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Effect of Different Planting Geometry and Nitrogen Levels on Quality, Nutrient Uptake and Economics of Rice Crop (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

Planting geometry also interacts significantly with nitrogen management, as plant density influences nutrient uptake efficiency and resource utilisation. A field experiment was conducted during kharif 2020 at the research farm of the College of Agriculture, Kaul (Kaithal), CCS Haryana Agricultural University, Hisar, to evaluate the effect of planting geometry and nitrogen levels on quality, nutrient uptake and economics of transplanted rice (*Oryza sativa* L.) variety HKR-128. The experiment was laid out in a factorial randomised block design with three planting geometries (20 × 15 cm, 20 × 20 cm and random transplanting) in main plots and five nitrogen levels (0, 50, 100, 150 and 200 kg N ha^{-1}) in sub-plots, replicated thrice. The experimental data were analysed statistically using analysis of variance (ANOVA) using the OPSTAT software developed by CCS Haryana Agricultural University. Results indicated that planting geometry had no significant effect

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on hulling recovery, milling recovery, head rice recovery or protein content. However, nutrient uptake (N, P and K) by grain and straw was significantly higher under 20 × 15 cm spacing. Nitrogen application significantly improved grain quality parameters and nutrient uptake, with the highest values recorded at 200 kg N ha^{-1}, statistically at par with 150 kg N ha^{-1}. Economic analysis revealed that maximum net returns and benefit-to-cost ratio were obtained with 150 kg N ha^{-1}, while planting geometry of 20 × 15 cm resulted in higher profitability compared to other spacings. The study concludes that 20 × 15 cm spacing combined with 150 kg N ha^{-1} is most economical and productive for transplanted rice under the agro-climatic conditions of Haryana.

Keywords: Rice; nutrient uptake; quality parameter; spacing; nitrogen levels.

1. Introduction

Rice (*Oryza sativa* L.) is one of the most important staple food crops in India and the second most widely consumed cereal in the world after wheat. It serves as a major source of dietary energy for nearly 40% of the global population, although it occupies only about 11% of the total cultivated agricultural area (Ghosh and Bhatt, 1998; Nikhil et al., 2026). More than 90% of global rice production and consumption is concentrated in Asia, where approximately three billion people derive nearly two-thirds of their caloric intake from rice (Raghuram and Asopa, 2008).

In India, rice is cultivated over an area of approximately 44 million hectares with a production of about 118.9 million tonnes (Anonymous, 2020a). India ranks first in the world in terms of rice acreage; however, its average productivity (2.7 t ha^{-1}) remains significantly lower than that of countries such as China (>6.0 t ha^{-1}) and the global average (4.0 t ha^{-1}). Rice contributes nearly 43% of total food grain production and about 55% of total cereal production in the country.

The relatively low productivity and profitability of rice cultivation in India can be attributed to several constraints, including climatic variability, low nutrient use efficiency, poor crop management practices and continued reliance on traditional cultivation methods (Balla & Goswami, 2022). Meeting the growing food demand of an increasing population, projected to reach 8.5 billion by 2025, necessitates a sustained annual increase of 2–3% in rice production within limited land resources.

Recent gains in rice productivity have largely been achieved through the introduction of high-yielding varieties, expansion of irrigated areas and increased use of chemical fertilisers. However, achieving sustainable productivity growth requires efficient resource management and adoption of cost-effective agronomic practices, including balanced fertilisation and optimised plant spacing (Haque and Haque, 2016).

Spacing is an agronomic practice that warrants careful consideration. The optimal inter- and intra-row spacing is influenced by several factors, including the crop variety, soil moisture conditions, and the degree of weed infestation (Stansluos et al., 2024).

Nitrogen is a key limiting nutrient in rice production, playing a critical role in vegetative growth, yield formation and grain quality.

It is a fundamental component of both proteins and chlorophyll, facilitating vegetative growth and imparting the characteristic green pigmentation in plants. Conversely, nitrogen (N) deficiency adversely affects crop productivity (Kamuruzzaman et al., 2024).

However, its efficiency is highly dependent on management practices. Excess application of nitrogen may lead to excessive vegetative growth, lodging and increased pest incidence, ultimately reducing yield. Conversely, nitrogen deficiency results in poor crop growth and reduced productivity. Therefore, the application of nitrogen in appropriate amounts is essential for achieving optimum yield and quality (Zhou et al., 2022).

Planting geometry also interacts significantly with nitrogen management, as plant density influences nutrient uptake efficiency and resource utilisation. Inappropriate spacing may lead to either competition for nutrients or inefficient fertiliser use. Farmers often compensate for suboptimal plant density under traditional transplanting systems by applying higher doses of nitrogen fertilisers, which may not necessarily improve productivity and can increase production costs.

Hence, there is a need to optimise planting geometry in combination with nitrogen levels to enhance productivity, nutrient use efficiency and economic returns in rice cultivation under prevailing agro-ecological conditions.

2. Materials and Method

A field experiment was undertaken during the kharif season of 2020 at the research farm of the College of Agriculture, Kaul (Kaithal), CCS Haryana Agricultural University, Hisar. The experimental soil was sandy clay loam in texture, with medium organic carbon content (0.53%), low available nitrogen (174 kg ha^{-1}), medium available phosphorus (30 kg ha^{-1}), and high available potassium (382 kg ha^{-1}). The soil was slightly alkaline in reaction (pH 8.2) with an electrical conductivity of 0.27 dS m^{-1}.

Rice variety HKR-128 was used in the study. The experiment was laid out in a factorial randomised block design (RBD) with three replications. Treatments consisted of three planting geometries, viz., 20 × 15 cm, 20 × 20 cm, and random transplanting, assigned to main plots, and five nitrogen levels, viz. 0, 50, 100, 150 and 200 kg N ha^{-1}, assigned to sub-plots.

2.1 Quality Parameters

The process of removing hull or husk by a huller is called hulling. A sample of 60 g was taken to compute the hulling recovery. The hulling recovery was calculated by the following formula.

$$\text{Hulling \%} = \frac{\text{Weight of hulled rice (g)}}{\text{Weight of paddy (g)}} \times 100$$

Removal of the bran and a part of the aleuronic layer from the hulled rice is called milling. Milling recovery was calculated by the following formula.

$$\text{Milling \%} = \frac{\text{Weight of milled rice (g)}}{\text{Weight of paddy (g)}} \times 100$$

Kernels of rice with more than two-thirds of the length of the whole grain (after milling) were weighed. The head rice recovery was calculated by the following formula.

$$\text{Head rice recovery \%} = \frac{\text{Weight of head rice (g)}}{\text{Weight of paddy (g)}} \times 100$$

The content of protein was computed by multiplying the per cent concentration of nitrogen in grains by a factor of 6.25.

2.2 Nutrient Studies

Grain and straw samples were oven-dried and finely ground prior to digestion using a di-acid mixture of H_2SO_4 and $HClO_4$ for nitrogen estimation via the Nessler's Reagent Method (Linder, 1944). For phosphorus and potassium determination, samples were digested with a di-acid mixture of HNO_3 and $HClO_4$, with phosphorus quantified using the Vanado-molybdo phosphoric yellow colour method (Koenig and Johnson, 1942) and potassium determined through flame photometry (Piper, 1966), respectively.

N, P and K uptake in grain and straw were obtained in kg/ha by using the following formulae:

$$\text{Nutrient uptake by grain (kg/ha)} = \frac{\text{Nutrient content in grain (\%) x Grain yield (kg /ha)}}{100}$$

$$\text{Nutrient uptake by straw (kg/ha)} = \frac{\text{Nutrient content in straw (\%) x Straw yield (kg /ha)}}{100}$$

2.3 Economics Studies

Gross return of all treatments was computed by the market rates prevailing at the time of marketing of the produce. The rate was Rs 1868/quintal (100 kg) for grain.

The cost of production was calculated based on the market price of the inputs used during the crop season. The net return was calculated by using the following formula.

Net return (Rs/ha) = Gross return (Rs/ha) - Cost of cultivation (Rs/ha)

Under every treatment, B: C was computed to reveal the economic viability by using the following formula.

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

Finally, the data were analysed using the software "OPSTAT" floated / available on the official website of CCS Haryana Agricultural University, Hisar, for ready use.

3. Results and Discussion

3.1 Quality Parameters

Hulling recovery, milling recovery and head rice recovery were not significantly influenced by either planting geometry or nitrogen levels. However, numerically higher values of these quality parameters were observed under closer spacing (20 × 15 cm) combined with 200 kg N ha^{-1}. In contrast, Gautam *et al*. (2008) reported significant variation in rice quality parameters with different planting densities and nitrogen levels, which differs from the present findings.

Protein content in grain was significantly affected by nitrogen levels, whereas planting geometry had no significant effect. The highest protein content was recorded at 200 kg N ha^{-1}, followed closely by 150 kg N ha^{-1} and 100 kg N ha^{-1} treatments. These results are in agreement with Gautam *et al*. (2008), who also reported an increase in grain protein content with higher nitrogen application due to enhanced nitrogen assimilation in rice plants.

3.2 Nutrient Studies

The N, P, and K content in both grain and straw was not significantly influenced by planting geometry. However, nutrient content increased significantly with increasing nitrogen levels, with higher values recorded under elevated nitrogen application compared to lower doses. This improvement in nutrient concentration may be attributed to enhanced nutrient absorption and assimilation by the crop under higher nitrogen availability. Similar findings were reported by Kabat and Satapathy (2011), who observed improved nutrient content in rice with increased nitrogen application.

Nutrient uptake of N, P, and K was significantly affected by both planting geometry and nitrogen levels. Uptake increased progressively with higher yield levels, indicating a strong relationship between biomass production and nutrient absorption. The highest nutrient uptake was recorded under closer spacing (20 × 15 cm) combined with 200 kg N ha^{-1}, which can be attributed to higher plant population and greater overall biomass production. These results are in agreement with Bommayasamy *et al*. (2010), Bezbaruha *et al*. (2011), and Negalur *et al*. (2016), who also reported increased nutrient uptake under higher plant density due to improved nutrient utilisation and crop growth.

3.3 Soil Nutrient Status after Harvest

The available nitrogen, phosphorus (P_2O_5) and potassium (K_2O) in soil after harvest were significantly influenced by both planting geometry and nitrogen levels.

Among planting geometries, higher residual soil fertility was recorded under random transplanting, which showed the highest available nitrogen (171.9 kg ha^{-1}), phosphorus (27.9 kg ha^{-1}), and potassium (376.9 kg ha^{-1}), followed by 20 × 20 cm spacing. The lowest residual nutrient status was observed under closer spacing of 20 × 15 cm, indicating greater nutrient uptake and removal by the crop under higher plant density. However, differences were statistically significant as indicated by CD values.

With respect to nitrogen levels, available nitrogen in soil increased progressively with increasing nitrogen application and was highest at 200 kg N ha^{-1} (177.4 kg ha^{-1}). In contrast, available phosphorus and potassium decreased with increasing nitrogen levels, with the lowest values recorded at 200 kg N ha^{-1} (23.7 kg ha^{-1} P_2O_5 and 368.4 kg ha^{-1} K_2O, respectively). This trend suggests higher nutrient uptake and depletion from soil under higher nitrogen application rates.

Overall, closer spacing and higher nitrogen levels resulted in greater nutrient uptake by the crop, leading to reduced residual soil fertility compared to wider spacing and lower nitrogen treatments.

Table 1. Quality parameters of transplanted rice as affected by plantinggeometry and nitrogen levels

Treatments	Quality parameters			
Planting geometry	**Hulling recovery (%)**	**Milling recovery (%)**	**Head rice recovery (%)**	**Protein content ingrain (%)**
P_1 (20 cm x 15 cm)	79.0	69.3	52.0	7.3
P_2 (20 cm x 20 cm)	78.4	69.0	50.7	6.9
P_3 (Random)	78.4	68.5	48.6	6.7
SE(m) ±	0.1	0.1	0.1	0.3
CD (P=0.05)	NS	NS	NS	NS
Nitrogen levels (kg ha^{-1})				
N_1=0	78.3	68.8	49.8	5.9
N_2=50	78.5	69.0	50.2	6.7
N_3=100	78.6	69.1	50.7	6.7
N_4=150	78.7	69.2	50.7	7.7
N_5=200	78.7	69.2	50.8	7.8
SE(m) ±	0.1	0.2	0.2	0.4
CD (P=0.05)	NS	NS	NS	1.1

Table 2. Nutrient (N, P and K) content in transplanted rice in grain andstraw as affected by planting geometry and nitrogen levels

Treatments	N, P and K content in grain (%)			N, P and K content in straw (%)		
Planting geometry	**N**	**P**	**K**	**N**	**P**	**K**
P_1 (20 cm x 15 cm)	1.17	0.18	0.45	0.56	0.16	1.38
P_2 (20 cm x 20 cm)	1.10	0.17	0.44	0.55	0.15	1.32
P_3 (Random)	1.08	0.16	0.43	0.53	0.14	1.31
SE(m) ±	0.05	0.01	0.02	0.01	0.01	0.02
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Nitrogen levels (kg ha^{-1})						
N_1=0	0.95	0.12	0.39	0.49	0.10	1.07
N_2=50	1.07	0.14	0.42	0.53	0.13	1.25
N_3=100	1.07	0.16	0.43	0.55	0.14	1.26
N_4=150	1.24	0.20	0.48	0.58	0.18	1.55
N_5=200	1.25	0.22	0.49	0.60	0.19	1.56
SE(m) ±	0.03	0.01	0.02	0.01	0.01	0.02
CD (P=0.05)	0.08	0.02	0.04	0.02	0.02	0.06

3.4 Economics Studies

The cost of cultivation under 20 × 15 cm planting geometry was 9.8% higher than that of random transplanting due to increased input requirements associated with a higher plant population. However, this treatment recorded higher gross returns, net returns, and benefit: cost (B: C) ratio compared to the other planting geometries. The maximum gross returns (₹1,58,632 ha⁻¹), net returns (₹41,432 ha⁻¹) and B: C ratio (1.35) were obtained under 20 × 15 cm spacing. Similar findings were reported by Luikham *et al*. (2008), Jena et al. (2010), and Mohan and Pillai (2014), who observed improved economic returns under closer planting geometry due to higher productivity.

Among nitrogen levels, the maximum cost of cultivation (₹1,11,812 ha⁻¹) was recorded with 200 kg N ha⁻¹, while the lowest cost (₹1,09,680 ha⁻¹) was observed in the control (0 kg N ha⁻¹). The highest gross returns (₹1,61,337 ha⁻¹) were obtained with 200 kg N ha⁻¹, whereas the lowest (₹1,11,543 ha⁻¹) was recorded under the control treatment. However, the maximum net returns (₹49,665 ha⁻¹) and B: C ratio (1.35) were achieved at 150 kg N ha⁻¹, indicating it as the most economically viable nitrogen level. These results are in agreement with Philip et al. (2012), Maqsood *et al*. (2013) and Yadav et al. (2016), who also reported optimum economic returns at intermediate nitrogen levels due to balanced crop growth and efficient resource utilisation.

Table 3. Nutrient (N, P and K) uptake in transplanted rice by grain andstraw as affected by planting geometry and nitrogen levels

Treatments	N, P and K uptake by grain (kg/ha)			N, P and K uptake by straw (kg/ha)		
Planting geometry	**N**	**P**	**K**	**N**	**P**	**K**
P_1 (20 cm x 15 cm)	98.6	15.2	38.4	57.9	16.2	142.8
P_2 (20 cm x 20 cm)	86.5	13.5	34.5	51.8	14.2	126.0
P_3 (Random)	76.9	11.5	30.9	44.1	11.8	109.1
SE(m) ±	4.1	0.5	0.4	0.8	0.5	2.3
CD (P=0.05)	11.9	1.4	1.2	2.3	1.4	6.7
Nitrogen levels (kg ha^{-1})						
N_1=0	57.5	7.5	23.8	37.7	7.8	82.2
N_2=50	77.8	10.5	30.3	48.2	11.8	113.4
N_3=100	86.8	12.8	34.7	52.7	13.3	120.7
N_4=150	107.0	17.5	41.4	57.1	17.8	154.3
N_5=200	107.5	18.7	42.7	60.6	19.7	159.1
SE(m) ±	5.3	0.6	0.5	1.0	0.6	2.9
CD (P=0.05)	15.3	1.8	1.6	2.9	1.9	8.7

Table 4. Nutrient (N, P and K) status of soil after harvesting of transplanted riceas affected by planting geometry and nitrogen levels

Treatments	Status of soil after harvest (kg ha^{-1})		
Planting geometry	**AvailableN**	**AvailableP_2O_5**	**AvailableK_2O**
P_1 (20 cm x 15 cm)	157.9	24.3	368.5
P_2 (20 cm x 20 cm)	163.9	26.4	373.1
P_3 (Random)	171.9	27.9	376.9
SE(m) ±	1.4	0.5	1.3
CD (P=0.05)	4.2	1.5	3.9
Nitrogen levels (kg ha^{-1})			
N_1=0	150.7	28.6	377.9
N_2=50	158.1	27.6	375.3
N_3=100	165.3	26.6	373.3
N_4=150	171.2	24.6	369.3
N_5=200	177.4	23.7	368.4
SE(m) ±	1.8	0.7	1.7
CD (P=0.05)	5.4	2.0	5.1

Table 5. Economics of transplanted rice as affected by planting geometryand nitrogen levels

Treatments	Economics			
Planting geometry	**Cost of cultivation (Rs/ha)**	**Gross Returns (Rs/ha)**	**Net returns (Rs/ha)**	**B: C**
P_1 (20 cm x 15 cm)	117200	158632	41432	1.35
P_2 (20 cm x 20 cm)	111400	142961	31561	1.28
P_3 (Random)	106740	130995	24255	1.23
Nitrogen levels (kg ha^{-1})				
N_1=0	109680	111543	1863	1.02
N_2=50	110213	135757	25544	1.23
N_3=100	110746	151397	40651	1.37
N_4=150	111279	160944	49665	1.45
N_5=200	111812	161337	49525	1.44

4. Conclusion

Hulling recovery, milling recovery and head rice recovery were not significantly influenced by either planting geometry or nitrogen levels. However, the highest protein content was recorded under 200 kg N ha^{-1}.

The N, P, and K content in grain and straw showed no significant variation with different planting geometries, whereas nitrogen levels significantly affected these parameters, with higher values observed under increased nitrogen application compared to lower doses. The maximum nutrient uptake (N, P, and K) was recorded under 20 × 15 cm spacing combined with 200 kg N ha^{-1}, indicating superior nutrient utilisation under higher plant density and nitrogen supply.

Economically, higher gross returns, net returns, and benefit-to-cost ratio were obtained under 20 × 15 cm planting geometry. Among nitrogen levels, the maximum net returns (₹49,665 ha^{-1}) and B: C ratio (1.35) were recorded at 150 kg N ha^{-1}, indicating it as the most economically efficient treatment.

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Competing Interests

Authors have declared that no competing interests exist.

References

Anonymous (2020a). Rice as a crop-ricepedia// ricepeida.org

Balla, J., & Goswami, K. (2022). Understanding the constraints and reasons to adopt natural farming-a study on rice growing farmers of Andhra Pradesh, India. *International Journal of Agricultural Sustainability*, *20*(6), 1209-1224. https://www.tandfonline.com/doi/abs/10.1080/14735903.2022.2070340

Bezbaruha, R., Sharma, R.C. and Banik, P. (2011). Effect of nutrient management and planting geometry on productivity of hybrid rice *(Oryza sativa* L.) cultivars. *American Journal of Plant Sciences*, 2(3): 297-302. https://doi.org/10.4236/ajps.2011.23033

Bommayasamy, N., Ravisankar, N. and Subramani, T. (2010). Influence of non-monetary inputs on growth and yield of rice (*Oryza sativa* L.) under system of rice intensification (SRI). *Indian Journal of Agronomy*, 55(2): 95-99. https://doi.org/10.59797/ija.v55i2.4735

Gautam, A. K., Kumar, D., Shivay, Y. S., & Mishra, B. N. (2008). Influence of nitrogen levels and plant spacing on growth, productivity and quality of two inbred varieties and a hybrid of aromatic rice. Archives of Agronomy and Soil Science, 54(5), 515-532. https://doi.org/10.1080/03650340802283470

Ghosh, B. C., & Bhat, R. (1998). Environmental hazards of nitrogen loading in wetland rice fields. Environmental Pollution, 102(S1), 123-126. https://doi.org/10.1016/S0269-7491(98)80024-9

Haque, M.A. and Haque, M.M. (2016). Growth, yield and nitrogen use efficiency of new rice variety under variable nitrogen rates. *American Journal of Plant Sciences*, 7(3): 612. https://doi.org/10.4236/ajps.2016.73054

Jena, S., Poonam, A., & Nayak, B. C. (2010). Response of hybrid rice to time of planting and plant density. *Oryza*, *47*(1), 48-52. https://indianjournals.com/api/article-view/oryza-47-1-009

Kabat, B., & Satapathy, M. R. (2011). Effect of planting date and nitrogen level on grain yield of hybrid rice. Oryza, 48(2), 186-187. https://arrworyza.com/AdminPanel/download/Effect%20of%20planting%20date%20and%20nitrogen%20level%20on%20grain%20yield%20of%20hybrid%20rice.pdf

Kamuruzzaman, M., Rees, R. M., Islam, M. T., Drewer, J., Sutton, M., Bhatia, A., Bealey, W. J., & Hasan, M. M. (2024). Improving Nitrogen Fertilizer Management for Yield and N Use Efficiency in Wetland Rice Cultivation in Bangladesh. *Agronomy*, *14*(12), 2758. https://doi.org/10.3390/agronomy14122758

Koenig, R. A., & Johnson, C. R. (1942). Colorimetric determination of phosphorus in biological materials. *Industrial & Engineering Chemistry Analytical Edition, 14(2), 155-156.* https://doi.org/10.1021/i560102a026

Lindner, R. C. (1944). Rapid analytical methods for some of the more common inorganic constituents of plant tissues. Plant Physiology, 19(1), 76-89. https://doi.org/10.1104/pp.19.1.76

Luikham, E., Yamtong, K., & Anal, P. S. M. (2008). Effect of planting geometry and nitrogen levels on productivity of black aromatic rice (Oryza sativa L.) under rainfed conditions. Agricultural Science Digest, 28(2), 153-154. https://indianjournals.com/api/article-view/asd-28-2-025

Maqsood, M., Shehzad, A., Ali, S.N.A. and Iqbal, M. (2013). Rice cultures and nitrogen rate effects on yield and quality of rice (*Oryza sativa* L.). *Turkish Journal of Agriculture and Forestry,*37: 665-673. https://doi.org/10.3906/tar-1203-5

Mohan, S.S. and Pillai, P.S. (2014). Effect of spacing, seedling density and nutrient management on the performance of hybrid rice (*Oryza sativa* L.) in Southern Kerala. *Current Advances in Agricultural Sciences*,6(2): 193-195.

Negalur, R.B., Halepyati, A.S., Reddy, B.G.M. and Narayanarao, K. (2016). Nutrient uptake and available soil nutrients in transplanted rice as influenced by land preparation and planting geometry. *Green Farming*,7(5): 1116-1120.

Nikhil, P. G., Bindu, M. R., Niji, M. S., & Shirsat, M. S. (2026). Evaluation of Rice (*Oryza sativa* L.) Genotypes for Iron Toxicity Tolerance under Hydroponic Conditions. *Journal of Advances in Biology & Biotechnology*, *29*(4), 894–904. https://doi.org/10.9734/jabb/2026/v29i43848

Philip, P., Jha, G., Singh, P. and Singh, S. (2012). Effect of different nitrogen levels on newly developed rice varieties under transplanted condition. *Agricultural Science Digest*,32(1): 75-78. https://arccjournals.com/journal/agricultural-science-digest/ARCC615

Piper, C.S. (1966). Soil and water analysis. Published by University Adelaid (Australia). Priyanka, S., Jitesh, B. and Babu, S. 2012. Aerobic rice, a new approach of rice cultivation. *International Journal of Research in Biosciences.* 1(1): 1-6.

Raghuram, G., & Asopa, V. N. (2008). Issues in infrastructure for export of rice from India (Working Paper *No. 2008-07-03). Indian* Institute of Management Ahmedabad. https://iima.ac.in/sites/default/files/rnpfiles/2008-07-03Raghuram.pdf

Stansluos, A. A. L., Öztürk, A., Türkoğlu, A., Piekutowska, M., & Niedbała, G. (2024). Planting Geometry May Be Used to Optimize Plant Density and Yields without Changing Yield Potential per Plant in Sweet Corn. *Plants*, *13*(17), 2465. https://doi.org/10.3390/plants13172465

Yadav, A.S., Ram, H. and Srivastava, D.S., (2016). Productivity of hybrid rice (*Oryza sativa* L.) as affected by nitrogen levels and plant geometry under transplanted situation in eastern Uttar Pradesh. *New Agriculturist*, 27(1): 125-134.

Zhou, W., Yan, F., Chen, Y., & Ren, W. (2022). Optimized nitrogen application increases rice yield by improving the quality of tillers. *Plant Production Science*, *25*(3), 311-319. https://www.tandfonline.com/doi/abs/10.1080/1343943X.2022.2061538

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