The Pharma Innovation Journal 2023; 12(9): 835-840

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(9): 835-840

www.thepharmajournal.com
Received: 07-06-2023
Accepted: 14-07-2023

Gajjela Indira
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India

Anjali
Department of Genetics and Plant Breeding, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India

T Kanna
Department of Agronomy, Agriculture College, Naira, Acharya N.G. Ranga Agricultural University, Andhra Pradesh, India

Alladi Chandrakanth
Department of Agronomy, Agriculture College, Bapatla, Acharya N.G. Ranga Agricultural University, Andhra Pradesh, India

Corresponding Author:
Gajjela Indira
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India

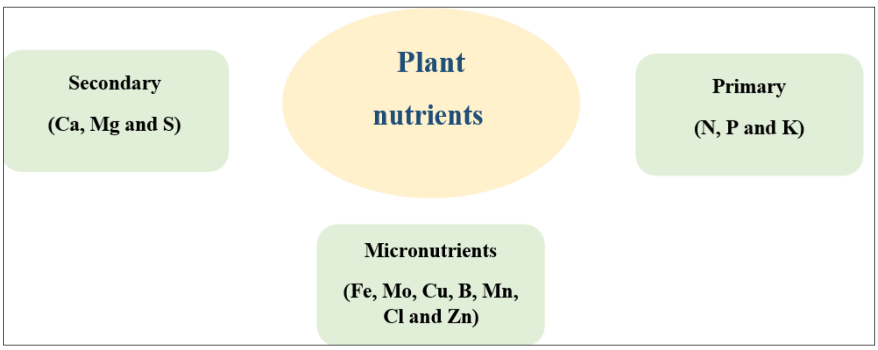
Effect of different nutrient management practices, quantities and application techniques on performance of Rice (*Oryza sativa*)

Gajjela Indira, Anjali, T Kanna and Alladi Chandrakanth

Abstract
Rice (*Oryza sativa* L.) is one of the most important cereal crops of the world, grown in wide range of climatic regions, to nourish the mankind. The abstract explores the multifaceted impact of diverse nutrient management practices, varying quantities, and innovative application techniques on the overall performance of Rice. The study delves into the intricate interplay between nutrient availability and rice growth, yield, and quality. Through an exhaustive review of pertinent literature and empirical analysis, the implication of nutrient management strategies in augmenting rice production can be understood. Key findings indicate that the choice of nutrient management practice significantly influences rice productivity. Organic and inorganic fertilizer applications, as well as integrated approaches, exhibit distinct effects on growth, nutrient uptake, and yield parameters. Furthermore, the ration of nutrients administered proves to be a critical factor, with both deficiency and excess leading to suboptimal outcomes. Achieving an equilibrium between nutrient supply and crop demand emerges as a pivotal consideration. Innovative application techniques, such as foliar spraying, fertigation, and precision nutrient delivery, offer novel avenues to enhance nutrient utilization efficiency. These techniques allow for targeted nutrient delivery, mitigating losses and maximizing plant uptake. Consequently, they contribute to elevated yield potential, improved grain quality, and sustainable agricultural practices. The need for context-specific nutrient management strategies, taking into account soil properties, climate conditions, and rice cultivars. In conclusion, the intricate relationships between nutrient management practices, quantities, and application techniques, elucidating their profound influence on the performance of Rice. The synthesis of empirical evidence and theoretical perspectives provides valuable insights for policymakers, researchers, and practitioners striving to advance sustainable rice cultivation and bolster global food systems.

Keywords: Nutrient use efficiency, sustainable agriculture practices, food security, rice cultivation and Nutrient management practices

Introduction



Nutrient sources
- Inorganic fertilizers
- Organic manures
- Biofertilizers
- Nanofertilizers

Fertilizer encompasses both individual or combined nutrient elements and any substances applied directly to the soil, aimed at stimulating plant growth, enhancing crop yields, or improving their overall quality.

Inorganic fertilizers

Inorganic (mineral) fertilizer- a term used by the International organization standardisation (ISO) for fertilizer in which the declared nutrients are in form organic salts obtained by extraction and by physical or chemical industrial process. Inorganic fertilizers are used to distinguish the manufactured product from natural organic materials of plant or animal origin. Some of the commonly used inorganic fertilizers are:

- Urea (46% N)
- Ammonium nitrate (32 -37.5% N)
- Ammonium sulphate (20.5% N)
- Di ammonium phosphate (18% N, 46% N)
- Single super phosphate (16% P2O5, 12% S)
- Gypsum (13-15% S, 16-19% Ca)
- Murate of Potash (48-50% K2O, 17.5% S)
- Potassium nitrate (13% N, 44% K2O)
- Zinc sulphate (33% Zn, 15% S)
- Borax (11% B)
- Iron sulphate (19% Fe)
- Boric acid (17% B)

Organic manures

Organic manures are natural fertilizers derived from plant, animal, and microbial sources, offering sustainable and eco-friendly alternatives to synthetic chemical fertilizers. These manures are rich in essential nutrients that enhance soil fertility and plant growth. They consist of various components that contribute to their effectiveness.

Plant-based components, such as composted leaves, crop residues, and kitchen waste, provide organic matter, improving soil structure, water retention, and microbial activity. Animal-based sources like manure from livestock yield vital nutrients like nitrogen, phosphorus, and potassium. Additionally, microorganisms present in organic manures break down complex compounds into simpler forms, facilitating nutrient absorption by plants.

This blend of organic matter, nutrients, and microbial life fosters long-term soil health, minimizes nutrient leaching, and reduces environmental pollution. By promoting sustainable agricultural practices, organic manures play a crucial role in maintaining fertile soils, enhancing crop yield, and ensuring food security while preserving the natural ecosystem.

Organic manures offer a multitude of benefits for both agricultural and environmental systems

Improved Soil Structure: Organic manures enhance soil texture and structure, promoting better water infiltration, aeration, and root penetration. This leads to healthier root development and overall plant growth.

Nutrient Enrichment: Organic manures provide a balanced array of essential nutrients (nitrogen, phosphorus, potassium, micronutrients) required for plant growth. These nutrients are released gradually, reducing the risk of nutrient imbalances and minimizing nutrient leaching.

Sustainable Nutrient Management: By recycling organic waste and utilizing animal byproducts, organic manures contribute to waste reduction and the sustainable management of resources, decreasing the need for synthetic fertilizers.

Microbial Activity: Organic manures foster a diverse microbial community in the soil, supporting nutrient cycling and enhancing plant nutrient uptake. This boosts overall soil health and resilience.

Carbon Sequestration: The organic matter in these manures increases soil carbon content, aiding in carbon sequestration and mitigating climate change by capturing atmospheric carbon dioxide.

Reduced Environmental Impact: Unlike synthetic fertilizers, organic manures release nutrients gradually, reducing the risk of nutrient runoff and pollution of water bodies.

Enhanced Crop Quality: Organic manures often result in improved taste, aroma, and nutritional quality of crops, contributing to healthier and more appealing produce.

Cost-effectiveness: Utilizing organic waste materials locally reduces disposal costs for municipalities while providing farmers with affordable nutrient sources.

Biodiversity and Ecosystem Support: Organic farming practices associated with the use of organic manures promote biodiversity, preserve beneficial insects, and foster a more resilient ecosystem.

Long-term Sustainability: The use of organic manures contributes to sustainable agriculture by maintaining soil fertility over the long term, reducing soil degradation, and ensuring food security for future generations.

Incorporating organic manures into agricultural systems not only enhances productivity but also supports environmental stewardship, making them a crucial component of sustainable and responsible farming practices.

Biofertilizers

Biofertilizers are natural and environmentally friendly alternatives to chemical fertilizers. They consist of beneficial microorganisms, such as bacteria, fungi, and algae, that enhance nutrient availability and uptake by plants. Biofertilizers play a vital role in nutrient management and sustainable agriculture for several reasons:

Nitrogen Fixation: Certain biofertilizers, like nitrogen-fixing bacteria (e.g., Rhizobium, Azotobacter), convert atmospheric nitrogen into plant-available forms, reducing the need for synthetic nitrogen fertilizers. This process improves soil fertility and minimizes nitrogen runoff, mitigating water pollution.

Phosphorus Solubilization: Phosphate-solubilizing microorganisms release bound phosphorus in the soil, making it more accessible to plants. This reduces phosphorus fertilizer application while enhancing crop growth.

Enhanced Nutrient Uptake: Biofertilizers increase the root's ability to absorb nutrients by promoting root development and enhancing nutrient-absorbing mechanisms.

Improved Soil Structure: The activities of biofertilizers enhance soil aggregation, water retention, and aeration, leading to improved soil structure and reduced erosion.

Disease Suppression: Some biofertilizers produce natural compounds that suppress harmful pathogens, contributing to plant health and reducing the need for chemical pesticides.

Reduced Environmental Impact: Biofertilizers decrease the environmental burden associated with synthetic fertilizer production, usage, and runoff, leading to decreased soil and water pollution.

Biodiversity Promotion: Beneficial microorganisms introduced through biofertilizers contribute to a diverse and resilient soil microbial community, supporting overall ecosystem health.

Sustainable Crop Production: By enhancing nutrient availability and soil health, biofertilizers contribute to sustainable and higher-quality crop yields over the long term.

Cost-effectiveness: While initial investments may be required, the long-term benefits of reduced fertilizer costs and improved soil productivity make biofertilizers cost-effective.

Adaptability: Biofertilizers can be integrated into various cropping systems, including organic and conventional practices, promoting adaptable and flexible nutrient management strategies.

Climate Resilience: Improved soil health through biofertilizer use can contribute to increased carbon sequestration, aiding in climate change mitigation and adaptation.

In essence, biofertilizers offer a natural and holistic approach to nutrient management, addressing the challenges of soil degradation, nutrient depletion, and environmental pollution associated with conventional farming practices. By promoting sustainable and regenerative agriculture, biofertilizers contribute to a more resilient and nourished planet.

Nano fertilizers

Nanofertilizers are a cutting-edge advancement in agricultural technology, utilizing nanotechnology to enhance nutrient use efficiency and improve crop productivity. These nanoscale materials are engineered to deliver nutrients more effectively to plants, resulting in several key benefits:

Enhanced Nutrient Uptake: Nanofertilizers are designed to release nutrients gradually and in a targeted manner, improving nutrient availability and uptake by plant roots. This reduces nutrient losses due to leaching and volatilization.

Increased Nutrient Use Efficiency: The precise delivery of nutrients through nanofertilizers minimizes wastage, allowing plants to absorb a higher proportion of applied nutrients. This leads to improved nutrient use efficiency and reduced fertilizer input requirements.

Minimized Environmental Impact: With reduced nutrient runoff and leaching, nanofertilizers help mitigate water pollution and minimize the negative environmental effects associated with excess fertilizer application.

Customized Nutrient Delivery: Nanotechnology enables the encapsulation of nutrients within nanoparticles, allowing controlled release based on plant needs and environmental conditions. This tailoring of nutrient delivery optimizes plant growth and development.

Improved Plant Health and Stress Tolerance: Some nanofertilizers are designed to enhance plant resistance to biotic and abiotic stressors, promoting overall plant health and reducing the need for chemical interventions.

Enhanced Soil Fertility: Nanofertilizers can improve soil structure and nutrient retention by facilitating better nutrient distribution within the soil matrix. This contributes to long-term soil fertility and health.

Precise Nutrient Management: Nanofertilizers enable farmers to apply nutrients with greater precision, minimizing over-application and ensuring that nutrients are delivered exactly where and when they are needed.

Sustainable Agriculture: By reducing fertilizer wastage and environmental pollution, nanofertilizers align with principles of sustainable and responsible agricultural practices.

Improved Crop Yields and Quality: The optimized nutrient delivery and enhanced stress tolerance provided by nanofertilizers often result in increased crop yields and improved quality of harvested produce.

Technological Innovation: Nanofertilizers showcase the potential of nanotechnology in revolutionizing agriculture, contributing to advancements in both crop production and resource management.

Despite their promise, the use of nanofertilizers also raises questions about their potential environmental and health impacts, necessitating thorough research and responsible application. As technology continues to evolve, nanofertilizers hold the potential to play a significant role in addressing the global challenge of enhancing food security while minimizing the ecological footprint of agriculture.

Method of fertilizer application

Methods of fertilizer application has a significant influence on fertilizer recovery. The application method varies according to the spacing of crop, type of fertilizer material, time of application. A brief account of these points could be explained as follows.

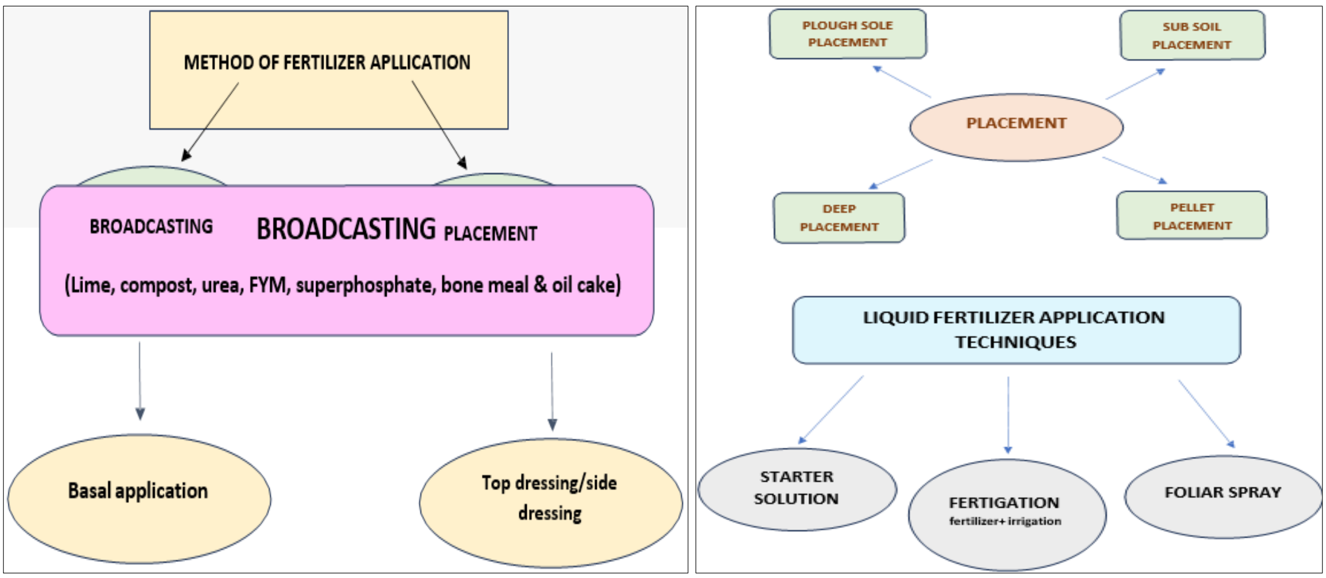


Fig 1: Fertilizer application techniques

Singh *et al*. (2017) [6] documented that applying 100% recommended dose of fertilizers (RDF) resulted in significantly higher grain and straw yields compared to the control. They found that rice crops fertilized with 75% RDF, along with alternating-year incorporation of green manures like dhaincha, sunhemp, and green gram, produced notably greater grain and straw yields compared to using 50% RDF along with green manures incorporated annually. The grain yield increases due to 75% RDF with green manures of dhaincha, sunhemp, and green gram incorporated alternately was approximately 15.3%, 14.8%, and 12.6% higher than when using 50% RDF with green manures. The study also determined that the effect of incorporating dhaincha as green manure, either annually or alternately, surpassed the impact of using sunhemp and green gram.

Aatheeswari *et al*. (2019) [1] observed that various integrated nutrient management (INM) practices significantly influenced rice growth and yield. The treatment utilizing soil test-based targeted yield (STCR) with inorganic and biofertilizer application at basal and 15th & 30th days after transplanting yielded the highest plant height, tillers per hill, productive tillers per hill, grain yield, and straw yield. STCR treatment with only basal biofertilizer application followed closely. The lowest growth and yield parameters were recorded in the RDF treatment with green leaf manure and basal biofertilizer application. The STCR treatment with biofertilizers at basal and foliar stages yielded the highest gross and net returns.

Gohil *et al*. (2021) [2] demonstrated that various treatments significantly affected rice grain and straw yield. The highest grain and straw yield were achieved using RDF along with 75% Zn, 75% Fe, and a bio NPK consortium. Similar results were observed with treatments T_5, T_6, T_7, T_8, and T_9 in terms of grain yield. Straw yield was comparable among all treatments except T_2. Application of either Zn or Fe with the bio-NPK consortium, or the combined use of 100% Zn and Fe without the consortium, showed similar effectiveness to 75% Zn and 75% Fe with the consortium.

In a study by Sahu *et al*. (2022) [10] at IGKV, Chattisgarh, foliar spray of nano urea significantly increased rice productivity. The highest grain yield was achieved using 75% of recommended dose of nutrients (RDN) with two foliar sprays of nano urea (AT and PI), which was on par with 50% RDN with the same foliar spray treatment, and 100% RDN with the same foliar spray treatment.

Mishra *et al*. (2020) [7] found that INM practices had a significant impact on yield-related traits, with maximum grain and straw yields recorded in the 100% RDF treatment, followed by 75% RDF with 25% N supplied through dhaincha incorporation. However, the 1000-grains weight was not significantly affected by the treatments.

Table 1: Yield attributes & yield of rice effected by different nutrient management practices

Treatment	Panicle length (cm)	Effective tiller m-2	Filled grains Panicle-1	1000- seed weight(g)	Grain yield (t/ha)	Straw yield (t/ha)
T_1	20.26	191	83.66	18.42	2.43	4.45
T_2	22.24	306	112.20	18.54	4.06	5.23
T_3	22.37	310	114.66	18.73	4.32	5.33
T_4	21.97	316	119.00	18.82	4.40	5.58
T_5	22.07	311	116.00	18.65	4.22	5.47
T_6	23.24	321	120.66	19.99	4.89	5.80
T_7	22.62	314	115.33	19.32	4.30	5.29
T_8	23.48	326	123.33	20.17	5.25	5.84
S.Em (±)	0.33	2.88	4.58	0.02	0.27	0.16
CD at 5%	1.02	8.82	14.04	0.09	0.38	0.5

T_1-Control (No fertilizer), T_2-NPK @ 80:40:40 kg/ha (RDF), T_3 -NPK @ 80:40:40 kg/ha +leaf manure (subabul) @ 2.5t/ha, T_4 - NPK @ 80:40:40 kg/ha + Vermicompost @ 2 t/ha, T_5-NPK @ 80:40:40 kg/ha+ FYM @5 t/ha, T_6-NPK @ 80:40:40 kg /ha+ ZnSO4 @ 25 kg/ha, T_7 - NPK @ 125% of RDF, T_8-NPK @ 125% of RDF +FYM @ 5 t/ha +Vermicompost @ 2 t/ha.

Karmakar *et al*., (2022) reported that the panicle length of rice varied from 20.26 to 23.48 cm with a variation of 17.04% over control. The maximum panicle length (23.48 cm) was achieved with the combined application NPK @125% RDF (100:50:50 kg/ha) +FYM@5 t/ha+ Vermicompost @ 2t/ha which was at par with NPK@125% RDF (100:50:50kg/ha). Effective tillers/m2 (326) was found significant obtaining best result NPK@125% RDF (100:50:50 kg/ha)
+FYM@5 t/ha+ Vermicompost @ 2t/ha which was followed by NPK @ 80:40:40 kg/ ha+ ZnSO4 @ 25 kg/ ha. The filled grain/panicle of transplanted Kharif rice was significantly influenced by integrated nutrient management practices. However, the number of filled grains panicle-1 recording the best value inNPK@125% of RDF (100:50:50 kg/ha) +FYM @ 5 t/ha +Vermicompost@2 t/ha was significantly superior (123.33). The lowest number of filled grain/panicles was recorded in the control plot (83.66). The grain, straw and 1000-seed weight were 5.25 kg/ha, 5.84 kg/ha and 20.17 gm with the application of NPK@125% of RDF (100:50:50 kg/ha) +FYM@5 t/ha+ vermicompost@2t/ha.

Joshi *et al*., (2019) [3] reported that Zinc application has a noticeable effect on panicle number, panicle length, panicle weight, number of filled grains panicle-1 and 1000 grain weight. Maximum value of yield attributes was found with 5 kg ha-1 Zn; however, it was similar with highest zinc level (7.5 kg ha^{-1}). The grain yield with the application of 75% Recommended dose of Nitrogen through Inorganic source along with Recommended dose of Nitrogen through organic source was greater than nitrogen dosage combinations. Table 2.

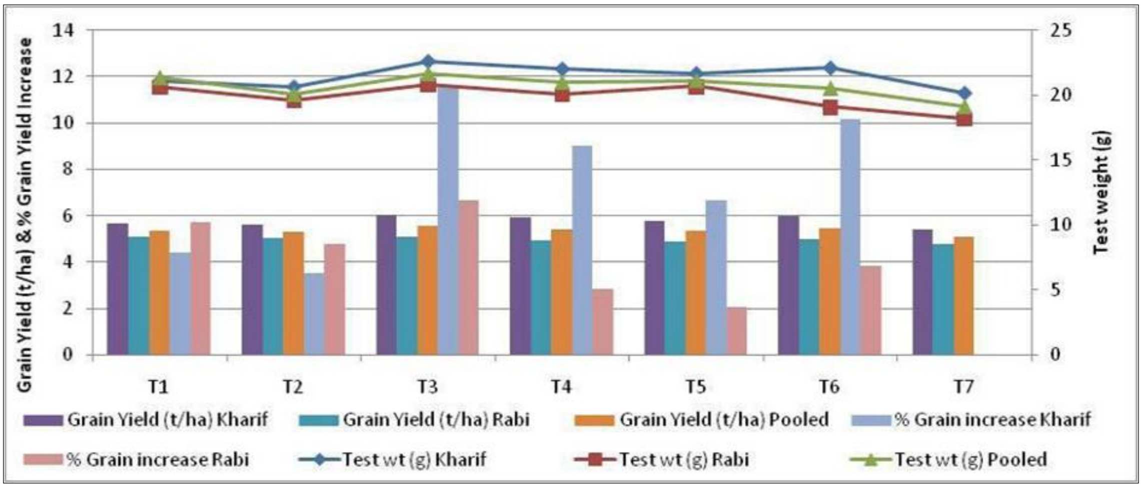


Fig 2: Effect of seaweed liquid biostimulants on yield of rice

T_1- LBS6@ 1ml/lts (1spray at seedling transplantation +2 spray (30 and 60 DAS) + Recommended Dose of Fertilizer); T_2 - LBS6@ 1ml/lts (1 spray transplantation + 2 spray (30 and 60 DAS 20% lower Recommended Dose of Fertilizer); T_3 - LBS6_S ml/lts (1 spray at seedling transplantation+ 2 spray (30 and 60DAT); T_4 - LBS8 @ 1 ml/ lts 1 spray at seedling transplantation+ 2 spray (30 and 60 DAT); T_5 - LBS9 1Ml/lts (1 Spay at seedling transplantation + 2 spray (30 and 60 DAT); T_6 - LBS10 1 ml/lts (1 spray at seedling transplantation + 2 spray (30 and 60 DAT); T_7 - Recommended Dose of Fertilizer (100 per cent)

Arun *et al*., (2019) from IIRR, Telangana studied about the effect of seaweed liquid biostimulants on yield of rice and reported that the highest test weight was recorded in LBS6_S (T_3) (21.68 g) followed by LBS6 (21.4 g) (pooled data). Application of seaweed bio-stimulants resulted in yield varying from 5.31 t/ha to 5.58 t/ha (pooled) and was significantly higher than recommended dosage. Grain yield increment was 3.51 to 11.62 % in *kharif* and 2.05% to 6.65% during *rabi* season over recommended dose of fertilizer.

Kumar *et al*., (2012) [5] reported that the application of 100% recommended NP(120:60 kg ha^{-1} of N: P2O5) with green manures recorded higher number of effective tillers, height, 1000- grain weight and yield of rice than recommended NP or control (without NP and organic sources). Application of organic sources with 75% recommended NP produced similar grain yield to that obtained with 100% recommended NP treatment. Green manuring with 100% NP produced significantly higher grain yield of rice (6.42 t ha^{-1}) than 100% NP (5.31 t/ha and 100% NP with wheat residue (6.02 t/ha).

Table 3: Effect of nutrient dosages and bio-organics on yield of rice

Treatments	No of panicles m^{-2}	1000 grain wt. (g)	Grain yield (q ha^{-1})	Straw yield (q ha-1)
NPK levels (% RDF-120:60:60 kg ha^{-1} of N: P2O5: K2O)				
0	253.07	19.80	39.67	59.50
50	287.52	21.55	47.44	71.17
75	298.97	22.28	50.03	76.02
100	312.36	22.94	52.28	79.19
S.Em±	2.98	0.23	0.75	1.13
CD (*p*=0.05)	8.74	0.69	2.22	3.32
Bio-organics				
FYM	279.05	20.87	44.92	67.72
FYM + BGA	188.57	21.66	47.46	71.55
FYM+BGA+PSB	296.23	22.41	49.69	75.14
S.Em±	2.58	0.20	0.65	0.98
CD (*p*=0.05)	7.57	0.60	1.92	2.88
Interaction	NS	NS	NS	NS

FYM @ 5t ha^{-1}

Nanda *et al*., (2016) [9] studied the effect of Bio-organics and NPK levels on performance of rice and reported that the NPK levels exerted significant effect on number of panicles m-2, 1000 grain weight, grain and straw yield of rice. The maximum number of panicles m-2, 1000 grain weight, grain and straw yields were recorded with 100% RDF where increasing NPK levels significantly increased number of panicles m^{-2} and grain yield up to 100% RDF, while all the NPK levels differed significantly among themselves, except 100 and 75% RDF for 1000 grain weight and straw yield.

Sharma *et al*., (2018) [11] reported that application of nutrient combinations comprising of 50% recommended NPK-**(**120:60:60 kg ha^{-1}) through fertilizers and 50% recommended N through FYM and 5 kg zinc resulted in better productivity and profitability of rice.

Conclusion

A holistic approach that integrates traditional knowledge with modern scientific insights is imperative for optimizing nutrient utilization, minimizing environmental impacts, and ensuring food security.

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