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Ajay Thorat
Department of Agronomy, College of Agriculture, DBSKKV, Maharashtra, India

Dr. Amol Dahiphale
Department of Agronomy, College of Agriculture, DBSKKV, Maharashtra, India

Dr. Prashant Bodake
Department of Agronomy, College of Agriculture, DBSKKV, Maharashtra, India

Dr. Namdev Mhaskar
AICRP on IFS, RARS, DBSKKV, Maharashtra, India

Dr. Nandkishor Meshram
AICRP on Agroforestry, DBSKKV, Maharashtra, India

Dr. Jeevan Kadam
Department of Plant Pathology, College of Agriculture, DBSKKV, Maharashtra, India

Dr. Shivram Bhagat
Chief Agronomist, AICRP IFS RARS, DBSKKV, Maharashtra, India.

Onkar Khavanekar
Department of Agronomy, College of Agriculture, DBSKKV, Maharashtra, India

Mrunal Parve
Department of Agronomy, College of Agriculture, DBSKKV, Maharashtra, India

Akshay Chavan
Department of Soil Science and Agricultural Chemistry, College of Agriculture, DBSKKV, Maharashtra, India

Filip Gavit
Department of Agronomy, College of Agriculture, DBSKKV, Maharashtra, India

Corresponding Author:
Ajay Thorat
Department of Agronomy, College of Agriculture, DBSKKV, Maharashtra, India

Impact of organic, inorganic, and integrated production systems on growth and yield of rice (*Oryza sativa* L)

Ajay Thorat, Dr. Amol Dahiphale, Dr. Prashant Bodake, Dr. Namdev Mhaskar, Dr. Nandkishor Meshram, Dr. Jeevan Kadam, Dr. Shivram Bhagat, Onkar Khavanekar, Mrunal Parve, Akshay Chavan and Filip Gavit

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Abstract
A field experiment was conducted during the *Kharif* season of 2022 at the Modern Agricultural Experiment Farm, Regional Agricultural Research Station in Karjat, Dist. Raigad, to investigate the influence of organic, inorganic, and integrated production systems on the growth and yield of rice (*Oryza sativa* L). The experiment was laid out with randomized block design with six treatments, including T_1-100% Organic N, T_2-50% Organic N + Beejamrit, Jeevamrit, and Ghanajeevamrit, T_3-100% Inorganic N, P_2O_5, and K_2O, T_4-Farmers practice, T_5-50% organic N + 50% Inorganic N, P_2O_5, and K_2O, andT_6- 25% Organic N + 25% Inorganic N, P_2O_5, and K_2O + Beejamrit, Jeevamrit, and Beejamrit, each replicated four times. The application of fertilizers and other agricultural practices for rice was tailored to each treatment. The experimental results indicated a significant impact of various nutrient sources on the growth and yield of rice. Treatment T_5 (50% organic N + 50% Inorganic N, P_2O_5, and K_2O) exhibited significantly higher growth attributes, including plant height (cm), number of functional leaves hill^{-1}, number of functional tillers hill^{-1}, and dry matter accumulation (g) hill^{-1}. Notably, T_5 also recorded a superior yield of rice. However, treatment T_3 (100% Inorganic N, P_2O_5, and K_2O) demonstrated comparable results to T_5, emphasizing its effectiveness in enhancing rice yield. The integrated approach of T_5, combining organic and inorganic components, demonstrated significant advantages in promoting both the growth and yield of rice under the specified experimental conditions.

Keywords: Rice, integrated nutrient management, organic

1. Introduction
Rice, scientifically known as *Oryza sativa* L., originates from Asia and is predominantly cultivated in South East Asia and India. Often considered as the "global grain," it holds a pivotal position as a fundamental food source for humanity. Notably, rice has received two United Nations awards, recognizing its unparalleled contribution to global food security. Despite its non-tropical origins, rice thrives in moist and humid climates. This versatile crop assumes a crucial role in the diets of at least 33 developing nations, constituting 27% of dietary calories, 20% of dietary protein, and 3% of dietary fat (Kennedy *et al.*, 2020) [6]. Following maize, rice stands as the world's second most vital cereal.
The Asia-Pacific region serves as the epicenter for rice production and consumption, accounting for over 90% of the global output. China, topping the charts, contributed 147 million tons to the global production of approximately 503.27 million tons. India follows closely, producing 124 million tons annually (Anonymous, 2022a) [1]. India, a cornerstone of rice cultivation, holds this grain as one of its most critical cereal crops, serving as a primary dietary staple for over half its population and wielding significant influence in the country's economy. Its adaptability allows cultivation across various climatic zones, covering an extensive 49.706 million hectares in India. Uttar Pradesh claims the largest area under cultivation at 0.57 million hectares, trailed by West Bengal and Chhattisgarh (Anonymous, 2022b) [2]. Constituting 46% of all cereal production and 43% of total food grain production in India, rice emerges as a key income source for rural communities.

Beyond its nutritional value, rice boasts therapeutic benefits and serves as a raw material for various byproducts, including beverages, snacks, and oils (Mahajan *et al*., 2017) [9].

2. Material and Methods

A present study was conducted during the *kharif* season of 2022 at the Modern Agricultural Experiment Farm within the Regional Agricultural Research Station situated at Karjat, District Raigad (M.S.). Geographically, experimental plot no. 6 at Modern Agricultural Experiment farm, Karjat is situated in the subtropical region at $18^0$54'49.1" N latitude and $73^0$19'31" E longitude having elevation of about 52 m above mean sea level. The experiment was laid out in a randomized block design with six treatments which were replicated four times *viz*. T_1: 100% Organic N, T_2: 50% Organic N + Beejamrit, Jeevamrit and Ghanajeevamrit, T_3: 100% Inorganic N, P_2O_5 and K_2O, T_4: Farmers practice, T_5: 50% organic N + 50% Inorganic N, P_2O_5 and K_2O, T_6: 25% Organic N + 25% Inorganic N, P_2O_5 and K_2O + Beejamrit, Jeevamrit and Beejamrit. A substantial rainfall of 3754.2 mm was recorded throughout the rice crop's growth period. The average daily sunshine duration stood at 2.67 hours. The crop was grown in soil with an organic carbon content of 11.4 g kg^{-1}, a pH level of 6.8, and an electrical conductivity measuring 0.125 dSm^{-1}.

3. Result and Discussion

3.1 Effect on growth parameters of rice

3.1.1 Plant height (cm)

The information presented in Table 1 indicates a direct relation between plant height and the crop's age, reaching its maximum at the time of harvest. The increase in plant height exhibited a consistent pattern during the early vegetative growth phase, up to 30 DAT, after which it experienced a significant surge from 30 DAT to 90 DAT. Subsequently, the rate of increase slowed down until the final harvest. Specifically, the mean plant height recorded at 30 DAT, 60 DAT, 90 DAT, and harvest for the rice crop were 15.87 cm, 38.41 cm, 75.84 cm, and 78.02 cm, respectively.

The plant height exhibited significant variations due to the application of different nutrient sources. Notably, treatment T_5 (50% organic N + 50% inorganic N, P_2O_5 and K_2O) demonstrated the highest plant height, registering values of 16.69 cm, 40.90 cm, 77.59 cm, and 80.03 cm at 30 DAT, 60 DAT, 90 DAT, and harvest, respectively. Following closely, treatment T_3 (100% inorganic N, P_2O_5 and K_2O) recorded plant heights of 16.52 cm, 40.00 cm, 76.97 cm, and 79.10 cm at the corresponding stages. The favorable impact on plant height can be attributed to the balanced supply of essential nutrients from both organic and inorganic sources. This observation aligns with the findings of Yadav *et al.* (2019) [17], Panwar *et al.* (2022) [11], and Sonamati *et al.* (2022) [14]. Integrated nutrient management practices, as highlighted by Mangaraj *et al.* (2022) [10], play a pivotal role in enhancing nutrient availability, thereby contributing to increased plant height.

3.1.2 Number of functional leaves $hill^{-1}$

The information presented in Table 2 highlights that the application of 50% organic N + 50% inorganic N, P_2O_5 and K_2O (T_5) resulted in a significantly higher number of leaves per hill, with values of 21.78, 39.68, 44.43, and 24.05 at 30 DAT, 60 DAT, 90 DAT, and harvest, respectively. Interestingly, the treatment T_3 (100% inorganic N, P_2O_5 and K_2O) demonstrated a similar leaf count and was on par with T_5. Conversely, the remaining treatments did not reach a level of statistical significance. This consistent trend was observed across the various stages of 30 DAT, 60 DAT, 90 DAT, and harvest for the rice crop.

The number of functional leaves per hill was significantly influenced by various treatments. As the crop ages, it is expected that the number of productive tillers stabilizes. The simultaneous application of multiple nutrients, particularly nitrogen, plays a crucial role in promoting vegetative growth, resulting in an augmentation of both functional tillers per hill and functional leaves per hill. This phenomenon aligns with observations made by Jiban *et al.* (2020) [4] and Singh *et al.* (2021) [13].

Table 1: Plant height of rice as influenced periodically by different treatments

Treatments	Plant height (cm)			
	30 DAT	60 DAT	90 DAT	At harvest
T_1- 100% N through organic sources	15.83	38.38	75.82	78.38
T_2- 50% organic N + beejamrit, jeevamrit and ghanajeevamrit	15.37	37.03	74.66	76.56
T_3-100% inorganic N, P_2O_5 and K_2O	16.52	40.00	76.97	79.10
T_4- Farmers practice	15.21	36.02	74.32	76.13
T_5- 50% organic N + 50% inorganic N, P_2O_5 and K_2O	16.69	40.90	77.59	80.03
T_6- 25% organic N + 25% inorganic N, P_2O_5 and K_2O + beejamrit, jeevamrit and ghanajeevamrit	15.63	38.13	75.70	77.94
S.Em. (±)	0.26	0.34	0.40	0.46
C.D. at 5%	0.80	1.02	1.21	1.39
General Mean	15.87	38.41	75.84	78.02

Table 2: Number of functional leaves $hill^{-1}$ of rice as influenced periodical by different treatments

Treatments	functional leaves $hill^{-1}$			
	30 DAT	60 DAT	90 DAT	At harvest
T_1- 100% N through organic sources	19.80	38.03	42.60	22.18
T_2- 50% organic N + beejamrit, jeevamrit and ghanajeevamrit	19.00	37.45	41.80	21.75
T_3-100% inorganic N, P_2O_5 and K_2O	20.25	39.10	43.65	23.35
T_4- Farmers practice	18.65	36.25	42.90	22.00
T_5- 50% organic N + 50% inorganic N, P_2O_5 and K_2O	21.78	39.68	44.43	24.05
T_6- 25% organic N + 25% inorganic N, P_2O_5 and K_2O + beejamrit, jeevamrit and ghanajeevamrit	19.60	37.85	42.10	21.78
S.Em. (±)	0.52	0.66	0.561	0.455
C.D. at 5%	1.56	2.00	1.690	1.373
General Mean	19.85	38.06	42.91	22.52

3.1.3 Number of functional tillers hill^{-1}
The data provided in Table 3 reveals significant variations in the number of functional tillers per hill across different treatments at 30 DAT, 60 DAT, 90 DAT, and the harvest stage of the crop. Specifically, the application of 50% organic + 50% inorganic N, P_2O_5 and K_2O (T_5) resulted in a markedly higher number of functional tillers per hill, with values of 6.73, 12.63, 13.85, and 11.90 at 30 DAT, 60 DAT, 90 DAT, and harvest, respectively. Notably, treatment T_3 (100% inorganic N, P_2O_5 and K_2O) exhibited comparable results to T_5. The simultaneous application of various nutrients, particularly nitrogen, plays a pivotal role in promoting vegetative development, thereby increasing the number of functional tillers per hill. This observation is consistent with findings reported by Jiban *et al*. (2020) [4] and Singh *et al*. (2021) [13].

Table 3: Number of functional tillers hill^{-1} of rice as influenced periodically by different treatments

Treatments	Number of functional tillers hill^{-1}			
	30 DAT	60 DAT	90 DAT	At harvest
T_1- 100% N through organic sources	6.48	11.85	13.15	11.15
T_2- 50% organic N + beejamrit, jeevamrit and ghanajeevamrit	6.38	11.38	12.65	10.95
T_3-100% inorganic N, P_2O_5 and K_2O	6.68	12.05	13.25	11.75
T_4- Farmers practice	6.08	11.30	12.60	10.80
T_5- 50% organic N + 50% inorganic N, P_2O_5 and K_2O	6.73	12.63	13.85	11.90
T_6- 25% organic N + 25% inorganic N, P_2O_5 and K_2O + beejamrit, jeevamrit and ghanajeevamrit	6.45	11.55	13.00	11.13
S.Em. (±)	0.13	0.23	0.21	0.20
C.D. at 5%	0.38	0.71	0.64	0.61
General Mean	6.50	11.79	13.08	11.28

3.1.4 Dry matter accumulation hill^{-1} (g)
The data depicted in Table 4 illustrates a consistent upward trend in dry matter accumulation per hill throughout the entire growth period, with the highest accumulation observed at the harvest stage. The rate of increase in dry matter per hill was notably rapid up to 60 DAT, followed by a more gradual increase from 60 DAT to the harvest stage. The above-ground portion of the crop played a significant role in this dry matter accumulation phenomenon. The mean dry matter accumulation per hill recorded at 30 DAT, 60 DAT, 90 DAT, and at harvest stage for the rice crop were 6.36 g, 21.06 g, 31.48 g, and 34.76 g, respectively.

The data revealed that, at 30 DAT, 60 DAT, 90 DAT, and harvest stages, treatment T_5 (50% organic N + 50% inorganic N, P_2O_5 and K_2O) recorded significantly higher dry matter accumulation per hill, measuring 7.07 g, 23.56 g, 34.08 g, and 37.48 g, respectively. Conversely, treatment T_3 (100% inorganic N, P_2O_5 and K_2O) demonstrated comparable dry matter accumulation per hill to treatment T_5, with values of 6.83 g, 22.44 g, 32.80 g, and 36.42 g at 30 DAT, 60 DAT, 90 DAT, and harvest, respectively. Jeyajothi and Durairaj (2016) [5] postulated that elevated dry matter production could be attributed to an increased availability of major nutrients facilitated by the mineralized nutrients from both organic and inorganic sources throughout the cropping period. Similar observations were reported by Kumar *et al*. (2017) [7], Singh *et al*. (2018) [12], and Takhellambam *et al*. (2019) [16].

Table 4: Dry matter accumulation hill^{-1} (g) of rice as influenced periodically by different treatments

Treatments	Dry matter accumulation (g)			
	30 DAT	60 DAT	90 DAT	At harvest
T_1- 100% N through organic sources	6.18	21.18	31.84	34.59
T_2- 50% organic N + beejamrit, jeevamrit and ghanajeevamrit	6.09	19.14	30.09	33.23
T_3-100% inorganic N, P_2O_5 and K_2O	6.83	22.44	32.80	36.42
T_4- Farmers practice	5.88	18.89	28.89	32.40
T_5- 50% organic N + 50% inorganic N, P_2O_5 and K_2O	7.07	23.56	34.08	37.48
T_6- 25% organic N + 25% inorganic N, P_2O_5 and K_2O + beejamrit, jeevamrit and ghanajeevamrit	6.12	21.13	31.16	34.48
S.Em. (±)	0.23	0.62	0.556	0.72
C.D. at 5%	0.69	1.88	1.68	2.16
General Mean	6.36	21.06	31.48	34.76

3.2 Effect on yield of rice
Table 5 presents data on the grain yield (kg ha^{-1}), straw yield (kg ha^{-1}), and harvest index (%) of the rice crop under the influence of different treatments.

Throughout the study, it became evident that the application of various nutrient sources had a significant impact on the grain yield (kg ha^{-1}). Specifically, the treatment involving 50% organic N + 50% inorganic N, P_2O_5 and K_2O (T_5) yielded the highest grain output, measuring 3360.00 kg ha^{-1}, surpassing T_1, T_2, T_4, and T_6 treatments. Treatment T_3 (3277.25 kg ha^{-1}) was comparable to T_5, while the lowest grain yield (2847 kg ha^{-1}) was recorded under treatment T_4. The data indicates a significant impact of various nutrient sources on straw yield (kg ha^{-1}). Specifically, the application of 50% organic N + 50% inorganic N, P_2O_5 and K_2O (T_5) resulted in the highest straw yield (3997.65 kg ha^{-1}), surpassing T_1, T_2, T_4, and T_6 treatments. Treatment T_3 was comparable to T_5, while the lowest straw yield was observed in treatment T_4. The average straw yield across treatments was 3719.05 kg ha^{-1}.

Regarding the harvest index (%), data from Table 5 reveals that treatment T_5 (50% organic N + 50% inorganic N, P_2O_5 and K_2O) demonstrated the numerically highest value at 45.66%, followed by treatment T_3 at 45.33%. In contrast, the numerically lowest harvest index value of 45.35% was found in treatment T_4. Singh *et al*. (2018) [12] reported improved rice yield with the combination of organic and inorganic nutrient sources. The consistent and gradual supply of the appropriate quantity of nutrients during various growth phases allowed for optimal absorption by the plants, leading to increased grain and straw yields. These findings align with research by Lamichhane *et al.* (2019) [8], Takhellambam *et al.* (2019) [16], Sonamati *et al.* (2022) [14], and Tahmina *et al.* (2022) [15].

Table 5: Grain yield, straw yield, biological yield and harvest index of *kharif* rice as influenced by different treatments

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
T_1- 100% N through organic sources	3213.75	3859.22	45.44
T_2- 50% organic N + beejamrit, jeevamrit and ghanajeevamrit	2908.75	3490.53	45.46
T_3-100% inorganic N, P_2O_5 and K_2O	3277.25	3952.96	45.33
T_4- Farmers practice	2847.00	3431.39	45.35
T_5- 50% organic N + 50% inorganic N, P_2O_5 and K_2O	3360.00	3997.65	45.66
T_6- 25% organic N + 25% inorganic N, P_2O_5 and K_2O + beejamrit, jeevamrit and ghanajeevamrit	2971.25	3582.52	45.34
S.Em. (±)	28.24	38.61	0.14
C.D. at 5%	85.12	116.40	NS
General Mean	3096.33	3719.05	45.43

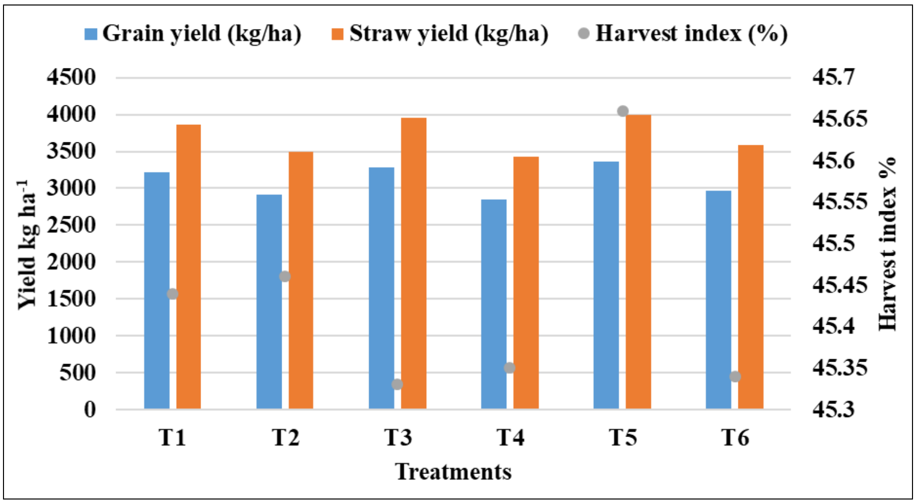

Fig 1: Grain yield, straw yield, biological yield and harvest index of *kharif* rice as influenced by different treatments

Conclusion

The application of a fertilizer blend comprising 50% organic N and 50% inorganic recommended doses of N, P_2O_5 and K_2O resulted in significantly improved growth parameters such as plant height (cm), number of functional leaves hill^{-1}, and number of functional tillers hill^{-1}, as well as enhanced accumulation of dry matter hill^{-1} in rice crops. This was observed to be superior to the application of the full recommended dose of inorganic N, P_2O_5, and K_2O. Furthermore, the use of the 50% organic N + 50% inorganic N, P_2O_5 and K_2O recorded the higher rice yield which was followed by 100% recommended dose of N, P_2O_5 and K_2O through inorganic fertilizers.

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