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Effect of bio organic fertilizers (BoF) with nano urea spray on nitrogen economy of rice

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Abstract
The field experiment was carried out at Agricultural College and Research Institute, Killikulam as summer rice in 2021-2022 for the management of nutrients in wet seeded rice by using the combination of both organic and inorganic sources of nutrients. The different nitrogen sources utilized in the experimental study were STCR based N application through conventional urea, liquid Nano urea as foliar spray at critical stages of rice and Bio Organic Fertilizer (BoF). The BoF was prepared by the combination of Rice Husk Biochar (RHB), vermicompost, rock phosphate and microbial consortia. The combination of both organic and inorganic source of nutrients excelled over the other treatments. The treatment combination of STCR-N, Liquid nano urea as foliar spray and Bio Organic fertilizer (BoF) (T_{13}) has the more plant height, a greater number of productive tillers, greater yield and higher B:C ratio among the other treatments.

Keywords: STCR N, bio organic fertilizers (BoF), liquid nano urea, growth and yield, wet seeded rice

1. Introduction
Rice (*Oryza sativa* L.) is the world's most significant cereal crop, feeding over half of the world's population. It covers around 155 million hectares (M ha) of area. It is cultivated from below 6 feet from sea level (as in Kerala, India) to 2700 feet above sea level in the Himalayas (Pathak *et al.*, 2021) [12]. Total production and productivity of rice in Tamil Nadu in 2020-2021 is 6.8 t ha^{-1} and 3379 kg ha^{-1}, respectively. (India stat, 2022). Due to labour diversion to non-agricultural industries, there is a severe scarcity of human labour and a high pay rate during the transplanting season in all rice growing locations. In the face of a severe labour scarcity, the conventional method of manual transplanting becomes more difficult to assure timely planting with optimal seedling age, resulting in transplanting delays, lower yield, and lower profit. To avoid the challenges of laborious transplanting, direct seeding with a drum seeder can be used instead (Ramulu *et al.*, 2020) [14]. Chemical fertiliser uses needs striking a balance between agricultural yield and long-term environmental sustainability. Inadequate chemical fertiliser use might suggest environmental damage (Zhen *et al.*, 2005; 2006) [19-20]. Nitrogenous fertilisers are the most common fertiliser utilised in Indian soils. The nitrogenous type of macronutrient is favoured in fertilizer application (Venugopal, 2004; Sharma and Thaker, 2011) [18, 15]. Combined manure and appropriate chemical fertiliser application improve soil health by altering soil organic carbon content and microbial and enzyme activity (Dhiman *et al.*, 2019 & Ozlu *et al.*, 2019) [2, 11]. Biochar has been found to improve soil chemical characteristics by neutralising pH and boosting total nitrogen, available phosphorous, and exchangeable cation contents, CEC, and base saturation, while decreasing exchangeable Al ion levels, which inhibit root development (Ogawa and Okimori, 2010) [10]. However during the recent past Nano fertilizers have unique properties that improve plant performance in terms of high absorption, increased production, increased photosynthesis, and large expansion of the surface area of the leaves. Application of Nano urea at a rate of 2 - 4 ml per litre of water at critical stages of crop growth stimulates crop response, meets nutritional requirements and enhances nutrients availability. It is quickly absorbed by the plant leaves due to its Nano size (Singh *et al.*, 2021) [ ]. Furthermore, regulated fertiliser release helps to reduce eutrophication and contamination of water resources (Kumar *et al.*, 2020). Therefore, there is need to optimize the nitrogen use application in the rice crop by utilizing the use of different levels of nitrogen fertilizers based on the STCR and use of Nano urea, Bio Organic fertilizers. Thus, a study on "effect of Bio Organic fertilizers (BoF) with nano urea spray on growth and yield of rice" was conducted.

2. Materials and Methods

2.1 Experimental site and season

The experimental study was carried out at Agricultural College and Research Institute, Killikulam, Tamil Nadu and it was geographically located in the latitude of 8°46' N, 77°42'E longitude and 40 m from the MSL. It comes under the East Coast Plains and Hills of the Indian agro climatic zone. The soil type of the field was sandy clay loam. The pH was 7.02 and EC was 0.31dsm^{-1}. The organic carbon content was medium (0.54%). The initial soil sample analysis showed that the available Nitrogen (231 kg ha^{-1}) content was low, available phosphorus (18 kg ha^{-1}) was medium and available potassium (412 kg ha^{-1}) was high. The crop is sown as summer rice.

2.2 Experimental Design and layout

The experimental design was Randomized block design (RBD) with three replications and thirteen treatments. Each replication was separated by an 1m alley. Treatments with different combination of N fertilizer sources are T_1-Absolute control, T_2-100% STCR based NPK, T_3-75% STCR-N + 75% N as Nano Urea foliar spray, T_4-75% STCR-N + 100% N as Nano Urea foliar spray, T_5-75% STCR-N + 2 t/ha Bio Organic Fertilizer, T_6-75% STCR-N + 1 t/ha Bio Organic Fertilizer, T_7-50% STCR-N + 2 t/ha Bio Organic Fertilizer, T_8-50% STCR-N + 1 t/ha Bio Organic Fertilizer, T_9-75% STCR-N + 75% N as Nano Urea foliar spray +2 t/ha Bio Organic Fertilizer, T_{10}-75% STCR-N + 100% N as Nano Urea foliar spray + 1 t/ha Bio Organic Fertilizer, T_{11}-50% STCR-N + 100% N as Nano Urea foliar spray + 2 t/ha Bio Organic Fertilizer, T_{12}-50% STCR-N + 50% N as Nano Urea foliar spray + 1 t/ha Bio Organic Fertilizer, T_{13}-100% STCR + 100% N as Nano Urea foliar spray + 2 t/ha Bio Organic Fertilizer.

The STCR based fertilizers management with target yield of 6 t ha^{-1} was applied to the respective treatments. The IFFCO liquid Nano urea was applied as foliar spray at critical stages of crop growth. The Bio Organic Fertilizer (BoF) was prepared with the composition of vermicompost (50%), Rice husk biochar (35%), rock phosphate (15%) microbial consortia @ 2 kg ha^{-1}. The various components are mixed and incubated for one month of period and applied as basal to the respective treatments. N & K fertilizers are applied in splits at critical stages of the crop as per the treatment schedule. P fertilizer is applied as basal. STCR based fertilizers are applied based on the initial soil sample analysis and recommended doses are mentioned in the table1.

Table 1: Dose of fertilizers applied based on the STCR recommendations.

Crop	Target (t ha^{-1})	Soil test values (kg ha^{-1})			Fertiliser doses (kg ha^{-1}) without FYM		
Rice (TPS 5)	6.0	SN	SP	SK	FN	FP_2O_5	FK_2O
		231	18.2	412	116	63	25

SN, SP and SK are soil available N, P and K in kg ha^{-1}

FN, FP_2O_5 AND FK_2O are the doses of fertilizer N, P_2O_5 and K_2O to be applied in kg ha^{-1} respectively.

2.3 Data collection

2.3.1 Growth parameters

Growth parameters like plant height (cm), dry matter production (kg ha^{-1}), total number of tillers hill^{-1} were recorded and statistically analysed.

2.3.1a. Plant height (cm)

Plant height was recorded in the crop at different stages like active tillering, panicle initiation and harvesting stage.

2.3.1b. Dry matter production (kg ha^{-1})

DMP was recorded at active tillering, panicle initiation and harvest stage of the crop. Plant sample was first sun dried and oven dried at 65 ^{0}c for 48 hrs. The weight was recorded until get constant value.

2.3.2 Physiological characters

2.3.2a. Chlorophyll content (SPAD readings)

The chlorophyll the content of the crop was analysed with the SPAD chlorophyll meter. The chlorophyll content was recorded at active tillering, panicle initiation and harvest stage of the crop.

2.3.3. Yield attributes

Yield parameters like grain yield, straw yield and harvest index were estimated.

2.3.3a. Grain yield (kg ha^{-1})

From plot area, every net plot was harvested and dried at 14% moisture. Then grain yield was recorded and expressed as kg ha^{-1}.

2.3.3b. Straw yield (kg ha^{-1})

After the harvest of the crop the grains were separated by threshing. Then straw yield was recorded for all plots after drying and recorded as kg ha^{-1}.

2.3.3c. Harvest index

The Harvest index was calculated by using the following formula.

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

2.3.4. Economics

2.3.4a. Cost of cultivation (₹. ha^{-1})

The cost incurred in input purchase, labour cost and prevailing market rates of produce taken for calculating the economics.

2.3.4b. Gross income (₹. ha^{-1})

The gross income was calculated with the following formula

Gross income (₹ ha $^{-1}$) = Yield (kg ha^{-1}) x marketable value of produce

2.3.4c. Net return (₹. ha^{-1})

The net return was calculated with the following formula

Net return (₹ ha $^{-1}$) = Gross income – Cost of cultivation

2.3.4d. Benefit cost ratio

The benefit cost ratio was calculated with the following formula

$$\text{B:C ratio} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3. Results and Discussion

3.1 Plant height (cm)

Effect of Bio Organic Fertilizers (BoF) and Nano urea spray on plant height at active tillering, panicle initiation and harvest stage were given in table 2. Treatment T_{13} -100% STCR + 100% N as Nano Urea foliar spray + 2 t/ha Bio Organic Fertilizer has recorded the higher plant height at active tillering (43.5cm), panicle initiation (84.8cm) and at harvest stage (112.5cm) among all other treatments. The treatment T_{11}-50% STCR-N + 100% N as Nano Urea foliar spray + 2 t/ha Bio Organic Fertilizer has recorded the next higher plant height at active tillering, panicle initiation and harvest stage, which was on par with the treatment T_9-75% STCR-N + 75% N as Nano Urea foliar spray + 2 t/ha Bio Organic Fertilizer at active tillering (38.29cm), panicle initiation (81.12cm) and at harvest stage (107.3cm). Control plot (T_1) has recorded the lowest plant height different stages of the plant growth among all the other treatments. Increased plant height in the treatments T_{13}, T_{11}, and T_9 was attributable to an increased rate of N translocation from culms to leaves, which leads to the production of photosynthates, which improves the transfer of nutrients to growing panicles. Treatments with low amount of nitrogen doses decreased the plant height as reported by (Singh *et al.*, 2014) [16]

Table 2: Effect of Bio Organic fertilizers (BoF) and nano urea foliar spray on plant height (cm) at different growth stages of rice.

Treatments	Active tillering (cm)	Panicle initiation (cm)	At harvest (cm)
T_1	22.0	65.4	86.4
T_2	27.6	74.1	93.8
T_3	29.0	75.0	96.1
T_4	30.1	76.1	98.6
T_5	32.8	76.9	101.8
T_6	24.1	72.1	91.1
T_7	25.7	73.2	92.4
T_8	23.7	70.2	90.1
T_9	38.2	81.1	107.3
T_{10}	36.0	79.8	105.2
T_{11}	39.9	82.3	109.2
T_{12}	34.6	77.2	103.1
T_{13}	43.5	84.8	112.5
SE d	0.90	2.07	2.75
CD (p=0.05)	1.96	4.50	5.96

3.2 Dry matter production (kg ha^{-1})

Effect of nano and Bio Organic fertilizers (BoF) on dry matter production at active tillering, panicle initiation and at harvest stage were given in table 3. Significantly higher DMP (kg ha^{-1}) was recorded in the Treatment combination of 100% STCR + 100% N as Nano Urea foliar spray + 2 t / ha Bio Organic Fertilizer (T_{13}) at active tillering (2281), panicle initiation (8683) and harvest stage (14313). The treatment combination of 50% STCR-N + 100% N as Nano Urea foliar spray + 2 t / ha Bio Organic Fertilizer (T_{11}) also recorded the next best dry matter production at respective stages. Treatment T_9 -75% STCR-N + 75% N as Nano Urea foliar spray +2 t/ha Bio Organic Fertilizer, has recorded dry matter production of 1981, 7683 and 13309 kg ha^{-1} at active tillering, panicle initiation and harvest stages, respectively. The control plot has recorded the lower DMP of 1551, 5523 11165 kg ha^{-1} in the respective stages of rice. The dry matter yield of the plant sample was substantially lower in the absence of fertiliser treatment, resulting in significantly less nutrient uptake than the remaining treatments. (Masulili *et al.*, 2010) [9] reported that in comparison with rice straw, rice husk and rice husk ash amendments increased the total plant biomass in rice.

Table 3: Effect of Bio Organic fertilizers (BoF) and nano urea foliar spray on dry matter production (kg ha^{-1}) at different growth stages of rice

Treatments	Active tillering (kg ha^{-1})	Panicle initiation (kg ha^{-1})	At harvest (kg ha^{-1})
T_1	1551	5523	11165
T_2	1688	7232	12852
T_3	1751	7683	13319
T_4	1769	6081	11713
T_5	1826	6365	11998
T_6	1624	6341	12053
T_7	1662	6752	12391
T_8	1596	6102	11682
T_9	1981	7683	13309
T_{10}	1934	7202	12887
T_{11}	2011	8241	13379
T_{12}	1871	6823	12453
T_{13}	2281	8683	14313
SE d	71	421	469
CD (p=0.05)	153	915	1019

3.3 Chlorophyll content (SPAD readings)

In rice, the rate of photosynthesis and grain yield are highly related to leaf nitrogen. The SPAD values of the crop at active tillering, panicle initiation and harvest stages of crop are given in the table 4. the SPAD value decreases as the crop reaches harvest stage due to the decrease in chlorophyll content. The higher SPAD value was recorded in the T_{13}-100% STCR + 100% N as Nano Urea foliar spray + 2 t/ha Bio Organic Fertilizer. Treatment plot at active tillering (43.88), panicle initiation (45.05) and harvest stages (40.86). The treatment T_{11}-50% STCR-N + 100% N as Nano Urea foliar spray + 2 t/ha Bio Organic Fertilizer, showed the second-best value at active tillering (43.11), panicle initiation (44.29) and harvest stages (40.23) which is on par with the treatment T_9-75% STCR-N + 75% N as Nano Urea foliar spray +2 t/ha Bio Organic Fertilizer, accounting 41.94, 43.11 and 38.64, respectively. Application of nitrogenous fertilizers increases the chlorophyll content in the plant. Duhan and Singh (2002) [5] also reported that uptake of nutrients increased significantly with increasing N levels the chlorophyll content increased in the plant. Asadi *et al.*, 2021 [1] reported that the increase in chlorophyll content of the crop with the application of rice husk biochar.

Table 4: Effect of Bio Organic fertilizers (BoF) and nano urea foliar spray on chlorophyll content at different growth stages of rice

Treatments	Active tillering (kg ha^{-1})	Panicle initiation (kg ha^{-1})	At harvest (kg ha^{-1})
T_1	36.17	37.31	32.41
T_2	39.23	40.42	35.88
T_3	40.21	41.39	36.02
T_4	41.10	47.27	36.21
T_5	41.29	42.48	36.34
T_6	38.62	39.79	34.64
T_7	39.10	40.27	35.41
T_8	37.78	38.95	33.87
T_9	41.94	43.11	38.64
T_{10}	41.69	42.87	37.12
T_{11}	43.11	44.29	40.23
T_{12}	41.56	42.79	36.86
T_{13}	43.88	45.05	40.86
SE d	1.10	1.138	1.01
CD (p=0.05)	2.40	2.47	2.19

3.4 Grain Yield

Different nutrient management techniques significantly changed the yield characteristics of the crop. The grain yield for different treatments is given in the table 5. Among the different treatments T_{13}-100% STCR + 100% N as Nano Urea foliar spray + 2 t/ha Bio Organic Fertilizer (T_{13}) produced the higher grain yield (6798 kg ha^{-1}). Followed by the treatment T_{11}-50% STCR-N + 100% N as Nano Urea foliar spray + 2 t/ha Bio Organic Fertilizer, recorded 6331 kg ha^{-1}. Which was on par with the treatment T_9-75% STCR-N + 75% N as Nano Urea foliar spray +2 t/ha Bio Organic Fertilizer, (6314). The control treatment plot T_1 (2108) recorded the lower yield among all the other treatments. When compared to the conventional urea application the use of nano urea foliar spray along with the Bio Organic Fertilizer (BoF) significantly boosted the grain yield and nitrogen use efficiency. (Kantwa and Yadav., 2022) [6] reported that an average 8% increase in yield has been witnessed with the spray of nano urea foliar spray.

3.5 Straw Yield

The straw yield for different treatments is given in the table 5. The treatment T_{13}-100% STCR + 100% N as Nano Urea foliar spray + 2 t/ha Bio Organic Fertilizer notably increased the straw yield (7598 kg ha^{-1}). Treatment T_{11} -50% STCR-N + 100% N as Nano Urea foliar spray + 2 t/ha Bio Organic Fertilizer has recorded the straw yield of 7154 kg ha^{-1} which is on par with the treatment T_9-75% STCR-N + 75% N as Nano Urea foliar spray +2 t/ha Bio Organic Fertilizer. Treatments which have the combination of STCR-N, nano urea foliar spray and Bio Organic Fertilizer has recorded higher straw yield. Grain and straw yields of rice were significantly influenced by different nitrogen management treatments. (Dixit and Gupta 2000) [3] reported that the improvement in NPK uptake was reflected in higher grain and straw yield. It may be due to the adequate supply of nutrients and metabolites for growth and development.

3.6 Harvest index

Harvest index is a function of grain yield to the total biological yield (grain + straw) and it was influenced due to various treatments. The harvest index of different treatments is given in the table 5. The HI ranged from 0.45 to 0.47. The T_{13} treatment recorded the maximum harvest index which is on par with the treatments T_9, T_{10} T_{11} T_{12}. However the control plot showed the harvest index of 0.46. Treatments which have the combination of STCR-N, Nano urea foliar spray and Bio Organic Fertilizer has recorded the high Harvest index. Conversely the treatments with the only STCR-N recorded the low range of harvest index.

Table 5: Effect of Bio Organic fertilizers (BoF) and nano urea foliar spray on grain yield, straw yield and harvest index of rice

Treatments	Grain yield (kg ha^{-1})	Straw yield (Kg ha^{-1})	Harvest index
T_1	2108	2461	0.46
T_2	3012	3655	0.45
T_3	3124	3658	0.46
T_4	3142	3679	0.46
T_5	4579	5286	0.46
T_6	2988	3379	0.47
T_7	3005	3515	0.46
T_8	2981	3488	0.46
T_9	6314	7134	0.47
T_{10}	4721	5421	0.47
T_{11}	6331	7154	0.47
T_{12}	4612	5211	0.47
T_{13}	6798	7598	0.47
SE d	164	185.4	
CD (p=0.05)	356.2	402.3	

4. Economics

To assess the treatment's practical impact on the agricultural community, it is crucial to analyse economic aspects including cost of cultivation, gross income, net returns, and B:C ratio. The primary reason of variation in gross income and net return on investment per rupee was grain yield. The cost of cultivation, gross income, net return and B: C ratio is given in the table 6. The cost of cultivation (₹.46995 ha^{-1}), gross income (₹.124764 ha^{-1}), net return (₹.77769 ha^{-1}) and B:C (2.65) ratio was maximum in the treatment 100% STCR + 100% N as Nano Urea foliar spray + 2 t/ha Bio Organic Fertilizer (T_{13}) among all other treatments. The next high B:C ratio was observed in the treatment T_{11}-50% STCR-N + 100% N as Nano Urea foliar spray + 2 t/ha Bio Organic Fertilizer (2.49) which is on par with the treatment T_9 75% STCR-N + 75% N as Nano Urea foliar spray +2 t/ha Bio Organic Fertilizer (2.49). The lowest B:C ratio (1.61) was recorded in the control plot (T_1). Kumar *et al.*, 2021 reported that significantly higher yield (6.39 t ha^{-1}) and B:C ratio was recorded in the treatment receiving 50% N, 0% Zn and 100% PK + alternate sprays of Nano N along with other Nano fertilizers.

Table 6: Effect of Bio Organic fertilizers (BoF) and nano urea foliar spray on economics of rice

Treatments	Cost of Cultivation (₹ ha^{-1})	Gross Income (₹ ha^{-1})	Net Return (₹ ha^{-1})	B:C ratio
T_1	24100	39003	14903	1.61
T_2	25481	56145	30664	2.20
T_3	24921	57834	32913	2.32
T_4	25071	58167	33096	2.32
T_5	46271	84543	38272	1.83
T_6	35371	54957	19586	1.55
T_7	46147	55620	9473	1.21
T_8	35247	55179	19932	1.57
T_9	46721	116112	69391	2.49
T_{10}	46871	87078	40207	1.86
T_{11}	46747	116427	69680	2.49
T_{12}	35547	84813	49266	2.39
T_{13}	46995	124764	77769	2.65

5. Conclusion

Chemical fertiliser uses needs balance between agricultural yield and long-term environmental sustainability. Rice crop depletes the nutrients present from the soil, mostly nitrogen is required for greater production potential of the crop. Approximately 17 kg of nitrogen is utilised for production of 1ton of rice crop. Low Nitrogen efficiency not only raises production costs but also causes crop lodging, insect pest susceptibility, and decreased net returns. Ensuring crop production sustainability demands the exploration of alternative nutrient sources as well as the modification of existing nutrient sources. Both organic and inorganic combination of fertilizers has significantly increased the yield of crop. This experimental study suggests that application of Bio Organic Fertilizer in conjunction with chemical fertilisers and Nano urea spray, may have reduced N loss and boosted availability throughout the crop growth period by forming organic-mineral associations therefore increased the yield and foliar treatment results in more effective nitrogen absorption and assimilation in crop production. Drum seeding and efficient use of nitrogenous fertilizers like STCR N, BoF, and nano urea foliar spray has resulted in the high yield and B:C ratio in this experimental study.

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