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Growth and Yield of Rice Cultivars as Influenced by Establishment Methods under Aerobic and Anaerobic Condition

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Abstract Field study on growth and yield of rice cultivars as influenced by establishment methods under aerobic and anaerobic condition revealed that square transplanting (25 cm × 25 cm) with 2 seedling hill^{-1} recorded significantly higher yield of grain both under aerobic unpuddled (41.4 q ha^{-1}) and anaerobic puddled (43.4 q/ha^{-1}) condition, associated with higher EBT m^{-2} and panicle length along with higher net return. Aerobic rice Pyari under aerobic and lowland rice Naveen under anaerobic condition was superior with respect to yield. Overall, on mean basis, the trend in respect to grain yield was anaerobic transplanting (42.2 q ha^{-1}) > aerobic transplanting (39.2 q ha^{-1}) > direct sowing (24.09 q ha^{-1}).

Keywords Direct sowing, Aerobic rice, Aerobic transplanting, Rectangular transplanting, Square transplanting.

Introduction

Rice is the staple food of over half the world's population and a vital nutritional source for rural population of most of the countries in the world by providing 20% of their dietary energy. Globally rice is grown in 162.3 mha, and India accounts for 27.47% with a cultivated area of 44.6 mha with corresponding production of 738.1 and 104.20 Mt. With its ability to adopt itself to a wide range of geo-hydrological situations, rice enjoys a unique place among the field crops. Based on environmental determinant of water and its degree of flooding, rice is established differently under different ecosystems. Conventional puddled transplanting is the wide spread establishment method of rice cultivation where 5–10 cm of standing water is maintained throughout its growth period. The resultant high water table, soil compaction and post harvest soil management has deteriorated the soil environment, besides the practice of consuming more water. To overcome such situation, some water saving technologies have been developed to optimise production with lesser use of water. Among these the aerobic rice production system has drawn attention of researchers. This system involves growing of especially developed aerobic rice varieties vis-a-vis their cultivation in well-drained, unpuddled, and un-flooded soil. Breeding of such genotypes is a long term strategy. Keeping this in view a field study was planned on growth and yield of rice cultivation as influenced by establishment methods under aerobic and an aerobic condition during wet season where two popular rice genotypes were compared with one aerobic rice cultivar, all of them belonging to medium duration group.

Materials and Methods

A field study was carried out at Agronomy Main Re-

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search Farm, Department of Agronomy, College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar during wet season of 2014 in split plot design with three replications. Eighteen treatment combinations consisting of six establishment methods (M_1–direct seeding with 20 cm row to row spacing, M_2–Aerobic conventional rectangular transplanting at 20 cm × 10 cm spacing with 2–3 seedling hill^{-1}, M_3–Aerobic square transplanting at 20 cm × 20 cm spacing with 1 seedling hill^{-1}, M_4–Aerobic square transplanting at 25 cm × 25 cm spacing with 1 seedling hill^{-1}, M_5–Aerobic square transplanting at 20 cm × 20 cm spacing with 2 seedling hill^{-1}, M_6–Aerobic square transplanting at 25 cm × 25 cm spacing with 2 seedling hill^{-1}) in main plot and three rice varieties (V_1–Naveen, V_2–Hiranmayee, V_3–Aerobic rice Pyari) in sub-plot. Another set of experiment as observation strip with same three varieties was also laid out under anaerobic condition with five establishment methods such as (S_1–Conventional rectangular transplanting at 20 cm × 10 cm spacing with 2–3 seedling hill^{-1}, S_2– Square transplanting at 20 cm × 20 cm spacing with 1 seedling hill^{-1}, S_3–Square transplanting at 25 cm × 25 cm spacing with 1 seedling hill^{-1}, S_4–Square transplanting at 20 cm × 20 cm spacing with 2 seedling hill^{-1} and S_5– Square transplanting at 25 cm × 25 cm spacing with 2 seedling hill^{-1}). The soil of both the experimental site was sandy loam in texture at surface with pH 5.34 and 5.98 having organic carbon 0.44% & 0.40% and EC 0.151 and 0.163 dSm^{-1}. The total available nitrogen, phosphorus and potassium under aerobic and anaerobic condition was 214.10, 54.32 & 110.12 and 286.0, 16.87 & 129.5 kg ha^{-1}, respectively. Nitrogen, phosphorus and Potassium @ 80–40–40 kg ha^{-1} were applied to all the plots through urea, DAP and MOP. Well decomposed FYM @ 5 t ha^{-1} was incorporated into the soil at final ploughing. Full dose of P and K and 25% of N was applied at final ploughing / puddling. Rest of N was applied in 2 : 1 ratio at tillering and panicle initiation stage, respectively. Crop during its growing period received a rainfall of 1348.7 mm within 78 rainy days. Crop was irrigated to supplement rainfall during the growth period. Seeds were directly sown in solid rows on well pulverised un puddled soil as per treatment under M_1. Dry nursery was prepared to raise the seedling for use in main experiment under aerobic transplanting as well as for observation strip (Puddled anaerobic condition) on the same date of sowing of M_1 treatment. For transplanting under aerobic (unpuddled) and an aerobic (puddled) condition, one seedling (M_3, M_4 and S_2, S_3 treatments) and two seedling (M_5, M_6 and S_4, S_5) at two leaf stage were used while for conventional transplanting (M_2 and S_1) 2–3 seedlings at four leaf stage were transplanted under aerobic and anaerobic conditions, respectively. A pre soaking irrigation was provided to the well pulverized soil under aerobic condition to facilitate the transplanting.

Results and Discussion

Yield attributing characters

Data revealed that under aerobic condition square transplanting at 25 cm × 25 cm spacing with two seedling hill^{-1} recorded significantly the highest EBT m^{-2} (353.9) and panicle length (29.4 cm) while number of filled grain panicle^{-1} was the highest under aerobic square transplanting at 20 cm × 20 cm with two seedling hill^{-1}, whereas under anaerobic condition square transplanting with 1 seedling at 25 cm × 25 cm spacing produced highest EBT m^{-2} (379.4) and filled grains panicle^{-1} of 115.5 (Tables 1 and 2). Data further indicated that among the methods under aerobic condition direct seedling at 20 cm row to row recorded the lowest value of all yield attributes and among the conventional transplanting rectangular geometry (20 cm × 10 cm spacing with 2–3 seedling hill^{-1}) produced less number of EBT m^{-2} (333.9 hill^{-1}) and having shortest panicle (25.8 cm) than square transplanting at 20 cm × 20 cm spacing (344.3 and 27.9 cm, mean of M_3 and M_5) and 25 cm × 25 cm spacing (350.4 and 27.8 cm, mean of M_4 and M_6) irrespective of number of seedlings planted per hill. Similarly, under anaerobic condition rectangular transplanting (20 cm × 10 cm spacing) recorded the lowest values of EBT m^{-2}, panicle length, filled grain panicle^{-1} and weight of 1000 grain. However, square transplanting at 20 cm × 20 cm was superior with respect of EBT m^{-2} (378) and panicle length (28.0 cm) over 25 cm × 25 cm spacing, while 25 cm × 25 cm planting was superior on account of number of fertile grains panicle^{-1} (112.3) over 20 cm × 20 cm spacing. Rajesh and Thanumathan [1] re-

Table 1. Ear bearing tillers m^{-2} and panicle characteristics at harvest as influenced by establishment methods and variety under aerobic condition.

	Establishment methods	EBT m^{-2}	Panicle length (cm)	Number of filled grain $panicle^{-1}$	1000-grain weight (g)	Grain yield (q ha^{-1})
M_1	Direct seeding 20 cm R–R	285.6	24.48	75.5	19.03	24.09
M_2	ACP 20 cm × 10 cm 2-3 seedlings $hill^{-1}$	333.9	25.85	112.3	20.60	35.30
M_3	ATP 20 cm × 20 cm 1 seedling $hill^{-1}$	335.8	28.65	104.7	20.50	40.70
M_4	ATP 25 cm × 25 cm 1 seedling $hill^{-1}$	346.8	26.27	104.7	21.40	37.62
M_5	ATP 20 cm × 20 cm 2 seedlings $hill^{-1}$	352.7	27.32	115.3	20.07	40.90
M_6	ATP 25 cm × 25 cm 2 seedlings $hill^{-1}$	353.9	29.41	113.8	20.60	41.39
SEm±		3.893	0.772	1.329	0.113	0.568
CD (0.05)		12.266	2.431	4.187	0.356	1.78
Variety						
V_1	Naveen	327.5	26.59	96.3	21.62	34.76
V_2	Hiranmayee	328.9	27.94	106.2	18.30	37.61
V_3	Pyari	347.8	26.50	104.3	21.18	37.64
SEm±		2.747	0.657	1.466	0.099	0.559
CD (0.05)		7.421	NS	3.960	0.267	1.512
Interaction		S	NS	S		NS

	SEm±	CD (0.05)	SEm±	CD (0.05)	SEm±	CD (0.05)	SEm±	CD (0.05)	SEm±	CD (0.05)
V within M	6.728	19.634		1.61	3.59	10.477	0.242	0.706	1.370	
M within V	6.733	20.172		1.525	3.219	9.52	0.227	0.677	1.255	

Table 1. Continued.

	Establishment methods	Straw yield (q ha^{-1})	Harvest index	Cost of cultivation Rs ha^{-1}	Net return Rs ha^{-1}	B : C
M_1	Direct seeding 20 cm R–R	37.68	0.389	23241.8	9897.3	1.42
M_2	ACP 20 cm × 10 cm 2-3 seedlings $hill^{-1}$	48.72	0.420	32764.2	15730.8	1.48
M_3	ATP 20 cm × 20 cm 1 seedling $hill^{-1}$	53.59	0.431	28071.8	26732.0	1.99
M_4	ATP 25 cm × 25 cm 1 seedling $hill^{-1}$	49.20	0.433	28143.2	23511.0	1.83
M_5	ATP 20 cm × 20 cm 2 seedlings $hill^{-1}$	53.46	0.433	30767.1	25390.9	1.82
M_6	ATP 25 cm × 25 cm 2 seedlings $hill^{-1}$	53.76	0.434	29397.9	27430.1	1.93
SEm±		0.571				
CD (0.05)		1.800				
Variety						
V_1	Naveen	48.04	0.419	29897.2	17856.8	1.59
V_2	Hiranmayee	50.48	0.427	29897.2	21757.2	1.72
V_3	Pyari	49.69	0.430	29897.2	21790.1	1.73
SEm±		0.645				
CD (0.05)		1.743				
Interaction		NS				

	SEm±	CD (0.05)
V within M	1.580	
M within V	1.41	

Table 2. Ear bearing tillers m^{-2} and panicle characteristics at harvest as influenced by establishment methods and variety under anaerobic condition (observation strip).

Establishment methods		EBT M^{-2}	Panicle length (cm)	Number of filled grains panicle^{-1}	1000 grain weight	Grain yield (q ha^{-1})
S_1	Transplanting 20 cm × 10 cm 2-3 seedlings hill^{-1}	345.6	24.40	96.5	19.60	39.70
S_2	Transplanting 20 cm × 20 cm 1 seedling hill^{-1}	378.0	28.10	107.0	20.63	42.56
S_3	Transplanting 25 cm × 25 cm 1 seedling hill^{-1}	379.3	26.70	115.5	20.62	41.90
S_4	Transplanting 20 cm × 20 cm 2 seedling hill^{-1}	378.3	27.90	114.2	20.40	43.10
S_5	Transplanting 25 cm × 25 cm 2 seedlings hill^{-1}	374.0	28.70	109.2	20.10	43.43
V_1	Naveen	328.2	27.64	112.0	21.30	43.24
V_2	Hiranmayee	367.0	26.94	106.8	18.66	41.94
V_3	Pyari	363.9	26.90	106.6	20.86	41.24

Table 2. Continued.

Establishment methods		Straw yield (q ha^{-1})	Harvest index	Cost of cultivation Rs ha^{-1}	Net return Rs ha^{-1}	B : C
S_1	Transplanting 20 cm × 10 cm 2-3 seedlings hill^{-1}	51.70	0.434	34969.2	19539.8	1.55
S_2	Transplanting 20 cm × 20 cm 1 seedling hill^{-1}	45.23	0.484	30276.7	28057.2	1.90
S_3	Transplanting 25 cm × 25 cm 1 seedling hill^{-1}	49.47	0.450	30348.2	27130.5	1.89
S_4	Transplanting 20 cm × 20 cm 2 seedling hill^{-1}	44.63	0.490	32972.1	21090.2	1.63
S_5	Transplanting 25 cm × 25 cm 2 seedlings hill^{-1}	46.00	0.485	31602.9	27926.9	1.88
V_1	Naveen	48.50	0.471	32033.8	27257.6	1.85
V_2	Hiranmayee	47.40	0.469	32033.8	25478.6	1.79
V_3	Pyari	46.32	0.487	32033.8	24515.8	1.76

ported that wider spacing avoided below and above ground competition and resulted in better grain filling, higher grain weight and more number of filled grains panicle^{-1}. Similar results from square planting with wider spacing of 25 cm × 25 cm has also been observed by Vijay Kumar et al. [2]. Overall, the trend with respect to direct seeding, aerobic (mean of M_2 to M_6) and anaerobic transplanting (mean of S_1 to S_5) was anaerobic transplanting (371) > aerobic transplanting (346) > direct sowing (286) for EBT, aerobic transplanting (27.5 cm) > anaerobic transplanting (27.2 cm) > direct sowing (21.5 cm) for panicle length, anaerobic transplanting (108.5) > aerobic transplanting (107.6) > direct sowing (75.5) for filled grain panicle^{-1} and aerobic transplanting (20.6 g) > anaerobic transplanting (20.3 g) > direct sowing (13.0 g) for test weight. Similar trend on yield attributing characters under anaerobic flooded condition have also been reported by Patel et al. [3]. The author further reported that some characters like EBT and 1000 grain weight were least influenced by water management.

Grain yield

Square transplanting at 25 cm ×25 cm with 2 seedling hill^{-1} produced highest grain of 41.39 and 43.43 q ha^{-1} both under aerobic and anaerobic condition, respectively. Data further revealed that an increase in number of hills from 16 (M_4) to 25 (M_3) recorded significantly more yield to the tune of 8.2% under aerobic condition though no significant difference in M_5 and M_6 was visible. Aerobic square transplanting (M_3 to M_6) with a mean grain yield of 40.13 q ha^{-1} was superior to M_1 and M_2 by 66.6 and 38.7%, respectively.

Data further revealed that grain yield was more under anaerobic puddled condition than under aero-

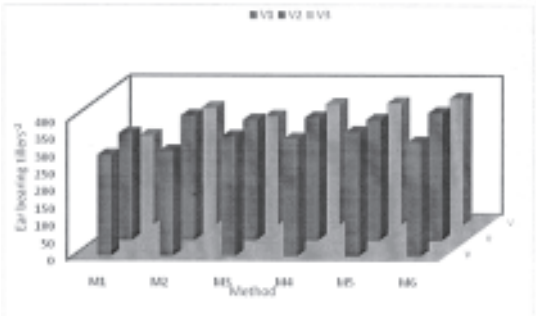

Fig. 1. Interaction effect (methods × variety) on Ear bearing tiller m^{-2} (aerobic condition).

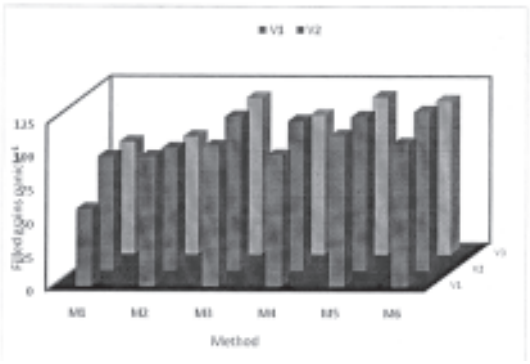

Fig. 2. Interaction effect (methods × variety) filled grain $panicle^{-1}$ (aerobic condition).

bic unpuddled condition and was in the order of anaerobic transplanting (42.18 q ha^{-1}) > aerobic transplanting (39.18 q ha^{-1}) > direct sowing (24.09 q ha^{-1}). Results are in confirmative with that of Singh et al. [4].

Effect of variety

Aerobic rice variety Pyari produced highest number of ear bearing tiller (347.8 m^{-2}) over Hiranamyee and Naveen, the two lowland high yielding varieties under aerobic condition, while under anaerobic condition variety Hiranmayee recorded the highest EBT m^{-2} (367), the longest panicle (27.94 cm) and highest (106.2) number of filled grain $panicle^{-1}$ under aerobic condition while lowland variety Naveen recorded the longest panicle (27.64 cm) and highest (112.0) filled grain under anaerobic condition.

Grain yield

Varietal performance under different hydrological situation differed according to their suitability to situations that finally reflected the yield. Highest grain yield (37.64 q ha^{-1}) was recorded with aerobic rice Pyari under aerobic condition while lowland rice Hiranmayee recorded the highest (43.24 q ha^{-1}) under anaerobic condition.

Two factor interaction between establishment method and variety was found to be statistically significant with respect to ear bearing tillers, filled grains $panicle^{-1}$ and weight of 1000 grains (Figs. 1 to 3). Variety Pyari and Hiranmayee produced significantly the highest ear bearing tiller (365 m^{-2}) and number of filled grain panicle (119) when 2 seedlings were transplanted aerobically with square geometry of 25 cm× 25 cm. On the other hand 1000 grain weight was the highest (22.8 g) when variety Naveen was transplanted conventionally with 2–3 seedlings $hill^{-1}$ in a rectangular geometry of 20 cm × 10 cm. No significant interaction effect on yield was observed and thus the varieties performed independently of establishment methods. Similar results have also been reported by Lenka and Gulati [5].

Otis and Talbert [6] emphasized that plant geometry has significant influence on growth and yield of aerobic rice. The differential pattern may avoide the acute competition between the plants for nutrients, water, air, light and space. An optimal plant density allows interception of photosynthetically active radiation more effectively by reducing mutual shading.

Straw yield

Straw yield was superior when 2 seedlings were transplanted at 25 cm × 25 cm spacing. Aerobic square transplanting recorded 7.7 and 39.3% higher straw yield over aerobic conventional transplanting (M_2) and direct sowing (M_1), respectively. While under anaerobic condition conventional transplanting at 20

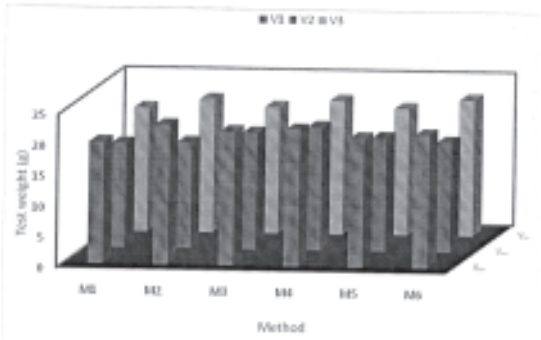

Fig. 3. Interaction effect (methods × variety) on test weight (aerobic condition).

cm × 10 cm spacing recorded the highest straw yield of 51.70 q ha^{-1}. The trend in overall straw yield under different situation was in the order of aerobic (51.75 q ha^{-1}) > anaerobic (47.40 q ha^{-1}) > direct sowing (37.68 q ha^{-1}). Hiranmayee recorded the highest (50.48 q ha^{-1}) straw yield under aerobic condition while Naveen recorded the highest (48.50 q ha^{-1}) under anaerobic condition.

Harvest index

Among the establishment methods transplanting at 25 cm × 25 cm spacing with 2 seedling hill^{-1} recorded highest harvest index (0.434) whereas transplanting of 2 seedlings at 20 cm × 20 cm recorded the highest (0.490) under anaerobic condition. Among the varieties, aerobic rice Pyari recorded the highest HI of 0.434 and 0.487 both under aerobic and anaerobic condition, respectively. Harvest index, also referred as coefficient of efficiency, is a measure of quantity of translocation trend of photosynthates from source to sink and indicated by the higher values.

Economics

Conventional aerobic rectangular transplanting at 20 cm × 10 cm spacing registered the highest cost of cultivation of Rs 32764.2 and 34969.2 ha^{-1} both under aerobic and anaerobic condition, respectively. On the basis of mean over treatment, anaerobic transplanting registered 7.3 and 37.8% higher cost of cultivation over that of anaerobic transplanting and direct sowing. Square aerobic transplanting at 25 cm × 25 cm spacing with 2 seedlings hill^{-1} produced highest net return of Rs 27430.1 ha^{-1} while square aerobic transplanting at 20 cm × 20 cm spacing with 1 seedling recorded the highest (1.99) benefit- cost ratio under aerobic condition. Under anaerobic condition square transplanting of 1 seedling at 20 cm × 20 cm spacing recorded the highest (Rs 28057.2 ha^{-1}) net return as well as benefit- cost ratio. Among the varieties, aerobic rice Pyari produced highest (Rs 21790.1 ha^{-1}) net return along with highest benefit- cost ratio (1.73) under aerobic condition whereas under anaerobic condition, lowland variety Naveen recorded the highest net return (Rs 27257.6 ha^{-1}) and benefit -cost ratio (1.85).

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