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Influence of foliar application of nano-fertilizers and organic source of nitrogen on growth and yield of direct seeded rice (*Oryza sativa* L.)

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Abstract
A field experiment was carried out in the *kharif* season of 2020 and 2021 at Hiyanglam Mayai Leikai in the Kakching district of Manipur. The experiment was laid out in a factorial randomized block design (FRBD) and replicated three times. The treatments comprised four levels of foliar application of nano NPK (19:19:19) and three levels of organic nitrogen through vermicompost. The pooled data showed that the highest plant growth characteristics were seen among the foliar treatments of nano NPK at 1.5%, including plant height, the number of tillers/m^2, the leaf area index at all stages of direct seeded rice growth and the highest grain yield of 6240 kg/ha and straw yield of 8227 kg/ha. Among the organic nitrogen sources, the application of 100% RDN using vermicompost yielded the highest grain production (5458 kg/ha), which was followed by applications of 75% RDN and 50% RDN. The direct seeded rice's growth characteristics and yield were significantly impacted by the interactions between the various foliar applied nano NPK and organic nitrogen.

Keywords: Nano-fertilizer, vermicompost, growth, yield, rice

Introduction
Rice (*Oryza sativa* L.) is one of the most important cereal crops of the world, grown in wide range of climatic zones. More than 60% of the world's population eats rice as a staple meal, and it provides 35 to 60% of the calories consumed by 2.7 billion people, the majority of whom live in South East Asia. Asia also produces and consumes 90% of the world's rice, which is planted worldwide. The most significant crop in India is rice, which takes up 23.3 percent of the total area planted to crops. The production of rice accounts for 43% of all food grains and 46% of all cereals. It is a crop that thrives in humid subtropical and rainy tropical climates. Population growth has increased the demand for rice is estimated to be 2,000 million tonnes by 2030 (FAO, 2002) [3].
Nano NPK (19:19:19) is a fully soluble balanced compound fertilizer with three essential nutrients, which helps increase benefit and profitably to plants and provides balanced supply of nutrients so as to recover deficiencies. It is required for vegetative growth in plants and increase growth, yield and improves the product quality. Today's large doses, unbalanced, and insufficient chemical fertilizers have caused the soil to become nutrient-deficient and to have worsened soil health, which has led to a decrease in crop response to appropriate doses of N-fertilizers. These toxic fertilizers damaged consumer health and reduced land fertility. Chemical fertilizers have also increased in price over time. As a result, organic manure and nano-fertilizer are becoming increasingly important. For a certain cropping system and soil, a suitable blend of chemical fertilizers and organic manures must be devised.
Any organic substance containing nitrogen is generally referred to as organic nitrogen. For instances, nucleotides, proteins, amino acids, etc. The most crucial component for growing rice is nitrogen and it is typically the nutrient that limits yields in the global rice industry world (Ladha and Reddy, 2003; Samonte*et al.*, 2006) [7, 21]. Vermicompost is becoming one of the best organic fertilizers which have an important contribution to agriculture. In fact, it contains more plant nutrients than that of organic compost. Vermicompost has been investigated for its appropriateness as a plant growth medium and for its potential commercial value by a number of researchers (Zhao and Huang, 1988; Pashanasi *et al.*, 1996) [27, 19].

Materials and Methods

The experiment was conducted in the *khari* season of 2020 and 2021 at Hiyanglam Mayai Leikai in the Kakching district of Manipur, which is located at an altitude of roughly 2545 meters above mean sea level and roughly at 24.48°N and 93.98°E in terms of latitude and longitude. The soil was clay with high amounts of organic carbon (1.35%), medium availability of nitrogen (313.64 kg/ha), phosphorus (36.8 kg/ha), potassium (240.53 kg/ha), and soil pH (5.36). The experiment was set up using a factorial randomized block design (FRBD) with three replications. The treatments included four levels of foliar application of nano NPK (19:19:19) were control (F_1), nano NPK (19:19:19) @ 0.5% (F_2), nano NPK (19:19:19) @ 1%(F_3) and nano NPK (19:19:19) @ 1.5% (F_4) and three levels of organic source of nitrogen N_1- vermicompost @100% RDN, N_2-vermicompost @75% RDN and N_3- vermicompost @ 50% RDN. Foliar spray were applied at active tillering stage (25 DAS) and panicle initiation stage (75DAS).The recommended dose of fertilizer for rice was N:P:K @ 60:40:30 kg/ha. Full dose of, single super phosphate (SSP), and muriate of potash (MOP) along with vermicompost as par treatment were applied and incorporated with the last land preparation. Rice was sown in the first week of June with a seed rate of 80 kg/ha at a spacing of 20 cmX10 cm. Growth characteristics were recorded at 30 days intervals from ten random sample plants from each plot. The crop was harvested in the first week of November. The resulting data were statistically analyzed using the analysis of variance approach outlined by Panse and Sukhatme (1995) [18], and the significance of the various sources of variation was assessed using the error mean square by Fisher and Snedecor's F test at a level of 0.05.

Results and Discussion

Growth attributes

Plant height (cm)

Rice plant height was significantly influenced by varied foliar application of nano NPK in both seasons and at all growth stage. The pooled data in Table 1 showed that F_4, which involved foliar application of nano NPK @1.5%, gave the highest plant height at 30 DAS, 60 DAS, 90 DAS and at harvest, measuring 41.55 cm, 86.89 cm, 108.5 cm and 131.2 cm, respectively. The control plot F_1 had the lowest plant height across all growth phases (33.19 cm, 64.35 cm, 89.39 cm, and 120.0cm). It might be due to increased nutrient availability, growing plants produce more dry matter, more chlorophyll and more photosynthesis, all of which contribute to improved plant growth. The modulation of plant gene expression and biological mechanisms that determine plant height are both impacted by nano fertilizer. Nano fertilizer has a direct effect on plant height, a crucial morphological trait. These findings are in intune with the findings of Rochester *et al*., (2001) [20], Meena *et al*., (2017) [10] Tredes (2012) [26].

In terms of organic nitrogen, all of the interventions were observed to significantly affect the height of the direct seeded rice plant at 30 DAS, 60 DAS, 90 DAS and at harvest (Table 1). The pooled data showed that N_1, or 100% RDN, gave significantly higher plant height at all growth phases, including 30 DAS, 60 DAS, 90 DAS, and at harvest, with plant heights of 38.56 cm, 82.02cm, 104.5cm, and 128.35cm, respectively. The lowest plant height was noted with 50% RDN at 30 DAS (35.81 cm), 60 DAS (75.68cm), 90 DAS (96.34cm) and at harvest (123.63cm) respectively. This could be explained by the fact that higher nutrient doses led to greater nutrient availability in the soil for plant nutrition. Furthermore, organic sources with slow release and continuous nutrient availability enhanced cell division, elongation, as well as various metabolic processes, which ultimately increased the plant height. Similar results were reported by Krishna *et al*., (2008) [6], Dutt and Chauhan (2010) [2], and Murthy (2012) [15].

The interaction between different doses of foliar applications of nano NPK and organic nitrogen significantly affected plant height (Table 1), with the interaction between nano NPK @ 1.5% + 100% RDN through vermicompost (N_1F_4) recorded the highest plant height of 135.24cm and the interaction between the control + 50% RDN through vermicompost (N_3 F_1) recorded the lowest plant height of 118.2.

Number of tillers/ m^2

The number of tillers/m^2 was significantly influenced by foliar application of nano NPK in both the *kharif* 2020 and 2021 growing seasons. The findings (Table 2) showed that from 30 DAS to 90 DAS, the number of tillers/m^2 were increased, and again decreased till harvest. At 30 DAS, 60 DAS, 90 DAS, and at harvest, F_4 produced the maximum tillers/m^2 (334.43, 605.79, 556.94, and 538.36, respectively) and followed by F_3. The control plot F_1 had the lowest tillers/m^2 at all growth stages, including harvest, with values of 201.63, 327.99, 265.38, and 255.36.The increase in the number of tillers/m^2 might be due to nitrogen application at vegetative stage can be explained by the fact that, nitrogen (N) is needed to produce chlorophyll which is crucial for photosynthesis. This result is in conformity with Munoz-Huerta *et al*., (2013).

The number of tillers/m^2 was found to be significantly influenced by the organic nitrogen at 30 DAS, 60 DAS and 90 DAS (Table 2). The same trend was also observed in both the seasons of direct seeded rice. Among the organic nitrogen the plot receiving @100% RDN through vermicompost i.e., N_1 gave the highest number of tillers/m^2 at 30 DAS (276.71), 60 DAS (526.02), 90 DAS (473.56) and at harvest (459.66) which was followed by the plot receiving @75% RDN through vermicompost. The lowest number of tillers/m^2 was observed in the plot receiving @50% RDN through vermicompost at all the growth stages i.e. 30 DAS, 60 DAS, 90 DAS and at harvest with a value of 234.44, 476.22, 437.77 and 419.11 respectively. Similar trend of variation was observed in both the seasons of study i.e., *kharif* season of 2020 and 2021, respectively. Tillering is the result of the growth of auxiliary buds, which is strongly related to the culm's nutritional status since a tiller obtains nutrients and carbohydrates from the culm during its early growth stage, which is enhanced by the addition of nitrogen. Available Increased plant growth, yield, and nutrient uptake in rice are caused by nitrogen and enzymes generated by microbes in vermicompost. This result was similar with the findings of Krishna *et al*., (2008) [6], Dutt and Chauhan (2010) [2], and Murthy (2012) [15].

The number of tillers/m^2 was significantly influenced by the interaction between various foliar application of nano NPK and organic nitrogen (Table 2).The highest number of tillers/m^2 at 30 DAS (379.22), 60 DAS (649.40), 90 DAS (568.82) were recorded with the interaction between nano NPK @ 1.5% + 100% RDN through vermicompost (N_1F_4) and at harvest (555.93) whereas the lowest was recorded from the interaction between the control + 50% RDN through vermicompost.

Leaf area index

All interventions were found to have a significant influenced on the LAI of direct seeded rice at 30 DAS, 60 DAS, 90 DAS, and at harvest (Table 3). The same pattern could be observed in both seasons. At 30 DAS (1.07), 60 DAS (3.34), 90 DAS (8.4), and harvest (7.78), F_4 gave the highest LAI followed by F_3.The lowest LAI was observed at control, F_1 at 30 DAS (0.78), 60 DAS (1.67), 90 DAS (3.7), and at harvest (2.74) respectively. Nano NPK fertilizer enhanced the vegetative growth which leds to an increase in the leaf area index of plant. Increase leaf area index of plant was due to the availability of nano NPK at a critical stages and more concentration in rice. Similar trend was reported by Naik *et al*., (2002) [16].

The plot receiving @100% RDN, N_1 had the highest LAI across all growth stages 30 DAS (1.01), 60 DAS (2.89), 90 DAS (7.11) and at harvest (6.35), respectively among the organic source of nitrogen. The plot getting @75% RDN, N_2 was the one that came next. Among the three nutrient management strategies, N_3 produced the lowest LAI for rice at all phases of growth (Table 3). The highest LAI, which is linked to photosynthesis and eventually shows that an increase in dry matter is connected to a rise in created more dry matter per unit leaf area, is indicative of this relationship. Similar finding was also reported by Malviya *et al*., (2018) [9].
LAI was significantly influenced by the interaction between various foliar application of nano NPK and organic nitrogen (Table 3), with the interaction between nano NPK @ 1.5% + 100% RDN through vermicompost (N_1F_4) recorded the highest LAI and the interaction between the control + 50% RDN through vermicompost (N_3 F_1) recording the lowest LAI.

Table 1: Influence of foliar application of nano-fertilizers and organic source of nitrogen on plant height (cm) of direct seeded rice

Treatment	30 DAS			60 DAS			90 DAS			Harvesting		
Foliar application	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**
F_1	31.16	35.22	33.19	65.57	63.12	64.35	90.51	88.26	89.39	120.84	119.58	120.21
F_2	32.57	39.47	36.02	78.04	80.87	79.46	99.88	101.98	100.93	123.54	124.67	124.10
F_3	33.33	41.64	37.48	80.87	84.48	82.68	102.25	104.30	103.28	125.49	127.70	126.60
F_4	37.10	46.00	41.55	84.87	88.91	86.89	106.97	109.93	108.45	129.62	132.87	131.24
S.E(d)(±)	0.51	0.42	0.33	0.69	0.60	0.46	0.14	0.11	0.089	0.64	0.67	0.46
CD (p=0.05)	1.06	0.88	0.73	1.42	1.24	1.00	0.28	0.24	0.20	1.32	1.38	1.01
Organic nitrogen												
N_1	35	42.13	38.56	81.32	82.73	82.02	104.22	104.83	104.52	127.40	129.30	128.35
N_2	33.17	40.45	36.81	76.02	78.63	77.33	100.41	100.93	100.67	123.75	125.53	124.64
N_3	32.45	39.17	35.81	74.69	76.67	75.68	95.09	97.60	96.34	123.46	123.79	123.63
S.Ed.(±)	0.44	0.37	0.29	0.59	0.52	0.39	0.12	0.10	0.077	0.55	0.58	0.40
CD(p=0.05)	0.92	0.76	0.63	1.23	1.08	0.87	0.25	0.20	0.17	1.14	1.20	0.88
Treatment Combinations												
N1F1	31.45	36.38	33.92	67.93	66.10	67.02	96.26	93.24	94.75	122.22	122.23	122.22
N1F2	33.61	40.33	36.97	80.97	83.56	82.26	103.40	103.81	103.60	126.41	127.57	126.99
N1F3	34.87	42.84	38.86	85.94	87.64	86.79	104.22	107.46	105.84	128.84	129.03	128.94
N1F4	40.06	48.97	44.52	90.42	93.61	92.02	113.00	114.80	113.90	132.12	138.36	135.24
N2F1	31.07	35.78	33.43	65.13	62.54	63.84	91.67	86.21	88.94	120.61	119.80	120.21
N2F2	32.43	39.10	35.77	77.07	81.20	79.13	100.02	103.26	101.64	121.38	123.92	122.65
N2F3	32.60	41.20	36.90	78.88	84.48	81.68	103.81	104.93	104.37	123.21	127.11	125.16
N2F4	36.57	45.73	41.15	83.00	86.30	84.65	106.12	109.33	107.73	129.81	131.27	130.54
N3F1	30.97	33.51	32.24	63.66	60.73	62.20	83.61	85.34	84.48	119.69	116.71	118.20
N3F2	31.67	38.96	35.31	76.08	77.86	76.97	96.21	98.88	97.55	122.82	122.51	122.67
N3F3	32.50	40.88	36.69	77.80	81.30	79.55	98.72	100.51	99.61	124.41	126.97	125.69
N3F4	34.67	43.31	38.99	81.20	86.80	84.00	101.81	93.24	103.74	126.92	128.98	127.95
S.E(d)(±)	0.89	0.73	0.57	1.19	1.04	0.79	0.24	0.20	0.15	1.10	1.15	0.80
CD(p=0.05)	1.84	1.52	1.26	2.47	2.16	1.74	0.49	0.49	0.34	2.29	2.39	1.76

F_1: Control; F_2: nano NPK (19:19:19) @ 0.5% at tillering and panicle initiation stage; F_3:nano NPK (19:19:19) @ 1% at tillering and panicle initiation stage; F_4: nano NPK (19:19:19) @ 1.5% at tillering and panicle initiation stage; N_1: @100% RDN through vermicompost; N_2:@75% RDN through vermicompost; N_3:@ 50% RDN through vermicompost

Table 2: Influence of foliar application of nano-fertilizers and organic source of nitrogen on number of tillers/m^2 of direct seeded rice

Treatment	30 DAS			60 DAS			90 DAS			Harvesting		
Foliar application	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**
F_1	196.30	206.96	201.63	341.24	314.74	327.99	272.48	258.28	265.38	263.01	247.71	255.36
F_2	229.59	240.95	235.27	508.64	533.26	520.95	475.64	485.89	480.77	452.09	473.74	462.92
F_3	247.44	262.68	255.06	528.30	569.31	548.80	520.20	524.27	522.24	487.47	512.78	500.13
F_4	321.58	347.27	334.43	589.00	622.58	605.79	553.06	560.81	556.94	526.80	549.91	538.36
S.E(d)(±)	1.28	1.44	0.96	1.29	1.11	0.85	0.38	0.36	0.26	1.56	1.66	1.14
CD (p=0.05)	2.65	2.99	2.12	2.67	2.31	1.87	0.79	0.74	0.57	3.23	3.45	2.51
Organic nitrogen												
N_1	268.44	284.98	276.71	516.28	535.77	526.02	471.73	475.39	473.56	456.53	462.79	459.66
N_2	249.15	268.13	258.64	492.79	508.04	500.41	456.46	458.85	457.66	429.93	447.66	438.80

N_3	228.59	240.29	234.44	466.32	486.11	476.22	437.84	437.70	437.77	410.57	427.66	419.11
S.E(d)(±)	1.11	1.25	0.83	1.12	0.96	0.74	0.33	0.31	0.23	1.35	1.44	0.99
CD(p=0.05)	2.29	2.59	1.84	2.31	2	1.62	0.68	0.64	0.50	2.79	2.99	2.17
Treatment Combinations												
N1F1	204.67	213.76	209.21	367.31	334.67	350.99	288.21	280.68	284.45	272.84	260.48	266.66
N1F2	240.28	256.48	248.38	526.70	549.89	538.30	490.68	504.92	497.80	480.28	490.33	485.31
N1F3	263.72	276.33	270.03	540.85	589.98	565.42	540.77	545.58	543.16	521.33	540.18	530.76
N1F4	365.10	393.34	379.22	630.25	668.54	649.40	567.26	570.37	568.82	551.67	560.19	555.93
N2F1	193.91	206.80	200.36	338.64	312.78	325.71	270.85	253.61	262.23	265.69	250.33	258.01
N2F2	229.81	245.71	237.76	519.75	532.60	526.17	472.71	481.81	477.26	447.31	470.24	458.76
N2F3	242.34	269.08	255.71	535.79	570.08	552.94	530.97	533.91	532.44	480.73	522.19	501.46
N2F4	330.55	350.91	340.73	576.97	616.69	596.83	551.30	566.08	558.69	526.00	547.87	536.94
N3F1	190.31	200.32	195.32	317.77	296.79	307.28	258.36	240.55	249.46	250.50	232.33	241.42
N3F2	218.68	220.67	219.67	479.47	517.30	498.39	463.53	470.95	467.24	428.68	460.66	444.67
N3F3	236.27	242.61	239.44	508.26	547.86	528.06	488.86	493.33	491.09	460.35	475.97	468.16
N3F4	269.10	297.55	283.32	559.77	582.50	571.14	540.62	545.98	543.30	502.74	541.67	522.21
S.E(d)(±)	2.23	1.93	1.67	2.23	1.93	1.48	0.66	0.62	0.45	2.69	2.88	1.97
CD (p=0.05)	4.63	4	3.67	4.63	4	3.25	1.37	1.28	0.99	5.59	5.97	4.345

F_1: Control; F_2: nano NPK (19:19:19) @ 0.5% at tillering and panicle initiation stage; F_3:nano NPK (19:19:19) @ 1% at tillering and panicle initiation stage; F_4: nano NPK (19:19:19) @ 1.5% at tillering and panicle initiation stage; N_1: @100% RDN through vermicompost; N_2 :@75% RDN through vermicompost; N_3:@ 50% RDN through vermicompost

Table 3: Influence of foliar application of nano-fertilizers and organic source of nitrogen on LAI of direct seeded rice

Treatment	**30 DAS**			**60 DAS**			**90 DAS**			**Harvesting**		
Foliar application	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**
F_1	0.81	0.75	0.78	1.90	1.44	1.67	4.31	3.07	3.7	2.84	2.65	2.74
F_2	0.90	0.91	0.90	2.52	2.40	2.45	7.06	7.27	7.17	6.52	6.79	6.65
F_3	0.97	0.96	0.96	3.15	2.65	2.90	7.78	8.02	7.9	6.99	7.35	7.16
F_4	1.05	1.10	1.075	3.58	3.11	3.34	8.48	8.38	8.4	7.66	7.90	7.78
S.E(d)(±)	0.004	0.006	0.004	0.005	0.005	0.160	0.005	0.007	0.004	0.005	0.006	0.004
CD (p=0.05)	0.009	0.012	0.008	0.011	0.010	0.351	0.010	0.014	0.009	0.010	0.012	0.008
Organic nitrogen												
N_1	0.99	1.02	1.01	2.95	2.84	2.89	7.21	7.01	7.11	6.21	6.49	6.35
N_2	0.90	0.90	0.90	2.78	2.52	2.65	7.05	6.77	6.91	5.96	6.18	6.07
N_3	0.91	0.87	0.89	2.64	1.85	2.24	6.46	6.27	6.36	5.83	5.85	5.84
S.Ed.(±)	0.004	0.005	0.003	0.004	0.004	0.138	0.004	0.006	0.004	0.004	0.005	0.003
CD(p=0.05)	0.008	0.010	0.007	0.009	0.008	0.304	0.008	0.012	0.008	0.008	0.010	0.007
Treatment Combinations												
N1F1	0.88	0.89	0.88	1.92	1.46	1.69	4.62	3.45	4.04	2.87	2.75	2.81
N1F2	0.91	0.93	0.92	2.91	2.78	2.85	7.31	7.51	7.41	6.88	7.27	7.08
N1F3	1.06	1.02	1.04	3.27	3.30	3.28	8.06	8.19	8.13	7.21	7.92	7.57
N1F4	1.12	1.26	1.19	3.71	3.81	3.76	8.86	8.91	8.89	7.89	8.00	7.94
N2F1	0.81	0.69	0.75	1.87	1.45	1.66	4.45	3.36	3.91	2.97	2.85	2.91
N2F2	0.85	0.90	0.88	2.78	2.54	2.66	7.22	7.42	7.32	6.25	6.82	6.54
N2F3	0.89	0.96	0.92	2.81	2.67	2.74	7.82	8.05	7.94	6.99	7.12	7.05
N2F4	1.04	1.06	1.05	3.65	3.41	3.53	8.72	8.25	8.49	7.65	7.94	7.79
N3F1	0.73	0.69	0.71	1.91	1.42	1.67	3.86	2.41	3.14	2.67	2.36	2.52
N3F2	0.94	0.89	0.91	1.86	1.87	1.87	6.66	6.88	6.77	6.43	6.27	6.35
N3F3	0.95	0.91	0.93	3.38	1.99	2.68	7.46	7.82	7.64	6.78	7.00	6.89
N3F4	1.00	0.97	0.99	3.39	2.11	2.75	7.85	7.97	7.91	7.45	7.77	7.61
S.E(d)(±)	0.008	0.010	0.006	0.009	0.008	0.276	0.008	0.012	0.007	0.008	0.010	0.006
CD(p=0.05)	0.016	0.020	0.014	0.019	0.017	0.608	0.017	0.024	0.016	0.017	0.020	0.014

F_1: Control; F_2: nano NPK (19:19:19) @ 0.5% at tillering and panicle initiation stage; F_3: nano NPK (19:19:19) @ 1% at tillering and panicle initiation stage; F_4: nano NPK (19:19:19) @ 1.5% at tillering and panicle initiation stage; N_1: @100% RDN through vermicompost; N_2 :@75% RDN through vermicompost; N_3:@ 50% RDN through vermicompost

Table 4: Grain yield kg/ha, straw yield kg/ha and harvest index (%) influenced by foliar application of nano-fertilizers and organic source of nitrogen in rice

Treatment	**Grain yield kg/ha**			**Strawyield kg/ha**			**Harvest index (%)**		
Foliar application	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**	**2020**	**2021**	**Pooled**
F_1	3362	3236	3298	5081	5166	5124	39.73	38.42	39.07
F_2	4799	5039	4919	6536	6773	6654	42.23	42.62	42.42
F_3	5245	5373	5309	6951	7178	7065	42.94	42.75	42.84
F_4	6148	6332	6240	8067	8387	8227	43.31	43.04	43.17
S.E(d)(±)	1.28	0.88	0.82	1.38	1.64	1.07	0.01	0.01	0.005
CD	2.65	1.83	1.27	2.86	3.41	1.67	0.02	0.01	0.008

Organic nitrogen									
N1	5434	5482	5458	7085	7191	7138	43.35	43.22	43.28
N2	4770	4893	4831	6736	6906	6821	41.17	41.08	41.12
N3	4462	4608	4535	6155	6531	6343	41.63	40.82	41.23
S.E(d)(±)	1.10	1.02	0.71	1.19	1.42	0.92	0.01	0.01	0.004
CD(p=0.05)	2.29	2.11	1.82	2.48	2.95	2.04	0.02	0.01	0.01
Treatment Combinations									
N1F1	3790	3693	3741	5220	5011	5116	42.06	42.43	42.24
N1F2	5577	5629	5603	7040	7324	7182	44.20	43.46	43.83
N1F3	5837	5968	5902	7232	7455	7344	44.66	44.46	44.56
N1F4	6532	6640	6586	8847	8974	8911	42.48	42.52	42.50
N2F1	3427	3240	3333	5412	5631	5521	38.77	36.52	37.65
N2F2	4339	4892	4615	6411	6578	6495	40.36	42.65	41.50
N2F3	5130	5182	5156	6963	7091	7027	42.42	42.22	42.32
N2F4	6183	6258	6220	8156	8323	8240	43.12	42.92	43.02
N3F1	2869	2768	2818	4611	4857	4734	38.36	36.30	37.33
N3F2	4481	4597	4538	6157	6415	6286	42.12	41.75	41.93
N3F3	4768	4970	4869	6657	6989	6822	41.73	41.56	41.64
N3F4	5730	6097	5913	7197	7864	7530	44.32	43.67	44.00
S.E(d)(±)	2.21	1.76	1.41	2.39	2.85	1.86	0.01	0.01	0.009
CD	4.58	3.66	3.11	4.95	5.90	4.09	0.03	0.02	0.02

F_1: Control; F_2: nano NPK (19:19:19) @ 0.5% at tillering and panicle initiation stage; F_3: nano NPK (19:19:19) @ 1% at tillering and panicle initiation stage; F_4: nano NPK (19:19:19) @ 1.5% at tillering and panicle initiation stage; N_1: @100% RDN through vermicompost; N_2:@75% RDN through vermicompost; N_3:@ 50% RDN through vermicompost

Grain yield (kg/ha)

The pooled data showed that among the various foliar application of nano fertilizer, the application of nano fertilizer @ 1.5% F_4 (6240 kg/ha) was found to produce the highest grain yield however, it was significantly higher than F_3, (5309 kg/ha**)** F_2 (4919 kg/ha) and F_1 (3298 kg/ha). The lowest grain yield was obtained from the control plot, F_1 (3298 kg/ha) which was significantly lower than any other treatments (Table 4). In comparison to the control, the plant grown with nano fertilizer showed increased dry weight, photosynthetic rate, and chlorophyll-a production. This increases photosynthetic translocation from the source (leaves) to the sink (economic part of the plant), which increases yield and quality parameters from plants treated with nano-fetilizers compared to plants treated with traditional fertilizers or without nano-fetilizers. Similar results were also observed by Ham *et al*., (2013) [4]; Liu and Lal (2014) [8] and Sirisena *et al*., (2013) [24].

The application of 100% RDN (5458kg/ha), which was significantly greater than the application of 75% RDN (4770 kg/ha) and 50% RDN (4462 kg/ha) showed in Table 4. Lowest grain yield was obtained in 50% RDN (4462 kg/ha). Increases in nitrogen levels have a significant impact on grain output. Increased nitrogen levels led to more leaves and a greater leaf area index, which increased photosynthesis and absorption rates, metabolic activity, and cell division, leading to a notable improvement in the growth characteristics and grain yield. The use of vermicompost, which had the twin advantages of improving the physical environment of the rhizosphere region and also assuring adequate nutrient supply to the plant, may be responsible for the higher yield quality in N_1. Increased nitrogen effects on growth and root development led to improved nutrient uptake, boosting rice's panicle mass, number of panicles, and grains per panicle. This might be due to the microbial stimulation of the vermicompost and the N provided through delayed mineralization. These results were supported by Singh *et al.*, (2010) [23], and Meenakumari and Shehkar (2012) [11].

The interaction of different doses of foliar applications of nano NPK and organic nitrogen had a significant impact on grain yield kg/ha (Table 4), with the interaction of nano NPK @ 1.5% + 100% RDN through vermicompost (N_1F_4) recorded the highest grain yield kg/ha and the interaction of the control + 50% RDN through vermicompost (N_3F_1) recorded the lowest grain yield kg/ha.

Straw yield (kg/ha)

The results in the table 4 showed that using various foliar application of nano NPK significantly increased rice straw yield. The pooled data showed that the application of nano NPK @1.5%, F_4 (8227 kg/ha), gave the maximum straw yield, followed by the application of nano @ 1%, i.e. F_3 (7075 kg/ha), and the lowest straw yield was recorded in control plot (5166 kg/ha). The quick uptake of the nano fertilizer by the plant and its ease of translocation may have contributed to better rates of photosynthesis and more dry matter formation, which in turn increased straw yield when applied as a foliar spray. Similar results were found by Khalil *et al.*, (2019) [5]. Rice straw yield is increased by foliar application of nano fertilizer because it accelerates photosynthesis, produces more dry matter and accumulates and transports photosynthesis-related compounds to the plant's productive regions. Similar results were observed by Apoorva *et al*., (2017) [1] and Mehta and Bharat (2019) [12].

The results in the table 4 showed that there was significantly difference between the various organic sources of nitrogen on the straw yield of rice. However, the application of 100%RDN, N_1 (7138 kg/ha), produced the highest straw yield and the lowest was observed in 50% RDF, N_3 (7343 kg/ha). This might be as a result of the nutrients being readily available, which significantly boosted vegetative growth and hence improved rice straw output. Due to the presence of sufficient levels of both nitrogen and soil moisture that improve accessibility and uptake of NH_4^+, increased straw biomass from the combination application of organic and inorganic fertilizer compared to other treatments. They added that an increase in nitrogen absorption coincides with increases in phosphorus and potassium absorption, which encourages the production of a lot of leaves (straw yield) and tillers. The combined application of organic and inorganic fertilizer, which was greater than the control treatment, produced the longest roots, nevertheless. This result was supported Sci *et al*., (2018).

The pooled data shown in Table 4, there was a significant correlation between the interaction of different foliar application of nano NPK and organic nitrogen on straw yield kg/ha. The interaction of nano NPK @ 1.5% + 100% RDN through vermicompost (N_1F_4) recorded the highest straw yield kg/ha, whereas the interaction between the control + 50% RDN through vermicompost (N_3F_1) recorded the lowest straw yield kg/ha.

Harvest index %

Harvest index of rice was significantly affected by the foliar application of nano fertilizers during both the years of experimentation as well as in the pooled data Table 4. However, higher harvest index (43.17%) was observed in the treatment receiving nano fertilizer @1.5%, (F_4) among the different foliar applications and lowest was observed in control plot (39.07%).The reversal of transport direction from importing to exporting may have been caused by the maturation of leaves, which is accompanied by numerous functional and anatomical changes. This may have triggered the transportation capabilities in terms of penetration movements within the plant system, leading to a higher biological yield and the highest harvest index. This result was similar with the findings of Midde *et al*., (2014) [13].

Among the different organic source of nitrogen N_1 i.e. 100% RDN through vermicompost recorded the maximum harvest index of 43.28%.The lowest was observed in the plot receiving 75% RDN (41.12%). This may be attributed to the best possible plant health brought on vermicompost, which encouraged the portioning of the photosynthates to reproductive parts and enhanced the grain to straw ratio. Similar finding was reported by Sudhakar (2016) [25].

Shown in Table 4, the interaction of various foliar nano NPK applications and organic nitrogen had a significant influenced on harvest index (%), with the interaction of nano NPK @ 1% + 100% RDN through vermicompost (N_1F_3) recorded the highest harvest index (%) and the interaction of the control+ 50% RDN through vermicompost (N_3F_1) recorded the lowest harvest index (%).

Conclusion

From the aforementioned findings, it can be inferred that organic fertilizers, such as vermicompost, have the ability to improve rice's growth characteristics and yield components. The growth, productivity and yield of the rice crop all benefited by using vermicompost as an organic fertilizer. The growth and production of the rice genotypes were significantly impacted by each treatment. Application of nanofertilizer, particularly nano NPK, increased rice growth, development, and antioxidant activity. This has the potential to improve crop productivity and plant nutrition, particularly in rice. Consequently, thorough knowledge about nano fertilizer application, especially right quantity, time and mode of application will enhance the growth, development and yield betterment of crops. In the current study, it was shown that 100% RDN through vermicompost, along with 1.5% nano NPK fertilizer, produced a greater growth and yield characteristics than the other treatments. The results of this study would also be helpful for further investigations into the use of nanotechnology in agriculture. From a financial perspective, farmers can use a combination of organic fertilizer and nano fertilizer to boost rice yields.

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