | 64.84 |
| M2 - Burning of residue | 62.46 | 45.38 | 17.22 | 12.91 | 20.73 | 73.35 |
| M3 - Incorporation of residue with rotovator without application of ANGRAU decomposer | 70.94 | 50.37 | 19.67 | 14.97 | 23.58 | 78.15 |
| M4 - Incorporation of residue with rotovator after application of ANGRAU decomposer | 79.80 | 56.41 | 23.42 | 17.51 | 27.58 | 86.75 |
| SEm (±) | 1.74 | 1.01 | 0.64 | 0.39 | 0.69 | 1.18 |
| CD (p=0.05) | 6.05 | 3.52 | 2.25 | 1.37 | 2.42 | 4.11 |
| CV (%) | 9.08 | 7.37 | 10.99 | 9.90 | 10.83 | 5.43 |
| **Nitrogen levels (kg ha-1)** |
| S1  - 0 | 43.77 | 32.91 | 11.40 | 7.28 | 13.81 | 55.46 |
| S2 - 40 | 64.88 | 46.14 | 17.39 | 12.65 | 21.02 | 73.49 |
| S3 - 80 | 73.73 | 52.18 | 21.21 | 16.07 | 25.27 | 82.63 |
| S4 - 120 | 84.40 | 60.36 | 25.05 | 19.47 | 29.36 | 91.50 |
| SEm (±) | 2.17 | 1.17 | 0.56 | 0.41 | 0.63 | 2.04 |
| CD (p=0.05) | 6.36 | 3.42 | 1.64 | 1.21 | 1.86 | 5.96 |
| CV (%) | 10.31 | 8.48 | 10.38 | 10.33 | 9.89 | 9.34 |
| **Interaction** |
| SEm (±)  | 4.35 | 2.34 | 1.12 | 0.82 | 1.27 | 4.08 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |

**Fig 1. NPK uptake (kg ha-1) in grain and stover of sorghum as influenced by rice crop residue management techniques and nitrogen levels**

**3.4 Effect of rice crop residue management techniques and nitrogen levels on economics**

Persual data on economics (Table 2)with respect to rice crop residue management techniques and nitrogen levels indicated that the highest gross return (Rs. 1,42,339 ha-1), net return (Rs. 1,03,081 ha-1) and B:C ratio (2.63) were obtained with incorporation of rice crop residue with rotovator after application of ANGRAU decomposer (M4) and with application of 120 kg N ha-1 (S4) which might be due to the higher yields. The lowest gross return (Rs. 62,880 ha-1) was found with no residue (M1) and no nitrogen (S1). Lowest net return (Rs. 28,277 ha-1) and B:C ratio (0.64) were obtained with burning of residue (M2) and no nitrogen (S1).

**Table 2 Economics of sorghum as influenced by rice crop residue management techniques and nitrogen levels**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **Cost of cultivation****(Rs. ha-1)** | **Gross returns****(Rs. ha-1)** | **Net returns****(Rs. ha-1)** | **B:C ratio** |
| M1S1 | 33407 | 62880 | 29473 | 0.88 |
| M1S2 | 33921 | 74791 | 40870 | 1.20 |
| M1S3 | 34433 | 91293 | 56860 | 1.65 |
| M1S4 | 34946 | 119498 | 84552 | 2.42 |
| M2S1 | 39844 | 72184 | 32340 | 0.81 |
| M2S2 | 40358 | 93393 | 53035 | 1.31 |
| M2S3 | 40870 | 114224 | 73354 | 1.79 |
| M2S4 | 41383 | 123012 | 81629 | 1.97 |
| M3S1 | 41282 | 72732 | 31450 | 0.76 |
| M3S2 | 41796 | 112790 | 70994 | 1.69 |
| M3S3 | 42308 | 122378 | 80070 | 1.89 |
| M3S4 | 42821 | 140944 | 98123 | 2.29 |
| M4S1 | 38969 | 80300 | 41331 | 1.06 |
| M4S2 | 39483 | 136678 | 97195 | 2.46 |
| M4S3 | 39995 | 139841 | 99846 | 2.49 |
| M4S4 | 40508 | 142339 | 101831 | 2.51 |

**NOTE:** Details of main plot treatments mentioned below -

M1- No preparatory cultivation

M2- One cultivator followed by two rotovators

M3- Two rotovators

M4- Application of ANGRAU decomposer followed by one rotovator

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) and application of 120 kg N ha -1 (S4 ) were found to be the most effective and sustainable approach to give better results in succeeding sorghum.

1. **Future Scope**

 Based on research work done, it can be used as reliable work for further reference. Studies need to be undertaken to evaluate the effect of timing of rice residue incorporation and nutrient management practices in rice-sorghum cropping system.

*“The future scope section is too general. It should suggest specific future research directions, such as:*

* *Evaluating the long-term impact of residue incorporation on soil organic matter and microbial diversity.*
* *Investigating alternative decomposers besides ANGRAU for residue breakdown.*
* *Assessing the environmental benefits of reduced residue burning.”*
1. **COMPETING INTERESTS DISCLAIMER:**

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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