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Integrated Evaluation of 'Geoxol.Com' and Organic Manures on Soil Health and Rice Productivity under Irrigated Conditions

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Abstract

A field experiment was conducted over two seasons (*rabi* 2020-21 and *kharif* 2021) at the ICAR-Indian Institute of Rice Research farm, Rajendranagar, Hyderabad to evaluate the graded levels of Geoxol.com, FYM (Farm Yard Manure) and vermicompost along with recommended doses of inorganic fertilizers. The experimental setup followed a randomized block design (RBD), involving eight treatments and three replications. Treatments included a control, RDF alone, and RDF in combination with FYM (10 t ha^{-1}), vermicompost (5 t ha^{-1}), and Geoxol.com at 10, 20, 40, and 60 kg ha^{-1}. The plant growth, yield and its components were significantly improved in all amended treatments over control. Although plant height and chlorophyll content showed no significant differences among treatments, the RDF + Geoxol.com combinations recorded the highest values. Yield attributes such as tillers, panicles per square meter and grains per panicle significantly enhanced with Geoxol.com application. RDF combined with 60 kg ha^{-1} Geoxol.com yielded the highest grain yield (6140 kg ha^{-1} reflecting a 27 % increase over RDF alone. Similarly, RDF + 40 kg ha^{-1} Geoxol.com and RDF + 20 kg ha^{-1} Geoxol.com also resulted in substantial yield improvements of 23 % and 19 %, respectively. Nutrient uptake of nitrogen, phosphorus, and potassium was significantly higher in Geoxol.com and FYM treated plots compared to control. While soil fertility parameters remained largely unchanged over a short period of two seasons, a slight increase in organic carbon was observed in Geoxol.com-treated plots. Notably, nutrient use efficiency indices particularly agronomic efficiency and partial factor productivity improved with Geoxol.com.

Key words: Geoxol.com, FYM, vermicompost, irrigated rice, yield

Introduction

Rice (*Oryza sativa* L.) is the staple grain consumed by more than half of the global population. Nearly 90 % of the world's rice is produced and consumed in Southeast Asian countries, where it serves as the principal food and cereal crop (Bandumula, 2018). The key challenge in the current scenario is to increase grain productivity while ensuring a sustainable food supply with minimal environmental impact. With the global population rising at an alarming rate, expanding net cultivable land for agriculture is no longer a viable option. To meet the escalating food demand, it is essential to optimize the yield potential of high yielding rice varieties through improved agronomic management practices.

Despite the past gains in rice production through chemical fertilizers, recent observations of stagnant or declining yields have highlighted the need of organic amendments to ensure long term sustainability of the crop production (Surekha *et al*., 2010). Additionally, the soil physical environment plays a crucial role in governing chemical and biological reactions essential for optimal plant growth, as well as in regulating water, nutrient, and oxygen availability and providing mechanical support to plants. This implies the need for integrated nutrient management in rice cultivation. Therefore, combining organic manures with inorganic fertilizers helps to maintain yield stability by addressing minor deficits of micro and secondary nutrients, establishing favourable soil physical conditions and enhancing the nutrient use efficiency.

Organic materials such as FYM and vermicompost are traditionally being used by rice farmers. Organic manure has several advantages as it provides a balanced supply of macro and micronutrients, enhance the microbial activity that aids in improving soil physical and chemical properties (Rostaei *et al*., 2024, Dhaliwal *et al*., 2023). According to Verma *et al*., (2024), the use of organic manures can aid in the regeneration of soil structure. In addition to improving structural integrity, it also increases water retention in the soil profile by improving air capacity, which allows roots to utilize a greater area of soil (Sarkar *et al*., 2003). Although farmyard manure and vermicompost provide essential macronutrients (N, P, K, Ca, Mg, S) and micronutrients (Fe, Mn, Cu, Zn) required for plant growth, its low nutrient concentration necessitates to apply in huge quantities leading to increased labour and transportation costs. To overcome these constraints a product "Geoxol.com" was developed by Privi life sciences pvt ltd., Navi Mumbai, Maharashtra, India as a viable alternative of FYM. It is a compressed granulated organic manure and contains 15 % total carbon, 1.50 % total nitrogen, 1.00 % total phosphorus, and 0.50 % total potassium. Although there is a growing concern about the use of organics, application of organic manures alone as a substitute to inorganic fertilizers is not enough to maintain the present levels of crop productivity of high yielding varieties. Therefore, integrated nutrient management in which both organic manures and inorganic fertilizers are used simultaneously is the most effective method to maintain a healthy and sustainably productive soil. In this context, the present study was undertaken to evaluate the performance of Geoxol.com, in combination with inorganic fertilizers, on yield, nutrient use efficiency, and soil properties of irrigated rice under vertisols at the ICAR–Indian Institute of Rice Research (ICAR-IIRR), Hyderabad.

Materials and Methods

Experimental site

The field experiment was conducted at ICAR-IIRR farm, Rajendranagar, Hyderabad during two seasons of *rabi* 2020-21 and *kharif* 2021 to study the effect of Geoxol.com in irrigated rice. The experimental site was located in on a hot semi-arid climate with mean annual rainfall of 906 mm. The soil of experimental site is a vertisol with neutral pH 7.95, EC (0.79), medium organic carbon (0.56 %) low available nitrogen (181 kg ha^{-1}), high phosphorus (68 kg P_2O_5 ha^{-1}) and high potassium (510 kg K_2O ha^{-1}).

Experimental design and Treatments details

The experiment was laid out in a Randomized Block Design (RBD) with eight treatments and three replications. The treatments involved graded doses of Geoxol.com (a product developed by Privi life sciences pvt. ltd., Navi Mumbai, India), farmyard manure (FYM), and vermicompost, each in combination with the recommended dose of fertilizers (RDF). The RDF application rates were 100:40:40 for both the *rabi* and *kharif* season. The rice cultivar "Chandra" was used for the experiment.

Table 1: Treatment details

T_1	Absolute control
T_2	RDF
T_3	RDF + 10 t ha^{-1} FYM
T_4	RDF + 5 t ha^{-1} Vermicompost
T_5	RDF + 10 kg ha^{-1} Geoxol.com
T_6	RDF + 20 kg ha^{-1} Geoxol.com
T_7	RDF + 40 kg ha^{-1} Geoxol.com
T_8	RDF + 60 kg ha^{-1} Geoxol.com

Growth, yield and yield components

Plant growth parameters were recorded at different intervals. Chlorophyll content was estimated by using a SPAD meter, readings were taken from an expanded leaf of uppermost part at regular interval for the entire plant growth period as suggested by Peng *et al.,* (1993). Plants harvested from 1 m^2 area were taken for determining the yield attributes *viz.,* number of tillers per m^2, number of panicles per m^2, grain number per panicle, 1000 grain weight, etc., after physiological maturity. Grain and straw yields were recorded from net plot areas of 5 m^2. Further, after shade drying, plants were oven-dried at 65 °C to a constant weight, powdered, and stored for chemical analysis. Grain and straw samples were analysed to determine nutrient uptake.

Nutrient uptake

The uptake of N and P nutrients was calculated using the following formula and expressed in kg ha^{-1}.

$$\text{Uptake of nutrients (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%) x dry matter production (kg ha}^{-1}\text{)}}{100}$$

Nutrient use efficiency indices

Nutrient use efficiency indices are calculated by using following formulas

$$\text{Agronomic efficiency} = \frac{\text{(Yield in treatment -yield in control plot)}}{\text{kg of fertilizer applied}}$$

$$\text{Partial factor productivity} = \frac{\text{kg grain}}{\text{kg nutrient added}}$$

$$\text{Internal efficiency} = \frac{\text{Grain yield}}{\text{Nutrient uptake}}$$

Soil sampling

Soil samples were collected from each plot after the harvest of the crop. The samples were air-dried, crushed using a wooden roller, sieved through a 2 mm mesh, and stored for further analysis.

Plant and soil analysis

The plant samples were digested with sulphuric acid and hydrogen peroxide. The content of nitrogen in the digested samples was determined by the micro-Kjeldahl determination method (Jackson, 1973). For phosphorus and potassium estimation, plant samples were digested with tri-acid mixture and determined by the colorimetric method and flame photometer method, respectively (Jackson, 1973).

Soil pH was measured (soil water ratio of 1:2.5) potentiometric ally, and electrical conductivity (EC) by conductometry (Jackson, 1973). Organic carbon (OC) content was assessed using the Walkley and Black method. Soil nitrogen was analyzed with the Kjeldahl method (Subbaiah and Asija, 1956). Available phosphorus from soil was extracted by Olsens reagent (0.5 M $NaHCO_3$) as described by Olsen *et al*., (1954). The blue colour was developed following ascorbic acid method of Watanabe and Olsen (1965) and the intensity of blue colour was measured at 660 nm by using spectrophotometer. Soil available K was extracted with neutral normal ammonium acetate (pH 7.0) and determined with a flame photometer.

Statistical analysis

Data collected over the two seasons were subjected to pooled analysis after testing for homogeneity of error variance. Analysis of variance (ANOVA) was performed using SPSS and treatment means were compared using the Critical Difference (CD) at 5 % level of significance ($p = 0.05$).

Results and Discussion

Growth attributes

The application of organic manures and Geoxol.com in combination with RDF did not significantly influence plant height, SPAD chlorophyll readings, NDVI values across treatments (**Table 1**). Although statistically non-significant, numerically higher values were recorded in the RDF + 40 kg ha^{-1} and RDF + 60 kg ha^{-1} Geoxol.com treatments. The SPAD values ranged from 36.1 to 40.8, with the maximum observed in RDF + 10 kg ha^{-1} Geoxol.com. Similarly, NDVI was highest (0.72) in RDF + 10 and 60 kg ha^{-1} Geoxol.com, indicating a potential enhancement in canopy greenness and photosynthetic activity due to better nutrient availability. This could be attributed to the fast release of nutrients from the inorganic source in combination with the organic supply, resulting in better vegetative development (Kumar *et al*., 2022).

Table 1: Effect of Geoxol.com on growth and yield parameters of rice (pooled mean)

Treatments	Plant height (cm)	SPAD	NDVI	Tillers/m^2 (No.)	Panicles/m^2 (No.)
Absolute control	76.8	36.1	0.63	217	166
RDF	86.3	38.9	0.68	260	197
RDF + 10 t/ha FYM	84.6	38.5	0.70	300	234
RDF + Vermicompost	82.7	38.1	0.69	238	194
RDF + 10 kg/ha Geoxol.com	84.7	40.8	0.72	265	217
RDF + 20 kg/ha Geoxol. com	86.8	39.0	0.69	265	223
RDF + 40 kg/ha Geoxol.com	87.8	38.9	0.70	282	239
RDF + 60 kg/ha Geoxol.com	83.5	39.6	0.72	306	255
SE(m)±	2.61	0.94	0.02	10.5	9.54
CD (P=0.05)	NS	NS	NS	30.5	27.64
CV (%)	7.667	5.94	4.17	9.67	10.83

Yield attributes and yield

Significant differences ($P \leq 0.05$) were observed in the number of tillers and panicles per square meter among the treatments (**Table 1**). The RDF + 60 kg ha^{-1} Geoxol.com recorded the highest number of tillers (306/m²) and panicles (255/m²), followed by RDF + 40 kg ha^{-1} Geoxol.com (282 and 239) and RDF + FYM treatments (300 and 234) tillers and panicles respectively. In contrast, absolute control recorded lowest number of tillers (217) and panicles (166) per unit area (m^2). These increases may be attributed to improved soil biological activity and nutrient availability from the combined use of organic and inorganic fertilizers. In contrast, the control treatment recorded the lowest tiller and panicle density, clearly indicating the importance of external nutrient input in irrigated rice production. The slower release of nutrients from organic sources during later stages of crop growth resulted in an increased number of tillers at harvest (Babu and Reddy, 2000).

The positive effect of Geoxol.com could be attributed to its ability to mimic the beneficial effects of FYM and vermicompost by supplying macro and micronutrients, improving soil microbial activity, and enhancing the physical condition of the soil. This is consistent with the findings of Ahmed *et al*., 2021, who highlighted the role of organic amendments in improving soil structure and crop establishment.

Pooled data indicated that, grain number per panicle varied significantly among the treatments and ranged from 98 to 122 with a mean of 112 grains per panicle (**Table 2**). The RDF + 20 kg ha^{-1} Geoxol.com treatment recorded the highest grain number (122 grains/panicle) except absolute control (98) and RDF (108) all other treatments recorded on par tiller number with the superior treatment. This indicates that integrating organic sources, especially Geoxol.com, effectively enhances sink capacity by improving grain setting. The control recorded the lowest number of grains (98/panicle), highlighting the critical role of nutrient input in spikelet fertility.

Table 2: Effect of Geoxol.com on yield parameters, yield of rice (pooled mean)

Treatments	Grains/ panicle	1000 grain weight (g)	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Harvest index
Absolute control	98	23.2	3505	4386	0.44
RDF	108	24.1	4829	6191	0.44
RDF + 10 t/ha FYM	114	23.8	5791	6861	0.46
RDF + Vermicompost	116	23.7	5367	6542	0.45
RDF + 10 kg/ha Geoxol.com	112	23.5	5464	6477	0.46
RDF + 20 kg/ha Geoxol. com	122	23.8	5737	678	0.46
RDF + 40 kg/ha Geoxol.com	113	23.7	5926	6726[a]	0.47
RDF + 60 kg/ha Geoxol.com	114	24.1	6140	695	0.47
SE(m)±	3.49	0.29	316	405	0.01
CD (P=0.05)	10.11	NS	1059	1354	NS
CV (%)	7.60	2.95	7.81	8.31	6.18

The 1000 grain weight remained statistically unaffected across treatments, ranging from 23.2 to 24.1 g (**Table 2**). This implies that nutrient management primarily influenced the number of grains rather than grain size or density. Similar non-significant variations in grain weight with organic and integrated nutrient management were reported by Satyanarayana *et al*., (2002).

Grain and straw yields

There was a significant increase in grain yield with application of Geoxol.com in different doses compared to only RDF application (**Table 2**). Grain yield differed significantly among the treatments and ranged from 3505 to 6140 kg ha^{-1} with an average grain yield of 5344 kg ha^{-1}.

The RDF + 60 kg ha^{-1} Geoxol.com treatment produced the highest grain yield (6140 kg ha^{-1}), followed closely by RDF + 40 kg ha^{-1} (5926 kg ha^{-1}), RDF + 10 t ha^{-1} FYM (5791 kg ha^{-1}) and RDF + 20 kg ha^{-1} (5737 kg ha^{-1}). While the absolute control yielded the lowest (3505 kg ha^{-1}). All integrated treatments, RDF either combined with FYM, vermicompost or Geoxol.com were on par and showed yield advantage over RDF alone (4829 kg ha^{-1}), underscoring the synergistic effect of combining organic inputs with inorganic fertilizers. While RDF ensures immediate nutrient availability, the inclusion of organic sources like FYM, vermicompost, and Geoxol.com contributes to gradual nutrient release, improved microbial activity, and enhanced soil structure, leading to better root growth and nutrient uptake. While the absolute control yielded the lowest (3505 kg ha^{-1}).

Among the integrated treatments, RDF + 60 kg ha^{-1} Geoxol.com recorded the highest grain yield (6140 kg ha^{-1}), reflecting a 27 % increase over RDF alone. Similarly, RDF + 40 kg ha^{-1} Geoxol.com and RDF + 20 kg ha^{-1} Geoxol.com also resulted in substantial yield improvements of approximately 23 % and 19 % respectively. All Geoxol.com treated plots (10, 20, 40, and 60 kg ha^{-1}) recorded higher grain yields compared to plots treated with vermicompost at 5 t ha^{-1}. However, when compared with FYM applied at 10 t ha^{-1}, only the 40 and 60 kg ha^{-1} doses of Geoxol.com resulted in higher yields. This trend suggests that Geoxol.com is not only comparable to conventional organics like FYM and vermicompost, but may offer greater efficiency at lower doses, likely due to its enhanced nutrient availability.

Straw yield followed a similar pattern to that of grain yield, with all integrated treatments outperforming the RDF alone (6191 kg ha^{-1}) and the control (4386 kg ha^{-1}) and presented in **Table 2**. RDF + 60 kg ha^{-1} Geoxol.com recorded the highest straw yield of 6959 kg ha^{-1}, followed closely by RDF + 10 t ha^{-1} FYM (6861 kg ha^{-1}), RDF + 20 kg ha^{-1} Geoxol.com (6787 kg ha^{-1}), and RDF + 40 kg ha^{-1} Geoxol.com (6726 kg ha^{-1}). These results suggest a positive correlation between integrated nutrient application and overall plant biomass production. The increased straw yield under integrated treatments could be attributed to enhanced vegetative growth due to improved nutrient availability and uptake. Organic manures, including Geoxol.com, likely enhanced soil microbial activity, soil aeration, and water retention, which collectively supported vigorous plant growth leading to greater straw accumulation. (Sande *et al*., 2024).

The superior performance of integrated treatments may also be attributed to improved nutrient synchronization, where the supply of nutrients matches the crop demand at critical stages of growth (Rahman *et al*., 2016). Furthermore, organic materials enhance cation exchange capacity and water-holding capacity of soil, promoting better nutrient retention and reducing losses through leaching or volatilization. Organic fertilizers have more potential in improving crops yield as they contain a high amount of most of the essential plant nutrients (Sultana *et al*., 2021). The harvest index (HI) did not differ significantly among treatments, ranging from 0.44 to 0.47. Treatments with Geoxol.com and organic manures recorded marginally higher HI values compared to RDF and control, indicating a balanced partitioning of assimilates towards grain and straw. These results are well corroborated with the findings of Nowshin *et al*., (2020) and Urmi *et al*., (2022), who found significant effects of combined application of organic manures and chemical fertilizers on straw yield and biological yield of rice.

Nutrient uptake

Total nitrogen, phosphorus and potassium uptake was significantly improved by the application of the organic materials (**Table 3**). Nitrogen uptake was significantly higher in all integrated treatments compared to the control (62.4 kg ha^{-1}), with values ranging from 97.7 to 111.4 kg ha^{-1}. The highest nitrogen uptake was recorded in RDF + FYM (111.4 kg ha^{-1}), indicating the effectiveness of traditional organic amendments in enhancing N availability. Geoxol.com treatments showed comparable nitrogen uptake, suggesting their efficacy as a viable alternative. The uptake of nitrogen by rice was relatively high (**Table 2**), which may have facilitated the enhanced absorption of phosphorus and potassium. Nitrogen is known to promote greater root and shoot development, which in turn can improve the plant's ability to access and accumulate other nutrients such as P and K (Urmi *et al*., 2022).

Table 3: Effect of Geoxol.com on total nutrient uptake (kg/ha) of rice at harvest (pooled mean)

Treatments	Nitrogen	Phosphorus	Potassium
Absolute control	62.4	12.8	73.0
RDF	98.6	16.4	89.5
RDF + 10 t/ha FYM	111.4	20.7	104.0
RDF + Vermicompost	97.7	18.5	96.0
RDF + 10 kg/ha Geoxol.com	99.9	19.0	101.5
RDF + 20 kg/ha Geoxol. com	102.9	21.2	104.5
RDF + 40 kg/ha Geoxol.com	100.7	19.8	110.5
RDF + 60 kg/ha Geoxol.com	100.5	22.2	113.5
SE(m)±	5.11	0.84	4.49
CD (P=0.05)	14.80	2.45	13.00
CV (%)	12.93	10.99	11.10

Phosphorus uptake was significantly influenced by treatments (**Table 3**). Application of RDF + 60 kg ha^{-1} Geoxol.com (22.2 kg ha^{-1}) and RDF + 20 kg ha^{-1} Geoxol.com (21.2 kg ha^{-1}) recorded the highest values, significantly greater than RDF alone (16.4 kg ha^{-1}) and the control (12.8 kg ha^{-1}). Potassium uptake showed a progressive increase with higher doses of Geoxol.com, peaking at 113.5 kg ha^{-1} under the 60 kg ha^{-1} treatment. This was significantly higher than the control (73.0 kg ha^{-1}) and RDF alone (89.5 kg ha^{-1}). These results indicate that Geoxol.com may improve phosphorus and potassium availability in soil, possibly through enhanced microbial activity and improved solubilization mechanisms. The continued application of organic fertilizers in combination with inorganic fertilizers enhanced the uptake and use efficiency of major nutrients more effectively than the use of inorganic fertilizers alone (Yadav *et al*., 2019).

Soil properties

The post harvest soil analysis revealed that integrated nutrient management practices improved soil fertility status compared to RDF alone and the control (**Table 4**). While soil pH and EC remained statistically unaffected across treatments, notable differences were observed in organic carbon content and nutrient availability.

Table 4: Effect of Geoxol.com on soil properties at harvest after second season

Treatments	pH (1:2.5)	EC (dSm^{-1})	O C (%)	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
Absolute control	8.15	0.79	0.47	123	47.2	440
RDF	8.14	0.81	0.59	162	65.7	533
RDF + 10 t/ha FYM	8.15	0.92	0.66	152	69.5	561
RDF + Vermicompost	8.23	0.88	0.69	175	54.5	533
RDF + 10 kg/ha Geoxol.com	8.21	0.87	0.65	178	56.3	530
RDF + 20 kg/ha Geoxol.com	8.14	0.89	0.63	169	75.4	510
RDF + 40 kg/ha Geoxol.com	8.22	0.79	0.72	176	78.3	593
RDF + 60 kg/ha Geoxol.com	8.17	0.87	0.74	186	84.2	538
SE(m)±	0.03	0.08	0.04	12.3	7.29	29.1
C.D (p = 0.05)	NS	NS	0.14	36.2	22.3	NS
C.V (%)	0.74	17.0	13.4	12.4	19.0	9.50

Soil organic carbon (OC) increased significantly with the application of organic amendments. Application of RDF + 60 kg ha^{-1} Geoxol.com registered highest organic carbon (0.74 %), except absolute control (0.47 %) and RDF (0.59 %) all other treatments recorded on par organic carbon status with the superior treatment. Application of Geoxol.com @ 60 kg ha^{-1} improved Organic carbon status to the tune of 7 – 12 % compared to FYM and vermicompost application, respectively. This trend reflects the positive contribution of organic inputs in enhancing soil organic matter, which is vital for nutrient retention and microbial activity.

Available nitrogen was highest in RDF + 60 kg ha^{-1} Geoxol.com (186 kg ha^{-1}), followed by RDF + 10 kg ha^{-1} Geoxol.com (178 kg ha^{-1}) and RDF + vermicompost (175 kg ha^{-1}), all outperforming RDF alone (162 kg ha^{-1}). This indicates the ability of organic materials to enhance nitrogen mineralization and retention in soil.

Available phosphorus (P_2O_5) was significantly increased in integrated treatments, particularly with higher Geoxol.com applications. RDF + 60 kg ha^{-1} Geoxol.com recorded the highest P_2O_5 level (84.2 kg ha^{-1}), indicating its superior solubilizing effect and improved P availability, likely due to microbial stimulation and organic acid release. Potassium availability (K_2O) did not show a significant difference among treatments, but RDF + 40 kg ha^{-1} Geoxol.com (593 kg ha^{-1}) showed the highest K levels.

Soil nutrient availability largely depends on its favourable physicochemical and biological properties. The incorporation of organic manures enhances the chemical attributes of soil by increasing the levels of organic carbon (OC), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulphur (S) (Islam *et al*., 2019). Sultana *et al*., (2021) stated that integrated treatment (organic and inorganic) gave higher values for soil N, P, K, and S contents, whereas the sole inorganic treatment gave significantly lower values for those nutrients. These findings are consistent with those of several recent studies, Sharma *et al*., (2017), Urmi *et al*., (2022), Surekha *et al*., (2024) which reported that the integrated application of organic and inorganic fertilizers significantly enhances post harvest soil properties, including increased levels of organic carbon, nitrogen, phosphorus, potassium, calcium, magnesium and sulphur.

Nutrient use efficiency indices

Analysis of nutrient use efficiencies revealed key differences across treatments (**Table 5**). Agronomic efficiency (AE) over RDF was highest for RDF + 60 kg ha^{-1} Geoxol.com (26.6), followed by RDF + 40 kg ha^{-1} Geoxol.com (22.1), RDF + 10 t ha^{-1} FYM (19.6), and RDF + 20 kg ha^{-1} Geoxol.com (18.3). This indicates that integrating organic sources like Geoxol.com significantly boosts the yield response per unit of nutrient applied beyond that achieved by RDF alone. Internal efficiency (IE) values for nitrogen, phosphorus and potassium were highest in RDF + 40 kg ha^{-1} Geoxol.com (60.6, 321.0 and 53.9 respectively), suggesting enhanced nutrient utilization efficiency at this dose. RDF + 20 kg ha^{-1} and 60 kg ha^{-1} Geoxol.com treatments also recorded consistently high IE, reflecting better nutrient assimilation. Partial factor productivity (PFP), which represents total yield per unit of nutrient applied, was also highest in RDF + 40 kg ha^{-1} Geoxol.com for all three nutrients (N, P, K at 60.7, 151.5 respectively). The improved nutrient use efficiencies in integrated treatments can be attributed to better synchronization of nutrient release with crop demand, enhanced microbial interactions, and improved root growth and activity. These efficiencies underscore the importance of balanced fertilization and integrated approaches in optimizing nutrient management in rice based systems. These results are in line with Urmi *et al*., 2022.

Table 5: Effect of Geoxol.com on nutrient use efficiency indices of rice

Treatments	Agronomic efficiency over RDF	Internal efficiency			Partial factor productivity		
		N	P	K	N	P	K
Absolute control		51.5	296	50.6	45.3	113	113
RDF		52.8	322	52.9	51.6	129	129
RDF + 10 t/ha FYM	19.6	53.5	331	56.7	57.1	143	143
RDF + Vermicompost	11.1	54.9	299	53.7	52.9	132	132
RDF + 10 kg/ha Geoxol.com	12.9	54.3	316	53.3	54.9	137	137
RDF + 20 kg/ha Geoxol. com	18.3	59.6	335	54.2	57.9	144	144
RDF + 40 kg/ha Geoxol.com	22.1	60.6	321	53.9	60.7	151	151
RDF + 60 kg/ha Geoxol.com	26.6	56.2	311	56.3	57.4	143	143

Conclusion

The study demonstrates that integrating organic sources FYM, vermicompost particularly Geoxol.com, with recommended fertilizer doses significantly improves rice yield, nutrient uptake, and soil health compared to RDF alone. Among treatments, RDF + 60 kg ha^{-1} Geoxol.com recorded the highest grain and straw yields, superior nutrient use efficiency, and enhanced post harvest soil fertility. These results highlight Geoxol.com as a possible alternative to traditional organics like FYM and vermicompost, offering comparable or superior benefits even at lower application rates and can be recommended for irrigated rice in vertisols, wherever bulky organic materials like FYM and VC are unavailable. Overall, the integrated use of Geoxol.com with RDF is a promising and sustainable nutrient management strategy for enhancing rice productivity and maintaining soil health in vertisols.

References

Ahmed S, Matiullah K, Taqi R, Ahmad R and Iqbal J. 2021. Integrated use of bio-organic and chemical fertilizer to enhance yield and nutrients content of tomato. *Eurasian Journal of Soil Sciences*, 11(2): 126-132.

Babu BTR and Reddy VC. 2000. Effect of nutrient sources on growth and yield of direct-seeded rice (*Oryza sativa* L.). *Crop Research*, 19(2): 189-193.

Bandumula N. 2018. Rice production in Asia: Key to global food security. *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences*, 88(3): 1323-1328.

Dhaliwal SS, Sharma V, Shukla AK, Verma V, Kaur M, Singh P, Gaber A and Hossain A. 2023. Effect of addition of organic manures on basmati yield, nutrient content and soil fertility status in north-western India. *Heliyon*, 9(3): 1-12.

Islam MM, Urmi TA, Rana MS, Alam MS, Haque MM. 2019. Green manuring effects on crop morpho-physiological characters, rice yield and soil properties. *Physiology and Molecular Biolology of Plants*, 25(1): 303–312.

Jackson ML. 1973. *Soil Chemical Analysis*. Oxford IBH Publishing House, Bombay. p. 38.

Kumar R, Jha S, Singh SP, Kumar M, Kumari N and Padbhushan R. 2022. Combined application of chemical fertilizer and enriched household vermicompost influences maize yield and soil quality under calcareous soil. *The Pharma Innovation Journal*, 11(8): 2069-2075.

Nowshin L, Rahman MA, Paul SK and Afrina R. 2020. Yield performance of aromatic fine rice as influenced by integrated use of vermicompost and inorganic fertilizers. *Journal of the Bangladesh Agricultural University*, 18(1): 260-265.

Olsen SR, Cole CV, Watnabe FS and Dean LA. 1954. Estimation of available phosphorus in soil by extracting with sodium bicarbonate. *USDA Circular* No. 939: 1-19, Washington.

Peng S, García FV, Laza RC and Cassman KG. 1993. Adjustment for specific leaf weight improves chlorophyll meter's estimate of rice leaf nitrogen concentration. *Agronomy Journal*, 85(5): 987–990.

Rahman F, Rahman MM, Rahman GKMM, Saleque MA, Hossain ATMS and Miah MG. 2016. Effect of organic and inorganic fertilizers and rice straw on carbon sequestration and soil fertility under a rice-rice cropping pattern. *Carbon Management*, 7(1): 41-53.

Rostaei M, Fallah S, Carrubba A and Lorigooini Z. 2024. Organic manures enhance biomass and improve content, chemical compounds of essential oil and antioxidant capacity of medicinal plants: A review. *Heliyon,* 10(17): 1-23.

Sande TJ, Tindwa HJ, Alovisi AMT, Shitindi MJ and Semoka JM. 2024. Enhancing sustainable crop production through integrated nutrient management: a focus on vermicompost, bio-enriched rock phosphate, and inorganic fertilisers–a systematic review. *Frontiers in Agronomy*, 6: 1422876 (1-27).

Sarkar S, Singh SR. and Singh RP. 2003. The effect of organic and inorganic fertilizers on soil physical condition and the productivity of a rice–lentil cropping sequence in India. *The Journal of Agricultural Science*, 140(4): 419-425.

Satyanarayana V, Vara Prasad PV, Murthy VRK and Boote KJ. 2002. Influence of integrated use of farmyard manure and inorganic fertilizers on yield and yield components of irrigated lowland rice. *Journal of Plant Nutrition*, 25(10): 2081-2090.

Sharma JK, Jat G, Meena RH, Purohit HS and Choudhary RS. 2017. Effect of vermicompost and nutrients application on soil properties, yield, uptake and quality of Indian mustard (Brassica juncea). *Annals of Plant Soil Research*, 19(1): 17-22.

Subbaiah BR and Asija GL. 1956. A rapid procedure for the estimation of available nitrogen in soils. *Current Science*, 25: 259-260.

Sultana M, Jahiruddin M, Islam MR, Rahman MM, Abedin MA and Solaiman ZM. 2021. Nutrient enriched municipal solid waste compost increases yield, nutrient content and balance in rice. *Sustainability*, 13(3): 1047 (1-12).

Surekha K, Jhansilakshmi V, Somasekhar N, Latha PC, Kumar RM, Shobha Rani N, Rao KV and Viraktamath BC. 2010. Status of organic farming and research experiences in rice. *Journal of Rice Research*, 3(1): 23-35.

Surekha K, Pragnya M, Kumar RM, Brajendra and Sundaram RM. 2024. Potential of rice straw as a carbon source in organic rice farming and its effect on global warming potential, *Journal of Rice Research,* 17(1): 81 - 87.

Urmi TA, Rahman MM, Islam MM, Islam MA, Jahan NA, Mia MAB, Akhter S, Siddiqui MH and Kalaji HM. 2022. Integrated nutrient management for rice yield, soil fertility, and carbon sequestration. *Plants*, 11(1): 138.

Verma S, Pradhan SS, Singh A and Kushuwaha M. 2024. Effect of organic manure on different soil properties: A review. *International Journal of Plant Soil Sciences*, 36(5): 182-187.

Watanabe FS and Olsen SR. 1965. Methods of soil analysis–chemical and microbiological properties. *Soil Science Society of America*, Madison, Wisconsin, USA.

Yadav SK, Benbi DK and Prasad R. 2019. Effect of continuous application of organic and inorganic sources of nutrients on chemical properties of soil. *International Journal of Current Microbiology and Applied Sciences*, 8(4): 2455-2463.