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Adaptability of aerobic rice to different establishment methods and levels of nitrogen under irrigated aerobic condition

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Abstract
A field experiment was conducted at Agronomy Main Research Farm, Department of Agronomy, Odisha University of Agriculture and Technology in summer 2016 and 2017. The experiment was laid out in split plot design with three replications under irrigated aerobic condition. Treatments comprising of five establishment methods like direct seeding in solid rows 20 cm apart (E_1), direct seeding by punji method (dibbling) at 20cm x 20cm (E_2), transplanting (under un puddle un flooded condition i.e. aerobic) with 1 seedling at 2 leaf stage at 20 cm x 20 cm (E_3), 2-3 seedlings at 4 leaf stage at 20 cm x 10 cm (E_4) and 2-3 seedlings at 4 leaf stage at 20 cm x 20 cm (E_5), in main plots, and four nitrogen level (N_1-30, N_2-60, N_3-90 and N_4-120kg N ha^{-1})in sub plots. Result reveled that aerobic rice adapted with significant superiority when 2-3 seedlings at 4 leaf stage were transplanted in square geometry of 20 cm x 20 cm (E5) on pulverised soil after a pre-soaking irrigation. The method recorded the highest yield attributing characters like EBT/ hill, panicle length, filled grains per panicle ,1000 grain weight and harvest index contributing to significantly higher grain yield of 4760 and 5142 kg/ha in the year 2016 and 2017, respectively. The corresponding straw yield was 5626 and 5938 kg/ha. Yields was found to increase with N-levels and was associated with higher values of yield attributing characters. The same treatment also registered highest net return (Rs.31663and Rs. 39675.) and B: C ratio (1.75an 1.95) in 2016 and 2017, respectively. Two factor interactions between methods and N-levels was also significant and significantly the highest grain and straw yield was recorded when the crop was transplanted under E5 treatment at 120kg N/ha. Functional relationship of nitrogen was established and optimum economic dose of nitrogen was found to be 110 and 118 kg N/ha in 2016 and 2017, respectively with corresponding optimum yield of 4546 and 5307 kg/ha. The resultant quadratic equation in 2016 was $y = -0.252x^2 + 5637 + 1402$ and in 2017 was $y = 0.269 X^2 + 6429 + 1467$.

Keywords: Establishment methods, growth parameters and aerobic rice

Introduction
Rice is the major contributor of this energy and supports nearly half of the world's population as staple food and accounts for more than 20% of all calories that mankind consumes and the researchers are facing an uphill task to keep pace with bourgeoning population under the challenging environment of present day. Rice is traditionally grown by transplanting seedlings on puddle soil for facilitating easy seedling establishment and suppressing growth of weeds. However, repeated puddling adversely affects soil physical properties by destroying soil aggregates, reducing permeability in subsurface layers and forming hard-pans at shallow depths, besides, the method is labour and energy intensive (Kumar *et al*., 2018) [14]. Under the looming water crises it is projected that in the next 25 years, 15–20 million hectares of lowland rice in Asia are to suffer from water scarcity (Tuong and Bouman, 2003) [10]. Thus, some adaptation strategies need to be developed for sustaining rice production and achieving global food security. Aerobic rice culture is an emerging technology designed to enhance water productivity in rice production, where, rice is grown like irrigated dry crop under non-flooded, well drained, un puddle and non-saturated soils with moderate use of external inputs and supplementary irrigation. Moisture status is maintained at or near field capacity that helps in increasing water productivity by 32-88% due to reduction in non- ET components (Toung and Bouman, 2003) [10]. The soil thus, remains aerated throughout its growing season facilitating greater microbial activity, root aeration and overall crop growth and development.

Lafittee *et al*. (2002) [12] termed this system of rice cultivation with provision of irrigation as aerobic rice. However, limited research endeavors has been done in different rice growing areas for optimizing the establishment techniques to assess its adaptability. The present investigation was aimed at to study the adaptability of aerobic rice to different establishment methods and levels of nitrogen under irrigated aerobic condition.

Materials and Methods

Field experiment was carried in the year 2016 and 2017 during summer at Agronomy Research Farm, Department of Agronomy, College of Agriculture, OUAT, Bhubaneswar, Odisha. situated at 20^0 15' N latitude and 85^0 52' E longitudes in East and South Eastern Coastal Plain Agro-Climatic Zone of Odisha. The soil of the experimental site was sandy loam, moderately acidic (pH 5.7) and medium in organic carbon (0.61%), available nitrogen (265.6kg ha^{-1}), phosphorus (20.25 kg ha^{-1}) and potassium (232.5 kg ha^{-1}). The crop received a total amount of 127.6 mm rainfall in first and 117.7 mm in second year in 13 and 9 rainy days, respectively. Supplemental irrigation was given to meet the crop water requirement. The maximum and minimum temperature during the period of growth ranged from a minimum of 15.7 ^oC in January to maximum of 40.8 ^oC in April, 2016 and 14.5 ^0C in January to 38.8 ^0C May, 2017.

The field experiment was laid out in split plot design under irrigated aerobic un puddle un flooded condition with three replications comprising five establishment methods like direct seeding in solid rows 20 cm apart (E_1), direct seeding by *punji* (dibbling) at 20cm x 20cm spacing (E_2), transplanting (under un puddle un flooded condition) with 1 seedling at 2 leaf stage at 20 cm x 20 cm spacing (E_3), with 2-3 seedlings at 4 leaf stage at 20 cm x 10 cm spacing (E_4) and with 2-3 seedlings at 4 leaf stage at 20 cm x 20 cm spacing (E_5) allotted to main plots with four nitrogen level like N_1-30kg N ha^{-1}, N_2-60kgN ha^{-1}, N_3-90kgN ha^{-1} and N_4-120kgN ha^{-1} in sub plots.

The land was ploughed at optimum moisture condition. Aerobic rice variety, Pyari, released from ICAR- National Rice Research Institute, Cuttack was selected for the experiment. The crop was established as per treatment. In treatment E_1 seeds were sown directly in solid rows while in E_2 treatment seeds were dropped directly (Dribbled, locally called as *punji*) in holes made by iron stick on pulverised soil. For transplanting treatments E_3 and E_5 having square geometry (resembling SRI system), seedlings were raised using recommended practice and for treatment E_4, rectangular geometry, the seedlings were raised as per conventional practices. In both cases dry nursery beds were used. The seedlings were transplanted in pulverised soil under un puddle condition after pre-soaking irrigation to facilitate transplanting. A dose of 45 kg each of P_2O_5 and K_2O ha^{-1} and 25% of nitrogen was applied uniformly in all treatments as basal at the time of final land preparation through urea, SSP and MOP, respectively. Remaining nitrogen of 50 and 25% dose was applied at active tillering stage and panicle initiation stage, respectively as per treatment.

Weed management, water management, plant protection and other intercultural operations were timely carried out to ensure proper plant growth. Pendimethalin @ 1.0 kg a.i./ ha was applied as pre-emergence to suppress the weed growth at initial stage followed by two hand weeding at 21 and 45 days after sowing/planting. Crop was irrigated with 20 and 15 irrigations in E_1 and E_2, 19 and 13 irrigations in E_3 and 15 and 12 irrigations in E_4 & E_5, during 2016 and 2017, respectively. The irrigation was scheduled at 20% of field capacity taking into account the rainfall received. Plant protection measures were taken as per recommendation against BLB infestation and insect pest like stem borer and leaf folder. The data on various yield attribute, yield and economics were collected following standard methods. Yield from net plots was recorded and expressed in kg/ha and reported at 14% moisture. Collected data were subjected to analysis of variance (ANOVA) as per standard statistical methods (Gomez and Gomez, 1984) [3].

Results and Discussion

Growth and Yield Attributes

Effect of establishment methods

The data revealed that number of ear bearing tillers / m^2, panicle weight, panicle length and 1000, grain weight were significantly affected due to various establishment methods in both years of study. Treatment (E_5) transplanting with 2-3 seedlings at 4 leaf stage in square geometry of 20 cm x 20cm counted significantly the highest(369 and 397) EBT/m^2 in the year 2016 and 2017, respectively, though at par with E_4 treatment with 347 and 394 EBT/m^2 in corresponding years, but plant height was the less (table 1). Further perusal of data (pooled over 2 years) indicated that all the establishment methods produced significantly higher ear bearing tillers over the treatment E_1 where seeds were directly seeded in solid rows that counted 296 EBT / m2. All other characters like panicle weight, panicle length, filled grains per panicle and 1000 grain weight responded in similar way in both the years of study. Data based on pool over two years reveled that E5 treatment produced significantly higher panicle weight (2.13 g), panicle length (26.1 cm), filled grains per panicle (113) and 1000, grain weight (20.51). However, the number of chaff per panicle and sterility percentage was significantly the highest in direct seeded treatment E_1 and E_2 in both the years. Values based on pool over two years were 25.6 and 26.2, and 19.7 and 19.4 5 in treatments E_1 and E_2, respectively. Significantly the lowest values for these two characters were noticed in treatment E_5 (table 2).

The results are in conformity with the earlier worker. Hugar *et al.* (2009) [5] recorded the tallest plant under normal method of paddy cultivation and the shortest under aerobic method during summer under irrigated conditions of Bhadra command area on red clay loam soils. Das *et al*. (2017**)** [7] reported that under aerobic condition 25 cm × 25 cm spacing with two seedling $hill^{-1}$ recorded significantly the highest EBT m^{-2} (353.9) Kipgen *et al*. (2018) [15] measured longest panicle (24.21cm) with 20 cm x 20 cm spacing being statistically at par with 20 cm x 15 cm (23.83 cm) and 15 cm x 15 cm (23.04 cm). Garbe *et al*., (2013) [16] opined that under wider spacing with less competition for nutrients, moisture and light, more photosynthetic product might be produced at the source and in turn it translocated to the sink. Sekhar *et al*. (2014) [9] reported minimum spikelet sterility (11.3%) with transplanted rice.

Yield of grain and straw

A perusal of data on yield (table 3) would reveal that yield of grain and straw and harvest were found to be affected significantly due to various establishment methods and transplanting aerobically with 2-3 seedlings having 4 leaves in a square geometry of 20 m x 20 cm (E_5) harvested significantly higher grains in both the years and it was 4951 kg/ha on pooled over two years. However, it was at par with treatment E_4 where, 2-3 seedlings having 4 leaves were transplanted aerobically in a rectangular geometry of 20 cm x 10 cm. Direct seeding, either in solid rows (E_1) or *punji* (E_2) produced the lower yield. E1 being significantly inferior to all the treatments. Data further revealed that punji method could produce significantly higher grains (4149 kg/ha) on pooled basis over E1, registering an increase of 34%. Similar trend was also observed with straw yield and it was significantly the highest (5782 kg/ha) on pooled basis under E_5. Direct seeding treatment also responded in similar fashion, and it was 4403 and 5595 kg/ha under E1 and E2, respectively on pooled basis. The harvest index under E_5, E_2, E_1 was 45.80, 41.87 and 39.58%, respectively on pooled basis.

Lenka and Gulati (2014) [13] found aerobic transplanting with spacing of 20 cm x 20 cm producing significantly the highest grain yield and direct seeding producing the lowest Kipgen *et al*. (2018) [15] observed that planting density greatly influences the straw yield and found that wider spacing was superior with highest straw yield as compared to closer spacing. Sonjui *et al* as early as 1990, reported that planting rice in square geometry transplanting could provide the environment with continuous availability of nutrients, higher carbohydrate synthesis and its subsequent translocation to the yield attributing points. Further, Wells and Faw (1978) [18] observed that dense population due to decreased light interception and CO2 accumulation limits the rice yield. The current results corroborates to these earlier findings.

Effect of Nitrogen levels

Data revealed that plant height, yield attributing characters and yield of rice increased with each successive incremental dose and were the maximum at 120 kg N /ha. Though it was at par with 90 kg N/ha. On two years pooled basis the maximum plant height at harvest (105.8 cm), number of ear bearing tillers/m^2 (378), panicle weight (2.58 g), panicle length (26.2cm), 1000, grain weight (20.52g) and number of filled grains per panicle (112) were the highest under 120 kg N/ ha. These higher values were associated in producing higher yield of grain (4910 kg/ha), straw (5939 kg/ha) and harvest index (44.38%). The two factor interaction between E x N was also significant and transplanting aerobically with 2-3 seedlings having 4 leaves in a square geometry of 20 m x 20 cm (E_5) produced significantly higher yield of grain of 5836 kg/ha under 120 kg N /ha (Fig.2). The higher values of these characters at higher levels of nitrogen application have also been reported by Metwally *et al* (2017) [8] and Gewaily *et al*. (2018) [4]. The number of chaffs and sterility percentage, however, showed a inverse relation with increasing N levels (table 1, 2, 3 & 4)

Functional relationship of nitrogen was established and optimum economic dose of nitrogen was found to be 110 and 118 kg N/ha in 2016 and 2017, respectively with corresponding optimum yield of 4546 and 5307 kg/ha. The resultant quadratic equation in 2016 was $y= - 0.252x^2 + 5637 + 1402$ and in 2017 was $y = 0.269 X^2+ 6429 + 1467$ (Fig 3).

Economics

Transplanting treatment E_5 was found to be more remunerative registering significant higher net return and B;C ratio of Rs. 35669/ha and 1.86, respectively (Fig.4). Direct seeding (E_1) registered significantly the lowest with corresponding values of Rs. 10429/ha and 1.30. the cost of cultivation, however, was significantly less in E_1 treatment (Rs. 37275/ha).

During the growing season a particular combination of soil, environment and the competition among the crop plants form a unique environment which, when interacts with the genotype, leads to the expression of the genotype, and ultimately the yield (Fisher, 2015) [17]. Optimum plant population and timely establishment is, thus, crucial for realizing the maximum of the inherent yield potential. It also answers the ability of a genotype to adapt itself. Direct seeding is common in upland situations and transplanting is the traditional way of establishing rice under low land puddle conditions. In present study the aerobic rice variety Pyari was subjected to different establishment methods involving direct seeding and transplanting on un puddle soil conditions i.e. irrigated aerobic conditions. An analysis of data (Fig 1) pooled over two years indicated that mean yield of grain, straw and harvest index was 27.8, 11.4 and 7.1% higher under aerobic transplanting (mean of E_3,E_4 and E_5) over direct seeding (mean of E_1 and E_2). Similarly, the net return and benefit: cost ratio was higher by 60.7 and 15.2%, respectively. though the direct seeding registered a low cost of cultivation (6.7% less).

Table 1: Yield and economics indices as influenced by direct seeding and transplanting methods

Particulars	Mean of Direct seeding treatments (E1 and E2)			Mean of transplanting treatments (E3, E4 and E5)		
	2016	2017	Pooled	2016	2017	Pooled
Grain yield, kg/ha	3330	3869	3599	4322	4876	4599
Straw yield, kg/ha	4625	5373	4999	5295	5843	5569
Harvest Index	40.76	40.69	40.73	44.59	44.77	44.68
Net return, Rs./ha	13911	23572	18742	25300	35748	30524
B: C ratio	1.37	1.65	1.51	1.61	1.86	1.74

Table 2: Yield attributing characters as influenced by different treatments under aerobic condition in summer

Treatment	Plant height (cm) at harvest			Ear bearing tillers (EBT) m^{-2}			Panicle weight (g)			Panicle length (cm)		
Establishment methods	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
E1	102.5	105.4	104.0	279	313	296	2.12	2.14	2.13	24.7	24.8	24.8
E2	101.0	103.0	102.0	320	384	352	2.30	2.30	2.30	25.5	25.2	25.3
E3	98.1	99.9	99.0	310	363	337	2.43	2.43	2.43	25.7	25.8	25.7
E4	100.8	100.9	100.8	347	394	371	2.40	2.40	2.40	25.9	26.0	25.9
E5	100.3	101.8	101.0	369	397	383	2.48	2.50	2.49	26.1	26.2	26.1
SEm±	1.218	1.107	0.823	8.083	7.886	5.647	0.062	0.036	0.036	0.374	0.350	0.256
CD(0.05)	NS	NS	2.467	26.36	25.71	16.93	0.20	0.12	0.11	NS	NS	0.77
N. Levels (kg h^{-1})												
N1	96.8	97.1	96.9	280	331	306	1.93	1.95	1.94	24.7	24.9	24.8
N2	99.5	100.8	100.2	304	364	334	2.33	2.29	2.31	25.4	25.2	25.3

N3	102.4	104.2	103.3	352	395	374	2.54	2.55	2.55	25.9	26.2	26.0
N4	104.8	106.7	105.8	364	392	378	2.57	2.59	2.58	26.1	26.2	26.2
SEm±	1.092	1.218	0.818	9.174	8.782	6.350	0.048	0.048	0.034	0.273	0.324	0.212
CD(0.05)	3.15	3.52	2.313	26.49	25.36	17.96	0.14	0.14	0.40	0.79	0.93	0.60
Pooled Interaction		SEm±	CD(0.05) NS		SEm±	CD(0.05)		SEm±	CD(0.05)		SEm±	CD(0.05)
E within N		1.533	NS		11.519	NS		0.065	NS		0.421	NS
N within E		1.829	NS		14.198	NS		0.076	NS		0.474	NS

E_1- Direct seeding (20 cm in solid row), E_2- Direct seeding by punji method (20cm x 20cm), E_3-Transplanting1 seedling at 2 leaf stage(20 cm x 20 cm), E_4- Transplanting 2-3 seedlings at 4 leaf stage (20 cm x 10 cm) E_5-Transplanting 2-3 seedlings at 4 leaf stage (20 cm x 20 cm), N_1- 30 kg Nitrogen ha $^{-1}$, N_2- 60 kg Nitrogen ha $^{-1}$, N_3- 90 kg Nitrogen ha $^{-1}$, N_4- 120 kg Nitrogen ha $^{-1}$ andNS- Non-significant.

Table 3: Yield attributing characters as influenced by different treatments under aerobic conditionin summer

Treatment	**Filled grains panicle^{-1}**			**1000 grain weight (g)**			**Chaffs panicle^{-1}**			**Sterility%**		
Establishment methods	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
E1	104	105	104	19.63	19.65	19.64	25.03	26.24	25.64	19.35	20.01	19.68
E2	111	106	109	20.45	20.10	20.28	24.85	27.46	26.16	18.23	20.58	19.41
E3	102	109	106	20.45	20.25	20.35	22.98	24.46	23.72	18.35	18.21	18.28
E4	111	110	112	20.53	20.35	20.44	22.08	24.65	23.36	16.25	18.27	17.26
E5	113	114	113	20.63	20.40	20.51	15.28	14.88	15.08	12.06	11.48	11.77
SEm±	1.674	1.530	1.134	0.185	0.220	0.144	0.527	0.252	0.292	0.528	0.500	0.364
CD(0.05)	5.46	4.99	3.40	0.60	NS	0.43	1.72	0.82	0.88	1.72	1.63	1.09
N. Levels (kg h^{-1})												
N1	103	104	104	19.86	19.76	19.81	24.16	25.32	24.70	19.00	19.58	19.29
N2	109	109	109	20.36	20.20	20.28	24.52	26.67	25.60	18.38	19.67	19.03
N3	111	111	111	20.46	20.26	20.36	22.16	26.73	24.45	16.62	19.40	18.01
N4	111	112	112	20.66	20.38	20.52	17.32	18.62	17.97	13.45	14.19	13.82
SEm±	1.564	1.313	1.021	0.264	0.258	0.185	0.383	0.206	0.217	0.435	0.499	0.312
CD(0.05)	4.52	3.79	2.89	NS	NS	NS	1.11	0.59	0.62	1.26	1.30	NS
Pooled Interaction		SEm±	CD(0.05)		SEm±	CD(0.05)		SEm±	CD(0.05)		SEm±	CD(0.05)
E within N		1.973	NS		0.326	NS		0.451	1.352		0.613	NS
N within E		2.283	NS		0.413	NS		0.486	1.374		0.699	NS

E_1- Direct seeding (20 cm in solid row), **E_2**- Direct seeding by punji method (20cm x 20cm), **E_3**-Ttransplanting1 seedling at 2 leaf stage(20 cm x 20 cm), **E_4**- Transplanting 2-3 seedlings at 4 leaf stage (20 cm x 10 cm), **E_5**- Transplanting 2-3 seedlings at 4 leaf stage (20 cm x 20 cm), **N_1**- 30 kg Nitrogen ha $^{-1}$, **N_2**- 60 kg Nitrogen ha $^{-1}$, **N_3**- 90 kg Nitrogen ha $^{-1}$, **N_4**- 120 kg Nitrogen ha $^{-1}$, **NS**- non-significant S – Significant.

Table 4: Grain and straw yield (kg ha^{-1}) and harvest index (HI) as influenced by different treatments under aerobic condition in summer

Treatment	**Grain yield (kg ha^{-1})**			**Straw yield (kg ha^{-1})**			**Harvest index (%)**		
Establishment methods	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
E1	2875	3224	3049	4140	4665	4403	39.58	39.58	39.58
E2	3784	4514	4149	5109	6081	5595	41.93	41.80	41.87
E3	3643	4392	4017	4908	5775	5341	42.30	42.58	42.44
E4	4563	5093	4828	5352	5817	5584	45.68	45.93	45.81
E5	4760	5142	4951	5626	5938	5782	45.80	45.80	45.80
SEm±	47.962	66.919	41.166	77.529	68.006	51.565	0.007	0.800	0.500
CD(0.05)	156.39	218.20	123.40	252.80	221.75	154.57	0.02	3.00	2.00
Nitrogen Levels (kg h^{-1})									
N1	2888	3148	3018	4068	4376	4222	41.22	41.28	41.25
N2	3808	4376	4092	4924	5595	5259	43.06	43.04	43.05
N3	4497	5054	4776	5651	6239	5945	43.60	43.80	43.70
N4	4507	5313	4910	5467	6411	5939	44.34	44.42	44.38
SEm±	53.445	50.550	36.782	55.425	75.166	46.695	0.006	0.500	0.400
CD(0.05)	154.34	145.98	104.04	160.05	217.06	132.07	0.02	2.00	1.00

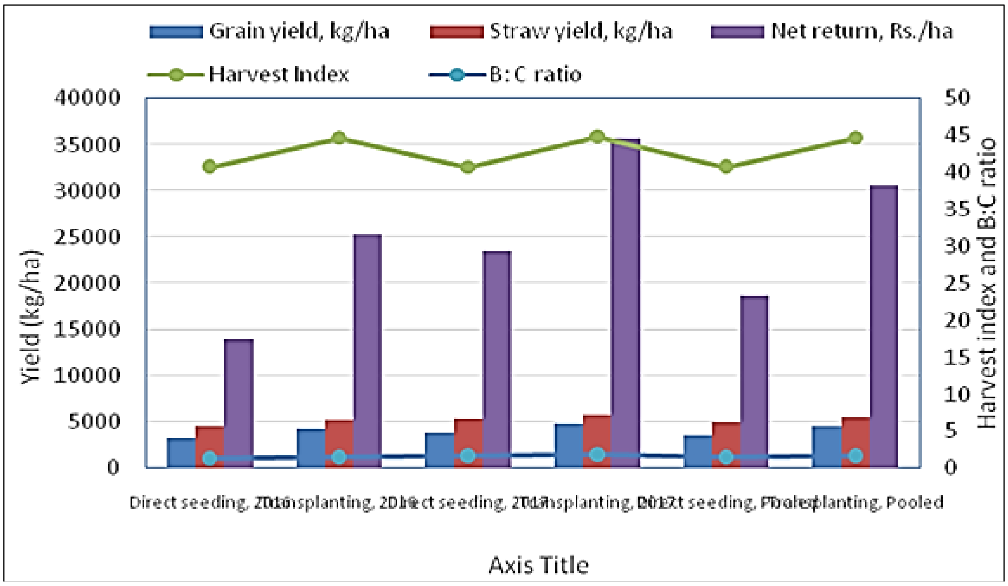

Fig 1: Yield and economics indices as influenced by direct seeding and transplanting

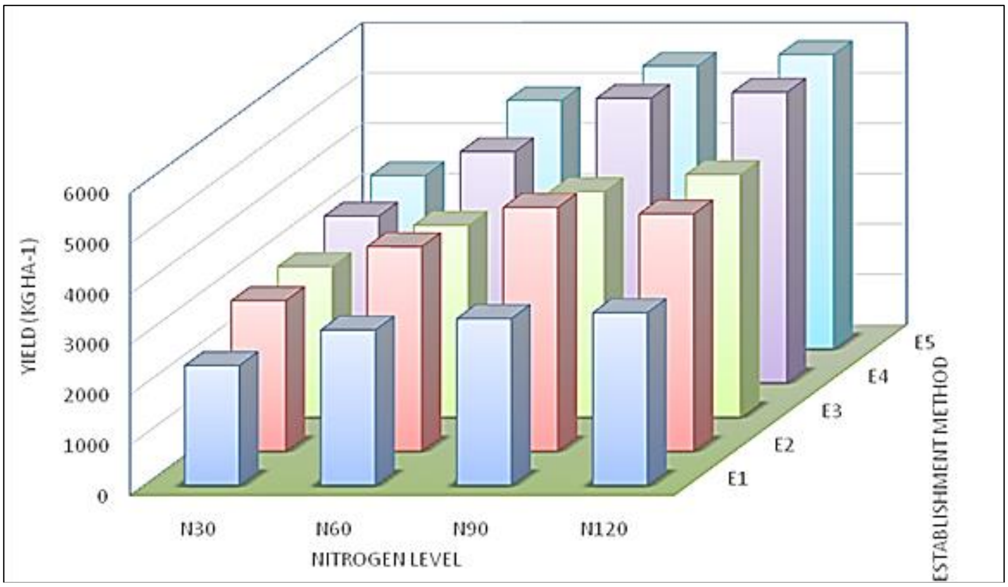

Fig 2: Interaction effect of establishment methods x nitrogen levels (E×N) on grain yield (kg ha^{-1}) under aerobic condition in summer

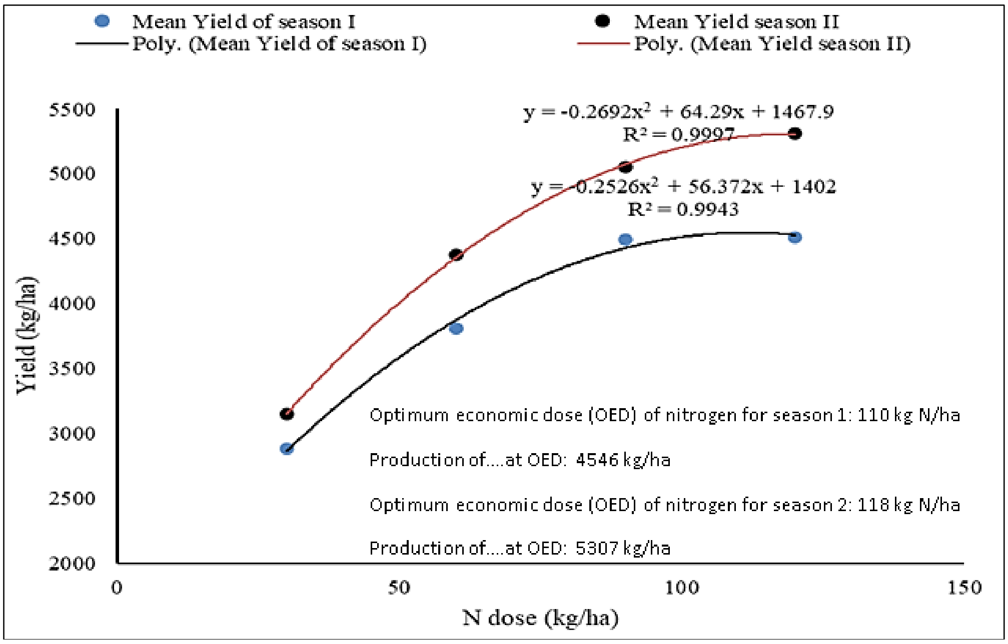

Fig 3: Functional relationship of grain yield and nitrogen under irrigated aerobic condition during summer.

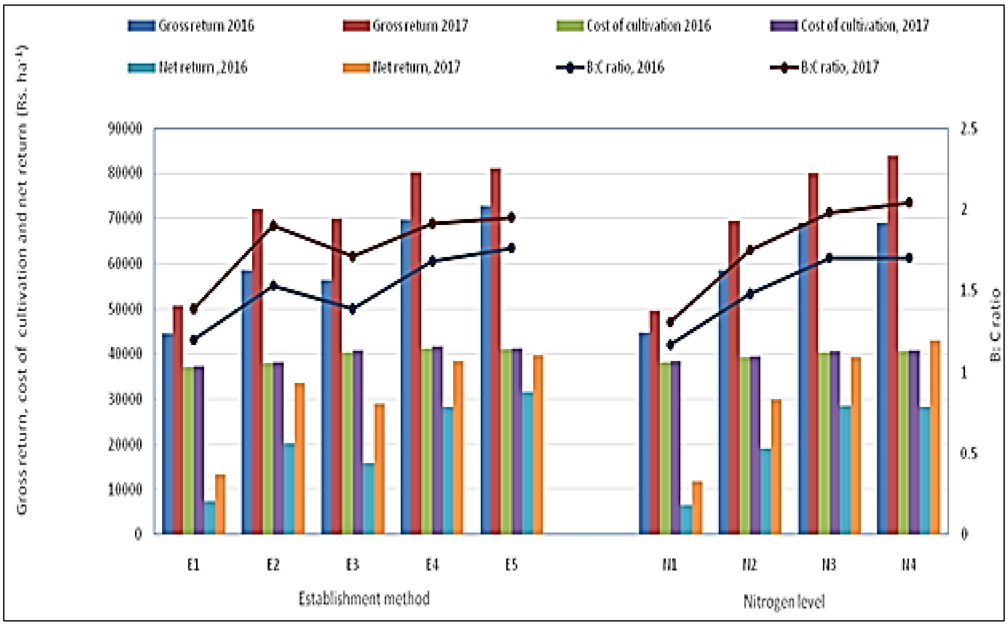

Fig 4: Economics of rice cultivation as influenced by different treatments under aerobic condition in summer

Conclusion

The aerobic rice variety Pyari, showed better adaptability to establishment method, aerobic transplanting with 2-3 seedlings at 4 leaf stage in square geometry of 20 cm x 20 cm) by recording higher values of growth and yield parameters besides being economically remunerative. It responded to application of nitrogen and optimum economic dose ranged from 110 to 118 kg N/ha, the functional relation being quadratic.

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