ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2025): 4.97
IJAFS 2025; 7(11): 289-294
www.agriculturaljournals.com
Received: 16-10-2025
Accepted: 17-11-2025

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Impact of seedling age, density and growth regulators on the yield performance of transplanted rice in the Konkan region

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DOI: https://www.doi.org/10.33545/2664844X.2025.v7.i11d.972

Abstract
The adoption of age and number of seedlings with growth regulator can significantly influence the growth and yield of transplanted rice under *konkan* region of maharashtra. A field experiment was conducted during the *kharif* seasons of 2018 at Agronomy Farm, College of Agriculture, Dapoli, Dist. Ratnagiri (M.S.) during *Kharif* season of 2018. The research experiments were aimed to study the effect of age and number of seedlings with growth regulator on the performance of growth and yield of transplanted rice under *konkan* region. The present research was conducted using a split-split-plot design with three replications. The experimental results revealed that transplanting 20-day-old seedlings (A_1) combined with 3 seedlings per hill (N_1) and application of humic acid (H_1), significantly enhanced number of panicle hill^{-1}, length of panicle (cm), weight of grain panicle^{-1} (g), number of filled grains panicle^{-1}, test weight (g), grain and straw yield (q ha^{-1}) in transplanted rice.

Keywords: Rice, age of seedling, number of seedlings, humic acid, transplanted rice and yield

Introduction

In India, rice is the most important food crop covering about one-fourth of the total cropped area and providing food to about half of the Indian population. It is the staple food of the people living in the eastern and the southern parts of the country. Rice occupies an area of 43.19 million hectares with production of 110.15 million tonnes and productivity of 2.55 tonnes ha^{-1}. Area coverage under rice is estimated to have decreased from 389.49 lakh hectares in 2016-17 to 387.16 lakh hectares in 2017-18 (Anonymous, 2017[a]) [2].

In Maharashtra area under rice crop in 2016-17 was 1.63 million hectares with production of 3.35 million tonnes. An average productivity of the state is 2059 kg ha^{-1}. The average productivity of the Maharashtra state is low as compared to other rice growing states viz. West Bengal, Uttar Pradesh, Punjab, Odisha, Tamil Nadu, Haryana, Andhra Pradesh etc. (Anonymous, 2017) [3].

The major rice districts in Maharashtra are Thane, Raigad, Ratnagiri, and Sindhudurg along with the west coast and Bhandara and Chandrapur in the eastern part of the states. Konkan region occupies an area of about 3.69 lakh hectares under rice with production of about 10.83 lakh tonnes and productivity around 2.93 t ha^{-1} (Anonymous, 2016) [1].

In Maharashtra state, rice is cultivated on 15.13 lakh hectares area in almost all four regions *viz.*, Vidharbha (7.95 lakh ha.), Konkan (3.83 lakh ha.), Western Maharashtra (3.23 lakh ha.) and Marathwada (0.12 lakh ha.) with annual production of 41.71 lakh tones unmilled (brown rice) and 28.78 lakh tones milled rice.

Timely planting and the use of seedlings of proper age are vital non-cash inputs for higher rice productivity (Pattar *et al.*, 2001) [24]. Tillering, which determines panicle number, grains per panicle, and yield, depends greatly on seedling age at transplanting (Pasuquin *et al.*, 2008) [22]. The ideal seedling age varies with crop variety and field conditions (Nandini and Ibopishak Singh, 2000) [15]. Hence, selecting appropriate seedling age ensures a uniform crop stand, better tiller production, grain formation, and improved yield.

The optimum number of seedlings per hill helps rice plants grow efficiently by utilizing light, nutrients, space, and water while reducing seedling cost. Too many seedlings cause

shading, lodging, and more straw than grain, while too few seedlings lead to fewer tillers, underutilized resources, and lower yield. Hence, determining the suitable number of seedlings per hill is essential for higher rice productivity.
Humic acid is considered to increase the permeability of plant membranes and enhance the uptake of nutrients. It also improve soil nitrogen uptake and encourage the uptake of K, Ca, Mg and P_2O_5 making these more mobile and available to plant root system (Pascual *et al.* 1990) [21].

Humic Acid Organic fertilizer
1) **The total humic:** (50-60)% Min.
2) **Organic matter:** (60-70)% Min
3) **Moisture:** 15% Max

Humic substances improve yield and quality of a variety of plants, including grains Ulukan, 2008) [33]. Humic substances improve plant growth by enhancing soil properties like aeration, water holding, and nutrient availability (Cimrin & Yilmaz, 2005; Sharif *et al.*, 2002) [5, 31]. They also directly aid nutrient uptake and transport in plants (Nardi *et al.*, 2002), leading to better yield and quality of crops including grains (Ulukan, 2008) [33].

Materials and Methods
The experiment was conducted at Agronomy Farm, College of Agriculture, Dapoli, Dist. Ratnagiri (M.S.) during *Kharif* 2018. Geographically the research farm located at 17.10º North latitude and 73.10º East longitude having elevation of 250 m above the mean sea level of India. The soil of the experimental field was as clay loam in texture, slightly acidic in reaction (pH 6.01), and rich in organic carbon content (1.19%). It exhibited an electrical conductivity (EC) of 0.35 dS m^{-1}. Nutrient analysis revealed that the soil was medium in available nitrogen (297.92 kg ha^{-1}), low in available phosphorus (11.82 kg ha^{-1}), and very high in available potassium (271.85 kg ha^{-1}). Employing a split-split-plot design, the research experiment was organized into three replications. Here, the main plots were allocated to the different age of seedlings, and sub plot allocated number of seedlings while the sub-sub plots were dedicated to the growth regulator. The main plots included four age of seedlings A_1 - 20 days old seedling, A_2 - 30 days old seedlings, A_3 - 40 days old seedlings and A_4 - 50 days old seedlings. The sub plots comprised number of seedling treatments: N_1 -3 seedlings $hill^{-1}$, N_2 -6 seedlings $hill^{-1}$ and N_3- 9 seedlings $hill^{-1}$. Sub-sub plot treatments consisted of growth regulator: H_0 - control, H_1 - Humic acid. Thus, the entirety of the experiment encompassed a total of 72 distinct treatments. Seeds of the rice variety Ratnagiri-1 were sown to raise a nursery, and seedlings were transplanted at different ages 20, 30, 40, and 50 days as per the treatment schedule. Seedlings were carefully uprooted from the nursery beds and transplanted on the same day using a spacing of 20 × 15 cm. The number of seedlings per hill 3, 6, or 9 was maintained according to the respective treatments. After transplanting each seedling age group into the field, two foliar sprays of humic acid were applied at 10 days after transplanting and the other at the panicle emergence stage each supplemented with 1% urea.

Note: The humic acid solution was prepared by diluting 1 ml of 6% humic acid in 1 liter of water. Data on various growth parameters was recorded under field condition. The technique followed for recording each of the observations is outlined in table 1.

Sr. No	Particulars	Procedure / formula	Period
1.	Number of panicle $hill^{-1}$	The numbers of panicle $hill^{-1}$ were counted from five selected hills for the biometric observation and average was worked out.	At harvest
2.	Length of panicle (cm)	Length of 5 panicles from each net plot was measured from the base of whorl i.e. peduncle up to the tip of the panicle and average length of panicle was worked out.	At harvest
3.	Number of filled grains $panicle^{-1}$	The number of filled grains were counted from 5 panicles selected for measuring length from each net plot and average number was worked out.	At harvest
4.	Weight of grains $panicle^{-1}$ (g)	Weight $panicle^{-1}$ was recorded from the five panicles used for measuring length and counting number of filled grains $panicle^{-1}$. The average weight $panicle^{-1}$ was worked out.	At harvest
5.	Test weight (1000 grain weight)	A representative sample of grains was taken from the total produce of each net plot. Total 1000 grains were counted and weight was recorded as per the treatments.	At harvest
6.	Grain yield (q ha^{-1})	The grain yield obtained after threshing the produce from each net plot was sun dried for about 4 to 5 days and grain yield was calculated on ha basis.	At harvest
7.	Straw yield (q ha^{-1})	The straw yield was obtained by weighing air dried straw which remained after threshing from each net plot and straw yield was calculated on hectare basis.	At harvest

The data on various parameters was subjected to statistical analysis by employing standard statistical methods for Split-split Plot Design as proposed by Panse and Sukhatme.

Results and Discussion
Number of panicle $hill^{-1}$
The data presented in Table 2 showed that transplanting 20-day-old seedlings significantly resulted in a higher number of panicles per plant (7.88), while the lowest number of panicles per plant was observed with 50-day-old seedlings. Prolonged nursery duration leads to degeneration of primary tiller buds, reducing tiller production and yield. Younger seedlings better utilize phyllochronic growth patterns, resulting in more functional leaves, higher leaf area index, improved photosynthesis, and efficient assimilate partitioning, thereby enhancing yield. Similar findings were reported by Hussain *et al.* (2012) [9], Pramanik and Bera (2013) [25], and Vijayalaxmi *et al.* (2016) [37].
Data presented in Table 2 revealed that the treatment involving 3 seedlings $hill^{-1}$ registered that a significantly higher number of $panicles^{-1}$ (7.92). In contrast, the lowest number of $panicles^{-1}$ was observed in the treatment with 9 seedlings $hill^{-1}$. This might be due to healthy and efficient individual plant growth at lesser seedling density. Planting less number of seedlings $hill^{-1}$ enabled the plant to produce healthy tillers which had undergone normal physiological

growth and duration, resulting in more healthy panicles. The findings are confirmed by the results of (Hossain *et al.* 2003) [8] and (Rasool *et al.* (2012) [38]

The application of humic acid resulted in a significantly higher number of panicles per hill (7.63) are presented in Table 2. The application of humic acid improved root development and nutrient absorption in plants, leading to better yield attributes such as productive tillers and filled grains per panicle. This resulted in higher yields compared to the control. Similar findings were reported by Dhanasekaran and Govindasamy (2002) [6], who noted that nutrient availability during the reproductive stage enhanced grain filling and increased grain weight. These findings are confirmed by Hoda *et al.* 2014) [7] and Vanitha and Mohandass (2014) [35].

Length of panicle (cm)

A significantly maximum length of panicle (21.07) was observed in the treatment with 20-day-old seedlings as shown in Table 2, whereas the 50-day-old seedlings exhibited a significantly minimum length of panicle. The 20-day-old seedlings produce longer panicles due to better early growth, faster root establishment, efficient nutrient uptake, and minimal transplant shock. These factors support stronger reproductive development and enhance panicle elongation. Similar findings are confirmed by More *et al.* (2007) [14], Jain and Upadhyay (2008) [10] and Vijayalaxmi *et al.* (2016) [37].

Data presented in Table 2. Indicated that transplanting three seedlings per hill recorded the maximum panicle length (21.14 cm), whereas the minimum panicle length was observed in the treatment with nine seedlings per hill. This could be attributed to reduced intra-hill competition for nutrients, light, and space in the lower seedling density, which allows individual plants to grow more vigorously and develop longer panicles. In contrast, higher seedling density likely increased competition among plants, limiting resource availability and thereby restricting panicle development. The findings are confirmed by the results of Nayak *et al.* (2003) [18], Sarkar *et al.* (2011) [30] and (Rasool *et al.* (2012) [38].

The application of humic acid resulted in a significant increase in panicle length, reaching a maximum of (20.22 cm) are presented in Table 2. Application of humic acid enhances nutrient availability and uptake particularly of nitrogen, phosphorus, and potassium by improving soil structure and microbial activity. Additionally, it stimulates root growth and increases chlorophyll content, leading to better photosynthetic efficiency. These combined effects promote overall plant vigor and contribute to improved panicle development. These findings are confirmed by Sao *et al.* (2010) [29], Saha *et al.* (2013) [28]. Kumar *et al.* (2014) [13] and Vanitha and Mohandass (2014) [35].

Weight of grain panicle^{-1} (g)

A significantly higher grain weight per panicle (2.95 g) was recorded in the treatment with 20-day-old seedlings are presented in Table 2, whereas the treatment with 50-day-old seedlings produced the lowest grain weight per panicle. This difference can be attributed to the greater vigor and better establishment of younger seedlings, which are more efficient in nutrient uptake and tiller formation. In contrast, older seedlings often experience transplanting shock and reduced root regeneration, leading to poor growth and ultimately lower grain filling and panicle weight. Similar findings were reported by D. Naresh (2012) [17] and Pramanik and Bera (2013) [25].

As presented in Table 2, the treatment with 3 seedlings per hill resulted in the highest grain weight per panicle (2.91 g), while the treatment with 9 seedlings per hill produced the lowest. his trend suggests that lower planting density improves grain weight due to reduced intra-hill competition, which allows better access to resources such as nutrients, water, and light. Enhanced growing conditions at lower densities promote stronger root systems, efficient photosynthesis, and better grain filling. Conversely, higher densities limit individual plant development and resource use efficiency, negatively affecting yield. These observations align with findings by Patra and Nayak (2001) and Kewat *et al.* (2002) [23, 12].

The application of humic acid significantly increased the grain weight per panicle, reaching 2.67 g, as shown in Table 2. This enhancement can be attributed to humic acid role in improving soil structure, enhancing nutrient availability, and promoting better root development. These factors contribute to improved plant vigour and greater resource uptake, ultimately resulting in higher grain weight per panicle. These findings are confirmed by Sao *et al.* (2010), Vanitha and Mohandass (2014) [35] and Kumar *et al.* (2014) [13]

No. of filled grains panicle^{-1}

A significantly higher number of filled grains per panicle (70.54) was recorded in the treatment with 20-day-old seedlings are presented in Table 2, whereas the treatment with 50-day-old seedlings registered the lowest number of filled grains per panicle. This can be attributed to the better establishment and faster growth of younger seedlings, which are more capable of adapting to field conditions, leading to stronger panicle development and higher grain filling. In contrast, older seedlings may experience more transplant shock and slower acclimatization, which negatively affects panicle development and grain filling, resulting in a lower number of filled grains. Similar findings are confirmed by Pramanik and Bera (2013) [25] and Vijayalaxmi *et al.* (2016) [37].

Data indicated in Table 2 revealed that the transplanting 3 seedlings per hill recorded a significantly higher number of filled grains per panicle (67.09), whereas the treatment with 9 seedlings per hill resulted in the lowest number of filled grains per panicle. Lower seedling density led to more filled grains due to reduced competition and better resource access, while higher density limited growth and grain filling. These findings are supported by Nayak *et al.* (2003) [18], Sarkar *et al.* (2011) [30], and Hossain *et al.* (2003) [8].

The application of humic acid to rice resulted in a significant increase in the number of filled grains per panicle (65.09) as shown in Table 2. This enhancement can be attributed to humic acid ability to improve soil structure, increase nutrient availability, and stimulate root development. These factors collectively enhance the plant's ability to take up nutrients and water more efficiently, leading to better panicle development and a higher number of filled grains. This was in the agreement with Kavitha *et al.* (2010) [11], Saha *et al.* (2013) [28] and Suntari *et al.* (2015) [32].

Test weight (g)

The treatment transplanting 20-day-old seedlings recorded a numerically higher test weight of rice (30.73 g) as presented in Table 2, while the lowest test weight was observed in 50-day-old seedlings. This might be due to the faster establishment and better nutrient uptake in younger seedlings, which promote efficient grain filling, whereas older seedlings may suffer from transplant shock and reduced growth, leading to lower test weight. The results are in the conformity with the work done by Hussain *et al.* (2012) [9] and Pramanik and Bera (2013) [25].

The treatment with 3 seedlings per hill recorded the numerically maximum test weight (30.55 g), as shown in Table 2 while the treatment with 9 seedlings per hill resulted in the minimum test weight. This is due to reduced intra-hill competition at lower densities, which allows for better resource availability and promotes higher grain development, whereas higher densities limit resource access and reduce plant vigor. The findings are confirmed by the results of Obulamma and Reddeppa (2002) [19], Nayak *et al.* (2003) [18], Sarkar *et al.* (2011) [30].

Data presented in Table 2 indicated that the application of humic acid resulted in the numerically maximum test weight of rice, 30.45 g. This can be attributed to humic acid's role in improving soil structure, enhancing nutrient availability, and stimulating root development, which collectively support better grain filling and contribute to a higher test weight. These findings are confirmed by Rahman (2011) [26], Hoda *et al.* 2014) [7] and Vanitha and Mohandass (2014) [35].

Grain yield (q ha^{-1})

The treatment 20-day-old seedlings recorded a significantly higher grain yield of rice, (43.27 q ha^{-1} are presented in Table 2, while the lowest yield was obtained from the 50-day-old seedlings. The increase in the age of seedling for transplanting resulted an increase in the duration but shorter vegetative phase in main field, lesser photosynthetic accumulation in the plants and higher spikelet sterility and thus, the grain yield was decreased when overage seedlings was transplanted. The results are in the conformity with the work done by Hussain *et al.* (2012) [9], Pramanik and Bera (2013) [25] and Vijayalaxmi *et al.* (2016) [37].

The data indicated in Table 2 revealed that transplanting of 3 seedlings per hill significantly increased grain yield, recording 41.22 q ha^{-1}, while the treatment with 9 seedlings per hill resulted in the lowest straw yield. This improvement might be due to greater panicle length, number of filled grains per panicle, and grain weight. The higher yield in lower seedling density may be attributed to healthier individual plant growth, a higher percentage of productive tillers, better light interception, and enhanced grain filling through remobilization of stored reserves and current photosynthesis. These findings align with those reported by Rasool *et al.* (2012) [38].

The application of humic acid significantly enhanced grain yield of rice, 40.74 q ha^{-1} as shown in Table 2. Foliar spray of humic acid might have improved the chlorophyll content, increased the CO_2 assimilation in plants this might be due to the increased uptake of more amount of nutrients and effective translocation of photosynthates from source to sink. The results are in confirmation with the results reported by Saha *et al.* (2013) [28].

Straw yield (q ha^{-1})

The highest straw yield, 53.06 q ha^{-1}, was recorded under the treatment of transplanting 20-day-old seedlings, while the lowest yield was observed with 50-day-old seedlings are shown in Table 2. This improvement may be attributed to enhanced morphological characteristics, such as increased plant height, number of leaves per hill, number of tillers per hill, and dry matter production per hill, observed in the 20-day-old seedlings. These findings are consistent with the results reported by Pramanik and Bera (2013) [25] and Upadhyay *et al.* (2003) [34].

The data presented in Table 2 results revealed that the highest straw yield of (50.15 q ha^{-1}) was significantly obtained in the treatment with 9 seedlings per hill, compared to the 3 seedlings per hill treatment. It was probably due to more dry matter accumulation hill^{-1} due to better nutrients absorption from soil, which increases metabolic process, rate of light absorption, photosynthetic activities, more number of leaves, and more number of tillers. The current results are in agreement with the investigation made by Bhowmik *et al.* (2012) [4].

The application of humic acid resulted in a significantly higher straw yield of (48.92 q ha^{-1}) are presented in Table 2. Application of foliar spray of humic acid might have improved the chlorophyll content, increased the CO_2 assimilation in plants this might be due to the increased uptake of more amount of nutrients and effective translocation of photosynthates from source to sink. The results are in confirmation with the results reported by Saha *et al.* (2013) [28] and Venkateshprasath *et al.* (2017) [36].

Table 2: Number of panicle hill^{-1}, length of panicle (cm), weight of grain Panicle^{-1} (g), number of filled grains panicle^{-1}, test weight (g), grain and straw yield of rice as influenced by different treatments

Treatment	No. of panicle hill^{-1}	Length of panicle (cm)	Weight of grain Panicle^{-1} (g)	No. of filled grains panicle^{-1}	Straw yield q ha^{-1}
	At harvest	At harvest	At harvest	At harvest	At harvest
A. Main plot: Age of seedlings (A)					
A_1: 20 days old seedling	7.88	21.07	2.95	70.54	53.06
A_2: 30 days old seedling	7.58	20.44	2.71	67.76	50.22
A_3: 40 days old seedling	7.15	19.82	2.37	62.07	44.92
A_4: 50 days old seedling	6.88	17.83	1.95	56.02	41.63
SE. m. (±)	0.12	0.32	0.04	0.87	1.08
C.D. at 5%	0.37	0.96	0.13	2.62	3.23
B. Sub plot: Number of seedlings (B)					
N_1: 3 seedlings hill^{-1}	7.92	21.14	2.91	67.09	44.98

N_2: 6 seedlings hill^{-1}	7.35	19.94	2.48	63.42	47.24
N_3: 9 seedlings hill^{-1}	6.86	18.29	2.10	61.79	50.15
SE. m. (±)	0.12	0.19	0.09	0.51	0.75
C.D. at 5%	0.35	0.57	0.27	1.52	2.24
C. Sub-Sub plot: Growth regulator (H)					
H_1: Control	7.12	19.35	2.32	63.11	45.99
H_0: Humic acid	7.63	20.22	2.67	65.09	48.92
SE. m. (±)	0.08	0.18	0.06	0.54	0.55
C.D. at 5%	0.24	0.54	0.19	1.58	1.59
Interactions					
A x N	NS	NS	NS	NS	NS
A x H	NS	NS	NS	NS	NS
N x H	NS	NS	NS	NS	NS
A x N x H	NS	NS	NS	NS	NS
General mean	7.37	19.79	2.49	64.10	47.46

Conclusion

Transplanting 20-day-old seedlings, using three seedlings per hill, and applying humic acid were found to be the most effective practices for enhancing the growth and yield performance of transplanted rice in the *Konkan* region. The 20-day-old seedlings showed superior growth due to rapid establishment, minimal transplant shock, and efficient nutrient use, resulting in the highest grain yield and straw yield. Similarly, planting three seedlings per hill optimized resource utilization and reduced intra-hill competition, leading to improved panicle traits and a grain yield. The application of humic acid further boosted physiological efficiency, nutrient uptake, and panicle development, contributing to a grain yield and straw yield of rice. Together, these practices form an integrated and sustainable approach to maximize rice productivity under the agro-climatic conditions of the *Konkan* region.

This study emphasizes the significance of combining the transplanting of 20-day-old seedlings, three seedlings per hill, and the application of humic acid as an integrated approach to enhance soil fertility, optimize plant growth, and improve overall rice yield. These agronomic practices collectively contribute to better root development, efficient nutrient uptake, and superior photosynthetic activity, thereby serving as crucial strategies for sustainable rice production in the Konkan region.

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