**Original Research Article**

**Organic Nutrient Sources And Biochar Co-Composting Technology For Enhancing Yield And Nutrient Uptake In Transplanted Rice Crop**

**Abstract**

The organic manures and biochar amendment plays a pivotal role in paddy production system. A study was conducted to evaluate the effect of organic sources of nutrients, biochar and their co-composting technology on rice yield along with mineral nutrients acquisition pattern. The results of this study revealed that the rice grain and straw yield (kg ha-1) was maximum in treatment T5 *i.e.,*100% RDF + poultry manure @ 5 t ha−1 (6041) and minimum in control T1 – 100% RDF (5013). The rice grain N and P uptake was maximum in T5 (74.25, 40.56 kg ha-1 in 2023 and 77.98, 42.56 in 2024), and minimum in T1 (48.45, 28.24 kg ha-1 in 2023 and 54.24, 30.78 in 2024), respectively. Similarly, rice straw N and P uptake was maximum in T5 (75.49, 25.40 kg ha-1 in 2023 and 78.83, 29.93 in 2024) and minimum in T1 (49.29, 15.98 kg ha-1 in 2023 and 51.62, 18.35 in 2024), respectively. Finally, it can be recommended that rice grain and straw yield (t ha-1) was maximum in 100% RDF + poultry manure @ 5 t ha−1 and nutrient uptake was also maximum in 100% RDF + poultry manure @ 5 t ha−1.

**Keywords**: Biochar, Organic manures, nutrient uptake and Yield.

**Introduction**

The major challenge in the 21st century will be feeding the world's growing population with the limited land resources. In addition to this, there is an effect of global climate change and increased rate of land degradation. Increasing food production, per decreased capita land resources require increased intensity of crop production, which may have undesirable consequences on the ecosystem. It is scathing that sustainable agricultural practices like, efficient use of land, water, crop residues, nutrients, protection of soil resources and minimizing adverse impacts on the environment are present and future challenge for mankind. Rice is the one of the major staple food for more than half of the world population and is cultivated in 113 countries of the world. Cultivation of high yielding crop varieties and multiple cropping is depleting the fertility status of soils at a rapid pace. The soils, which were, once well supplied with available nutrients, are now gradually becoming deficient. Soil organic matter encourages granulation, increases cation exchange capacity (CEC) and is responsible for adsorbing power of the soils up to 90%. Addition of organic materials like FYM, green leaf manure, poultry manure and biochar increases the availability of both macro and micro nutrients. The increased availability was attributed to enhanced microbial activity in the soil and the consequent release of complex organic substances that could have prevented nutrients from precipitation, fixation, oxidation and leaching and also addition of these nutrients through organic sources. The unbalanced use of N fertilizers has at times led to environmental confrontations, disturbance in soil nutrient balance and depletion of soil fertility. Even the introduction of high yielding varieties and intensive cultivation with excess and imbalanced use of chemical fertilizers and irrigation showed reduction in the soil fertility status.

**Material and Methods**

**Experimental site description**

A study was conducted at Agricultural College Farm, Bapatla located at an altitude of 5.49 m above mean sea level, 15o54**'** North latitude, 80030**'** East longitude and about 8 km away from Bay of Bengal. It is located in Krishna agro-climatic zone of Andhra Pradesh. The results of the initial soil analytical data indicated that the experimental soil was sandy clay loam, neutral in reaction, low in organic carbon and available nitrogen, and medium in available phosphorus and high in potassium, while all micro-nutrients (Fe, Mn, Zn and Cu) were above critical levels.

**Experimental design and treatments**

Three different types of organic manures *viz*. Farmyard manure (FYM), poultry manure (PM), green leaf manure and maize stalk (MS) biochar were used. The total number of treatments was 8, and the treatment was distributed in randomized block design (RBD) with three replications per treatment. The treatment were T1: 100% RDF; T2: 100% RDF + Biochar @ 2.5 t ha-1; T3: 100% RDF + Green leaf manure (GLM) @ 10 t ha-1; T4: 100% RDF + Co-Compost (Biochar: GLM @ 25:75); T5: 100% RDF + Poultry manure @ 5 t ha-1; T6: 100% RDF + Co-Compost (Biochar: Poultry manure @ 25: 75); T7: 100% RDF + FYM 10 t ha−1; T8: 100% RDF + Co-Compost (Biochar: FYM @ 25:75).

**Grain and straw yield**

At maturity, the border rows from each plot were harvested first, leaving the net plot area. Later, the crop in each plot was harvested after separating the plants designated for recording biometric observations. The crop harvested from net plot area was threshed separately using pedal operated rice thresher for recording grain and straw yields. Both grain and straw from each plot was dried under sun separately to a constant weight before recording their final weights.

**Plant analysis details**

**Collection and preparation of plant samples**

The plant samples collected at harvest were washed with dilute HCl and then with double distilled water. The samples were shade dried initially and then oven dried at 65ºC temperature and powdered using willey mill. One gram of powdered plant sample was taken in 150 ml Erlenmeyer flask and digested with diacid mixture (HNO3 and HClO4 in 9:4 ratio). The sample digest was filtered through Whatman No. 42 filter paper by washing the residue with double glass distilled water till chloride free and made up to 100 mL volume and the clear extract was used for the determination of different nutrients. The nitrogen content in rice plant was estimated by micro Kjeldahl distillation method (Piper, 1966). Phosphorus in the diacid extract of plant samples was estimated by vanado molybdo phosphoric yellow colour method using spectrophotometer at 420 nm wave length as described by Jackson (1973). Potassium in the diacid extract of plant samples was determined using flame photometer as per the method described by Jackson (1973). The data was statistically analyzed using randomized block design (Gomez and Gomez, 1984) and means were tested for significance.

**Results and discussion**

**Grain and straw yield**

Close observation of data related to grain and straw yield presented in table 1. revealed that different nutrient management practices had shown significant influence on grain and straw yield of rice. Among all the treatments, application of 100% RDF + PM @ 5 t ha-1 (T5- 6041, 6869 kg ha-1 in 2023 and 6190, 7095 kg ha-1 in 2024) recorded significantly highest grain and straw yield, respectively which was on par with the treatments that received 100% RDF + Co-Compost (Biochar: PM @ 25: 75) (T6- 5891, 6669 kg ha-1 in 2023 and 5958, 6986 kg ha-1in 2024), 100% RDF + Green leaf manure (GLM) @ 10 t ha-1 (T3- 5812, 6627 in 2023 and 5905, 6909 kg ha-1 in 2024), 100% RDF + FYM @ 10 t ha-1(T7- 5738, 6531 kg ha-1 in 2023 and 5815, 6826 kg ha-1 in 2024) , 100% RDF + Co-Compost (Biochar: GLM @ 25: 75) (T4-5602, 6451 in 2023 and 5699, 6678 kg ha-1 in 2024) and 100% RDF + Co-Compost (Biochar: FYM @ 25: 75) (T8-5523, 6394 in 2023 and 5646, 6547 kg ha-1 in 2024) in grain and straw during both the years of study, respectively. The lowest grain and straw yield was recorded in the treatment T1 *i.e*., control (5013, 5789 and 5101, 5934 kg ha-1) during 2023 and 2024, respectively. The results revealed that combined application of organics and inorganics recorded significantly highest yields which could be due to higher nutrient uptake and improvement of soil environment (Krishna *et al.,* 2007 and Humne *et al.,* 2008). Combined application of organics and inorganics were beneficial in reducing the fixation or precipitation of nutrients with those of soil components and played complementary role to boost the crop yield. Economic yield is a fraction of total biological yield of the crop and drymatter accumulation, which is an important determent of the grain yield (Dhiman *et al.,* 2000). Total drymatter accumulation may reflect on economic yield in view of the fact that vegetative part of the plant serves as the source, whereas the spikelets serve as sink. During the vegetative growth stage, accumulation of drymatter and its distribution to yield attributes during reproductive stage through a process of translocation from source to sink and finally determine the economic yield of the crop (Raju and Reddy, 2000). Swathi *et al.* (2024) had reported that poultry manure is an excellent organic fertilizer, containing high nitrogen, phosphorus, potassium and other essential nutrients. It also indicated that poultry manure more readily supplies P to plants than any other organic manure sources. The increased grain and stover yield in poultry manure treatments might be due to integrated application of poultry manure with inorganic nutrients improved the soil’s physical, chemical and biological environment, which encouraged the proliferation of roots, resulting in more absorption water and nutrients from a larger area and depth, resulting in improvement in growth characters like plant height, drymatter accumulation, higher yield attributes *viz.,* panicle length, number of filled grains and test weight. The improved growth and yield attributes contributed towards the increase in yield of rice in poultry manure plots.

**Table 1 Effect of biochar, organic manures and their co-compost on grain yield (kg ha-1) and straw yield (kg ha-1) of rice**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatments | *Kharif* 2023 | | *Kharif* 2024 | |
| Grain Yield  (kg ha-1) | Straw yield  (kg ha-1) | Grain Yield  (kg ha-1) | Straw yield  (kg ha-1) |
| T1 - 100% RDF | 5013 | 5789 | 5101 | 5934 |
| T2 - 100% RDF + Biochar @ 2.5 t ha-1 | 5069 | 5911 | 5147 | 6172 |
| T3 - 100% RDF + Green leaf manure (GLM) @ 10 t ha-1 | 5812 | 6627 | 5905 | 6909 |
| T4 - 100% RDF + Co-Compost (Biochar: GLM @ 25: 75) | 5602 | 6451 | 5699 | 6678 |
| T5 - 100% RDF + Poultry manure @ 5 t ha-1 | 6041 | 6869 | 6190 | 7095 |
| T6-100% RDF + Co-Compost (Biochar : Poultry manure @ 25:75) | 5871 | 6669 | 5958 | 6986 |
| T7 - 100% RDF + FYM @ 10 t ha-1 | 5738 | 6531 | 5815 | 6826 |
| T8 - 100% RDF + Co-Compost (Biochar: FYM @ 25:75) | 5523 | 6394 | 5646 | 6547 |
| SEm± | 222.6 | 223.0 | 230.2 | 240.4 |
| CD (P=0.05) | 675.2 | 676.42 | 698.3 | 729.3 |
| CV (%) | 6.90 | 6.03 | 7.01 | 6.27 |

**Nitrogen Uptake**

Nitrogen uptake at harvest o f rice crop was presented in table 2. Persual of the data revealed that the application of 100% RDF+ PM @ 5 t ha-1 *i.e*., T5 (74.25, 75.49 kg ha-1 in 2023 and 77.98, 78.83 kg ha-1 in 2024) recorded significantly highest N uptake at harvest (in grain and straw) stage over all other treatments and it was on par with T6 *i.e.,*100% RDF + Co-compost (biochar: PM @ 25:75) (71.49, 72.48 kg ha-1 in 2023 and 75.44, 77.35 kg ha-1 in 2024), T3 *i.e*., 100% RDF+ GLM @ 10 t ha-1 (68.26, 70.46 kg ha-1 in 2023 and 71.27, 74.19 kg ha-1 in 2024) and T4 treatment that received 100% RDF + Co-compost (biochar: GLM @ 25:75) (64.38, 66.68 kg ha-1 in 2023 and 68.86, 71.46 kg ha-1 in 2024).

The lowest N uptake (48.45, 49.29 kg ha-1 and 52.24, 51.62 kg ha-1) at harvest (in grain, straw) stage in 2023 and 2024, respectively was recorded in the treatment T1 that received 100% RDF. Among the manures without biochar treatment, rice grain and straw nitrogen uptake was maximum in poultry manure treatment compared to other manures. The results also showed that among the manures with biochar treatment the grain and straw nitrogen uptake was maximum in poultry manure and biochar co-compost compared to other manure and biochar co-compost. The increase in N uptake could be ascribed to slow and continuous supply of the nutrients, coupled with reduced N losses via denitrification or leaching, which might have improved the synchrony between plant N demand and supply from the soil (Haile *et al.*, 2012 and Tilahun *et al*., 2013). Application of organics in combination with inorganic fertilizers, exhibited better response in nutrient uptake over chemical fertilizer due to steady supply of nutrients throughout the growing period of crops (Laxminarayana and Patiram, 2006). The uptake being the product of nutrient content and drymatter accumulation, the increase in N uptake by the crop might be due to increased availability of nitrogen and higher grain and straw yields. Similar results were also reported by Vijay and Yashbirsing (2012), Das *et al*. (2024) and Swathi *et al*. (2024).

**Phosphorus uptake**

Data pertaining to grain and straw P uptake was presented in table 3. The highest grain and straw P uptake was recorded in the treatment T5 *i.e*., 100% RDF+ PM @ 5 t ha-1 with 40.56, 25.40 kg ha-1 in 2023 and 42.56, 29.93 kg ha-1 in 2024 and it was on par with treatment T6 (39.89, 24.80 kg ha-1 in 2023 and 40.02, 28.68 kg ha-1 in 2024) that received 100% RDF + Co-compost (biochar: PM @ 25:75), T3 *i.e*., 100% RDF + GLM @ 10 t ha-1 (36.06, 22.68 kg ha-1 in 2023 38.87, 27.67 kg ha-1 ) and T4 treatment that received 100% RDF + Co-compost (biochar: GLM @ 25:75) (34.82, 22.04 kg ha-1 and 37.24, 24.46) at harvest (in grain, straw) stages of rice, respectively. The lowest P uptake (28.24, 15.98 kg ha-1 in 2023 and 30.78, 18.35 kg ha-1 in 2024) was recorded in the treatment T1 *i.e.,* 100% RDF at harvest stage of crop growth. The increased P uptake could be due to higher drymatter accumulation as uptake being the product of nutrient content and drymatter accumulation. CO2 produced during mineralization of organic sources play a vital role in solubilization of native P (Nirukumari *et al.*, 2013). The higher P uptake could be attributed to the increased P availability and increased root growth of the crop. These results were in conformity with the findings of Das *et al*. (2024) and Swahi *et al*. (2024). The pH of the soil also indicated a positive change *i.e.,* a shift towards neutrality. This positive change enhanced the solubility of different nutrients especially phosphorus in the soil.

**Table 2 Effect of biochar, organic manures and their co-compost on uptake of nitrogen (kg ha-1) at harvest of rice**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatments | *Kharif* 2023 | | *Kharif* 2024 | |
| Grain  (kg ha-1) | Straw  (kg ha-1) | Grain  (kg ha-1) | Straw  (kg ha-1) |
| T1 - 100% RDF | 48.45 | 49.29 | 52.24 | 51.62 |
| T2 - 100% RDF + Biochar @ 2.5 t ha-1 | 51.89 | 52.18 | 53.48 | 53.48 |
| T3 - 100% RDF + Green leaf manure (GLM) @ 10 t ha-1 | 68.26 | 70.46 | 71.27 | 74.19 |
| T4 - 100% RDF + Co-Compost (Biochar: GLM @ 25: 75) | 64.38 | 66.68 | 66.86 | 71.46 |
| T5 - 100% RDF + Poultry manure @ 5 t ha-1 | 74.25 | 75.49 | 77.98 | 78.83 |
| T6 - 100% RDF + Co-Compost (Biochar:Poultry manure @ 25:75) | 71.49 | 72.48 | 75.44 | 77.35 |
| T7 - 100% RDF + FYM @ 10 t ha-1 | 61.73 | 62.34 | 67.24 | 69.18 |
| T8 - 100% RDF + Co-Compost (Biochar: FYM @ 25:75) | 57.24 | 59.83 | 63.69 | 62.83 |
| SEm± | 3.27 | 3.00 | 3.05 | 2.74 |
| CD (P=0.05) | 9.93 | 9.38 | 9.25 | 8.32 |
| CV (%) | 9.11 | 8.42 | 8.01 | 7.05 |

Table 3 Effect of biochar, organic manures and their co-compost on uptake of phosphorus (kg ha-1) at harvest of rice

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatments | *Kharif* 2023 | | *Kharif* 2024 | |
| Grain  (kg ha-1) | Straw  (kg ha-1) | Grain  (kg ha-1) | Straw  (kg ha-1) |
| T1 - 100% RDF | 28.24 | 15.98 | 30.78 | 18.35 |
| T2 - 100% RDF + Biochar @ 2.5 t ha-1 | 28.98 | 16.67 | 31.02 | 18.98 |
| T3 - 100% RDF + Green leaf manure (GLM) @ 10 t ha-1 | 36.06 | 22.68 | 38.87 | 27.67 |
| T4 - 100% RDF + Co-Compost (Biochar: GLM @ 25: 75) | 34.82 | 22.04 | 37.24 | 24.46 |
| T5 - 100% RDF + Poultry manure @ 5 t ha-1 | 40.56 | 25.40 | 42.56 | 29.93 |
| T6-100% RDF + Co-Compost (Biochar : Poultry manure @ 25:75) | 39.89 | 24.80 | 40.02 | 28.68 |
| T7 - 100% RDF + FYM @ 10 t ha-1 | 32.28 | 20.40 | 34.50 | 24.82 |
| T8 - 100% RDF + Co-Compost (Biochar: FYM @ 25:75) | 31.78 | 18.90 | 33.28 | 22.24 |
| SEm± | 1.92 | 1.10 | 1.85 | 1.46 |
| CD (P=0.05) | 5.77 | 3.37 | 5.61 | 4.40 |
| CV (%) | 9.66 | 9.21 | 8.90 | 10.37 |

**Potassium Uptake**

Close examination of data related to potassium uptake in rice was presented in the table 4 and the results revealed that, different nutrient management treatments applied to *kharif* rice had shown significant influence on K uptake. Irrespective of the year of study, significantly highest K uptake was recorded in the treatment T3 *i.e*., 100% RDF+ GLM @ 10 t ha-1 (46.64, 117.9 kg ha-1 and 49.64, 128.4 kg ha-1) at harvest (in grain, straw) stages during 2023 and 2024, respectively and it was on par with T4 *i.e.,* 100% RDF + Co-compost (biochar: GLM @ 25:75) (44.28, 112.8 kg ha-1 in 2023 and 47.61, 121.3 kg ha-1 in 2024), T5 *i.e*., 100% RDF + PM @ 5 t ha-1 (40.76, 107.5 kg ha-1 in 2023 44.34, 116.3 kg ha-1 in 2024) and T6 treatment that received 100% RDF + Co-compost (biochar: PM @ 25:75)

**Table 4 Effect of biochar, organic manures and their co-compost on uptake of potassium (kg ha-1) at harvest of rice**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatments | *Kharif* 2023 | | *Kharif* 2024 | |
| Grain  (kg ha-1) | Straw  (kg ha-1) | Grain  (kg ha-1) | Straw  (kg ha-1) |
| T1 - 100% RDF | 31.31 | 88.5 | 35.42 | 92.89 |
| T2 - 100% RDF + Biochar @ 2.5 t ha-1 | 33.03 | 92.2 | 37.38 | 97.56 |
| T3 - 100% RDF + Green leaf manure (GLM) @ 10 t ha-1 | 46.64 | 117.9 | 49.64 | 128.38 |
| T4 - 100% RDF + Co-Compost (Biochar: GLM @ 25: 75) | 44.28 | 112.8 | 47.61 | 121.29 |
| T5 - 100% RDF + Poultry manure @ 5 t ha-1 | 40.76 | 107.5 | 44.34 | 116.34 |
| T6-100% RDF + Co-Compost (Biochar : Poultry manure @ 25:75) | 38.82 | 103.8 | 42.49 | 110.83 |
| T7 - 100% RDF + FYM @ 10 t ha-1 | 37.34 | 101.9 | 40.71 | 106.48 |
| T8 - 100% RDF + Co-Compost (Biochar: FYM @ 25:75) | 35.89 | 88.5 | 39.44 | 102.37 |
| SEm± | 1.95 | 4.55 | 1.81 | 4.75 |
| CD (P=0.05) | 5.93 | 13.80 | 5.49 | 14.42 |
| CV (%) | 8.80 | 7.65 | 7.44 | 7.52 |

(38.82, 103.8 kg ha-1 in 2023 and 42.49, 110.8 in 2024) at harvest (in grain, straw) stages of rice, respectively. The lowest potassium uptake was recorded in the treatment that received 100% RDF *i.e.,* T1 (31.31, 88.5 and 35.42, 92.89 kg ha-1) in grain and straw during 2023 and 2024, respectively. The increase in uptake of potassium in combined application of organics and inorganics was due to the release of K from organic manures during decomposition and solubilisation and release of native and fixed forms of potassium, charging the soil solution with K+ ions (Hemalatha *et al.,* 2000). Incorporation of green manures have improved the soil environment, which encouraged proliferous root system resulting in better absorption of nutrients from lower layers and thus resulting in higher yield and nutrient uptake (Vinay, 2006). Nirukumari *et al.* (2013) noticed faster rate of mineralization and greater utilization of nutrients through the use of green manuring in combination with chemical fertilizer. Similar observations were reported for NPK uptake by Raghuveer *et al*. (2015) and Suryakrishna, (2022).

**Conclusion**

Significantly higher grain yield, straw yield and nutrient uptake was recorded with application of organic sources along with inorganic sources compared to inorganic source alone. Among the organic manures without biochar application significantly higher grain yield, straw yield and nutrient uptake was recorded with poultry manure compared to other manures. Results also revealed that among the manures with biochar application highest grain yield, straw yield and nutrient uptake was maximum in treatment that received biochar and poultry manure co-compost compared to other co-compost treatments during the two years of study.

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