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Root Characteristics of Aerobic Rice (*Oryza sativa L.*) under Aerobic and Anaerobic Conditions as Influenced by Establishment Methods and Nitrogen Levels

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A B S T R A C T

A field experiment was conducted at Agronomy Main Research Farm, Department of Agronomy, Odisha University of Agriculture and Technology in summer 2016 and 2017 to study the root characteristics of aerobic rice under different establishment methods and nitrogen levels under two hydrological situations of aerobic and anaerobic during summer. The experiment was laid out in split plot design with three replications comprising five establishment methods, under aerobic condition, like direct seeding in solid rows 20 cm apart (E_1), direct seeding by *punji* method (dibbling) at20cm 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 with 2-3 seedlings at 4 leaf stage at 20 cm x 20 cm (E_5), allotted to main plots, and 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} were allotted to sub plots. Similar set of treatments was employed in an observation strip (un replicated) under anaerobic condition where sprouted seeds were sown directly in puddle (anaerobic) soil in E_1 and E_2 treatment and transplanted under puddle anaerobic condition in E_3,E_4 and E_5 treatments for comparison. The study revealed that root traits like root length, spread, root length: root spread ratio and shoot: root ratio were more under aerobic un puddle condition while the traits like root dry weight and volume were more in anaerobic puddle condition. Transplanting in a square geometry of 20 cm x 20 cm spacing with 2- 3 seedlings $hill^{-1}$ at 4 leaf stage (E_5) in both the hydrological conditions of aerobic and anaerobic produced significantly higher values of different root trait.All the root characters increased with each incremental dose of nitrogen in both the hydrological situations of aerobic and anaerobic.

Introduction

With water scarcity looming over the earth, rice will need to grow under the management options requiring lesser water without compromising the yield. Aerobic rice is an attractive option to farmer to replace traditional transplanting method and there is a gradual shift in system of rice cultivation from traditional transplanted anaerobic to aerobic system. Though, direct seeding of rice, either broadcast or in solid rows, is common, its performance under varying geometry and density both under direct seeding and transplanting under un puddle un flooded aerobic condition becomes worth to examine as the aerobic rice cultivation largely depends on initial plant establishment. Roots are the key morphological features of crop that provides anchorage to plants and influences its capacity to yield by transmitting plant nutrients and water from soil as a conduit to meet nutritional and transpiration need of plant to maintain soil-plant-water-atmosphere continuum. Roots remain in direct contact with soil and are therefore, potentially the first sites of damage as well as first lines of defense.The performance of root with respect to penetration and lateral spread are variety and environment dependent (Uphooff and Amiharisoa, 2007 and Kato and Okami, 2011). The response of root growth and development to its environment is an important aspect for understanding the aerobic adaptation (Bengough *et al*, 2011). Further, the altered environment from aerobic to anaerobic also changes the form of nutrient availability present in soil. It necessitates to quantify the nitrogen requirement for aerobic rice with particular reference to establishment methods and management conditions. Hence present investigation was planned and carried out to assess theroot characteristics of aerobic rice under different establishment methods and nitrogen levels under two hydrological situations.

Materials and Methods

Field experiment was carried in the year 2016 and 2017 during summerat Agronomy Research Farm, Department of Agronomy, College of Agriculture, OUAT, Bhubaneswar, Odisha. The soil of the experimental site was sandy loam, moderately acidic in nature (pH 5.7), 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 need. The mean monthly temperature during the period of growth ranged from a minimum of 14.5 ^{o} C in January to maximum of 40.8 ^{o} C in May and the evaporation from 3.4 in January to 8.0 mm d^{-1} in the month of May.

The experiment was laid out in split plot design under 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) method at20cm x 20cm spacing (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 spacing (E_3), 2-3 seedlings at 4 leaf stage at 20 cm x 10 cm spacing (E_4) and 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. Similar set of treatments was employed in an observation strip (un replicated) under anaerobic condition where sprouted seeds were sown directly in puddle (anaerobic) soil in E_1 and E_2 treatments and transplanted under puddle anaerobic condition in E_3,E_4 and E_5 treatments for comparison.

The land under aerobic experiment was ploughed at optimum moisture condition where as under anaerobic observation strip, the land was puddled. Irrigation channels were made to carry out irrigation. A set of buffer channel was also laid out to avoid lateral seepage of water to adjoining aerobic experimental site. In aerobic hydrological situation the crop was established as per treatment by direct seeding on pulverised soil (E_1 and E_2) and in transplanting treatment (E_3, E_4 and E_5) seedlings under un puddle condition were transplanted 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.

Root samples for study of various traits were collected following the method as given by Mishra and Ahmed (1998). Data on different root characters like root length, spread and dry weight and volume were taken periodically and various were computed as per method given by Kota and Okama (2010). The data were subjected to analysis of variance (ANOVA) as out lined by Gomez and Gomez (1984). The comparison of treatment means was made by critical difference (CD) at 5 percent level of significance.

Results and Discussion

Root length

Root length increased with age up to 90 days after sowing (DAS) and decreased marginally, thereafter at harvest irrespective of treatments employed (Table 1 & 2). On an average the mean root length under aerobic condition was more compared to anaerobic condition in both the years of study. Among the establishment method, roots were significantly the longest at 90 DAS in treatment E_5 where rice was transplanted under un puddle (aerobic) and puddle (anaerobic) condition at 20 cm x 20 cm spacing with 2- 3 seedlings $hill^{-1}$ at 4 leaf stage. The corresponding length 33.5 and 33.6 cm in 1st year and 2^{nd} year under aerobic and 27.7 and 25.5 cm under anaerobic (puddle) condition during the same period. The length increased at a faster rate during initial stages of growth in all the treatments.

Root length found to increase with increasing levels of nitrogen and it was the longest (33.2 cm in 2016) and (34.2 cm in 2017) at 90 DAS. Similar trend was also observed under anaerobic condition with lower values of 25.7 and 25.6 cm in respective years of study at 120 kg N/ha. The results are in conformity of earlier findings of Singh *et al.,* (2015).

Patel *et al.,* (2007) concluded that adaptability of rice genotype to aerobic situation is associated with fewer arrenchymatous cells, thickened roots and larger xylem area Kato, *et al.,* (2010) reported that the longer roots under aerobic un flooded situation shows its adaptive ability towards changed moisture regime and assimilate partitioning under mild water stress. Sandhu *et al.,* (2012) concluded that increased root length is indicative of aerobic adaptation in terms of water acquisition. The response of root traits to applied nitrogen is indicative of its ability to remove more nutrient and water from the soil.

Root spread

Similar increasing trend with age of crop was noticed with respect to root spread up to 90 DAS which reduced at harvest marginally both under aerobic and anaerobic conditions (Table 3 & 4). Root spread was, however, more under aerobic un puddle condition than under anaerobic puddle one. The maximum horizontal spread under E_5 treatment measuring 25.3 and 26.1 cm in 2016 and 2017, respectively was recorded 90 days after sowing of seeds under aerobic condition up by 19.3 and 21.9 % over anaerobic puddle condition. Spread found to increase with nitrogen levels with higher values of 22.9 and 23.7 cm under aerobic and 18.4 and 18.6 cm under anaerobic condition during 2016 and 2017, respectively at 120 kg N/ha. Uphoof and Amiharisoa (2007) reported that lateral spread in rice is genotype and environment dependant. Kumaraswamy, *et al.*, as early as 1977, found that rice roots a depth of 16 -24 cm with corresponding lateral distance of 10 cm to 15 cm. Further, Kamath (1970) classified rice varieties into shallow spreading, deep spreading, and shallow compact and deep compact root system. In this study, the aerobic rice variety Pyari exhibited higher values under aerobic hydrological situation than the anaerobic one, which is indicative of their changed distribution pattern.

Root length- root spread ratio is a good measure of compactness. It was found to increase up to 30 DAS and decreased gradually, thereafter towards harvest (Fig. 1 and 2). Data further revealed that the ratio was more under direct seeding treatments (mean of E_1 and E_2) compared to transplanting (mean of E_3+ E_4+ E_5) in both the hydrological conditions. The corresponding mean values under aerobic and anaerobic conditions were 1.26 and 1.24 and 1.13 and 1.10, respectively. The altered physical condition due to Puddle soil, reduces soil porosity and increases compactness of soil, thereby reducing the ratio in anaerobic condition. Similar trend was also noticed by Lenka and Gulati (2015).

Root dry weight

Root dry weight increased progressively with age and attained its highest values 90 days after sowing under both the establishment environment, the values being higher under anaerobic condition (Table 5 and 6). Significantly the highest root dry weight of 102.5 and 109.8 g m^{-2} was recorded at 90 DAS during 1st and 2nd year of study, respectively under aerobic transplanting (E_5) treatment.

Table.1 Periodic root length (cm) as influenced by establishment methods and nitrogen levels under aerobic condition

Periodic observation, Days After Sowing (DAS)

Treatment	15		30		60		90		At harvest	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Establishment methods										
E_1	2.74	2.82	10.98	10.88	18.90	18.50	29.19	29.25	25.45	24.67
E_2	2.75	2.94	10.53	11.63	17.26	18.00	32.26	31.85	28.67	26.54
E_3	2.62	2.67	7.46	6.40	20.33	20.45	32.87	32.96	28.45	27.64
E_4	2.71	2.70	6.65	6.85	19.05	19.50	31.86	32.05	27.62	28.46
E_5	2.65	2.68	8.28	6.69	21.65	20.28	33.49	33.56	29.52	29.67
SEm±	0.050	0.065	0.107	0.151	0.419	0.486	0.860	0.583	0.532	0.510
CD (0.05)	NS	NS	0.35	0.49	1.37	1.58	NS	1.90	1.73	1.66
Nitrogen Levels										
N_1	2.23	2.36	7.92	7.27	17.81	17.24	30.44	29.38	26.45	24.77
N_2	2.55	2.67	8.48	8.08	19.06	18.71	31.53	31.36	27.86	26.99
N_3	2.85	2.93	9.00	8.95	20.12	20.06	32.58	32.84	28.41	28.21
N_4	3.14	3.09	9.73	9.66	20.76	21.38	33.18	34.15	29.04	29.62
SEm±	0.049	0.062	0.123	0.157	0.453	0.250	0.676	0.712	0.706	0.498
CD (0.05)	0.14	0.18	0.36	0.45	1.31	0.72	1.95	2.06	NS	1.44

Table.2 Periodic root length (cm) as influenced by establishment methods and nitrogen levels under anaerobic condition periodic observation, Days After Sowing (DAS)

Treatment	15		30		60		90		At harvest	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Establishment methods										
E_1	1.84	1.92	7.98	7.88	15.90	15.50	21.26	21.33	18.12	17.14
E_2	1.92	2.06	7.53	7.65	14.26	15.26	23.42	22.25	19.25	18.55
E_3	1.62	1.82	5.34	4.40	17.03	16.45	24.68	23.68	20.12+	19.38
E_4	1.76	1.88	4.65	4.76	17.35	17.50	26.54	24.25	20.38	20.15
E_5	1.54	1.76	5.46	4.67	18.65	18.28	27.65	25.49	21.49	21.62
Nitrogen Levels										
N_1	1.56	1.62	4.43	5.77	15.81	15.32	19.49	19.52	18.25	18.32
N_2	1.67	1.69	5.98	6.56	16.06	16.66	21.36	21.42	19.63	19.45
N_3	1.72	1.86	6.49	7.42	17.12	18.42	23.67	23.56	20.56	20.65
N_4	1.87	1.95	6.97	7.87	17.78	18.72	25.69	25.63	22.68	22.63

Table.3 Periodic root spread (cm) as influenced by different establishment methods and nitrogen levels under aerobic condition
Periodic observation, Days After Sowing (DAS)

Treatment	15		30		60		90		At harvest	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Establishment methods										
E_1	1.56	1.62	5.62	5.72	12.63	13.24	21.24	21.73	20.00	20.21
E_2	1.76	1.63	5.54	5.83	12.52	13.62	22.46	22.06	21.32	21.67
E_3	1.35	1.59	5.63	6.02	14.63	15.53	24.34	26.67	22.43	23.57
E_4	1.58	1.57	4.26	5.63	13.57	15.42	23.58	25.32	21.56	22.37
E_5	1.51	1.62	4.34	5.74	14.12	15.73	25.32	26.07	23.38	24.47
SEm±	0.024	0.030	0.112	0.116	0.276	0.268	0.500	0.503	0.427	0.310
CD (0.05)	0.08	NS	0.36	NS	0.90	0.88	1.63	1.64	1.39	1.01
Nitrogen Levels										
N_1	1.22	1.55	3.78	5.74	12.45	12.38	22.11	22.22	20.27	20.92
N_2	1.48	1.59	4.71	5.78	13.25	13.86	23.30	24.10	21.66	22.17
N_3	1.74	1.64	5.14	5.80	13.69	15.92	23.61	25.30	22.16	23.06
N_4	1.91	1.65	5.88	5.84	14.59	16.67	24.54	25.86	22.86	23.68
SEm±	0.016	0.029	0.108	0.097	0.346	0.308	0.474	0.444	0.493	0.321
CD (0.05)	0.05	0.08	0.31	NS	1.00	0.89	1.37	1.28	1.42	0.93

Table.4 Periodic root spread (cm) as influenced by establishment methods and nitrogen levels under anaerobic condition Periodic observation, Days After Sowing (DAS)

Treatment	15		30		60		90		At harvest	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Establishment methods										
E_1	1.23	1.25	4.69	4.61	10.84	10.74	17.56	17.83	15.67	15.72
E_2	1.32	1.35	4.38	4.74	10.68	10.53	18.36	18.45	16.42	16.57
E_3	1.28	1.33	4.51	4.14	11.55	11.65	20.38	20.61	18.73	18.26
E_4	1.31	1.41	3.85	4.36	10.82	11.37	19.67	19.08	17.65	17.45
E_5	1.34	1.49	4.05	4.52	11.64	11.84	21.16	21.35	19.35	19.55
Nitrogen Levels										
N_1	1.05	1.09	3.27	4.23	10.24	9.64	18.63	18.27	16.25	16.38
N_2	1.16	1.17	3.97	4.36	10.88	10.45	19.46	19.63	17.56	17.72
N_3	1.29	1.26	4.35	4.48	11.26	12.46	19.74	20.74	17.73	17.92
N_4	1.43	1.44	4.62	4.62	12.28	12.82	20.59	20.86	18.44	18.55

Table.5 Periodic root dry weight (g m^{-2}) as influenced by establishment methods and nitrogen levels under aerobic condition Periodic observation, Days After Sowing (DAS)

Treatment	15		30		60		90		At harvest	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Establishment methods										
E_1	12.61	10.03	15.01	15.58	40.68	44.12	54.43	65.75	52.72	61.13
E_2	16.88	12.08	25.03	16.80	46.05	43.08	51.68	62.30	50.13	58.80
E_3	11.78	11.15	17.00	15.35	42.60	41.08	53.55	56.24	51.08	54.83
E_4	12.70	11.10	21.51	20.35	50.37	58.33	72.11	78.00	62.35	64.05
E_5	18.20	20.61	28.30	29.17	68.99	74.75	102.50	109.84	99.60	104.53
SEm±	0.281	0.286	0.334	0.450	0.945	10.10	1.452	1.454	1.290	1.564
CD (0.05)	0.92	0.93	1.09	1.47	3.09	3.29	4.74	4.74	4.21	4.53
Nitrogen Levels										
N_1	13.31	11.52	19.97	17.50	47.48	49.37	64.08	68.83	56.17	64.19
N_2	14.28	12.63	21.08	19.30	48.85	51.67	66.60	73.48	59.36	67.82
N_3	14.93	13.55	21.98	20.06	50.70	53.36	67.80	76.66	67.14	70.54
N_4	15.21	14.27	22.44	20.93	51.92	54.70	68.92	78.74	70.04	72.11
SEm±	0.179	0.290	0.479	0.442	1.092	12.43	1.714	1.772	1.228	1.569
CD (0.05)	0.52	0.84	1.38	1.28	3.15	35.89	NS	5.12	3.55	4.53

Table.6 Periodic root dry weight (g m^{-2}) as influenced by establishment methods and nitrogen levels under anaerobic condition Periodic observation, Days After Sowing (DAS)

Treatment	15		30		60		90		At harvest	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Establishment methods										
E_1	27.87	25.84	30.57	30.88	58.68	59.65	74.43	80.34	69.72	76.56
E_2	32.14	29.56	40.65	34.80	62.05	58.45	69.68	77.58	69.13	73.96
E_3	27.77	26.58	32.54	31.35	58.60	56.78	70.55	71.69	68.08	69.99
E_4	27.97	26.69	36.86	35.78	69.37	73.78	90.11	93.54	78.35	79.64
E_5	33.67	35.93	43.69	44.64	87.99	89.96	120.50	124.96	117.60	119.67
Nitrogen Levels										
N_1	28.87	27.52	35.13	33.50	63.48	64.58	81.08	83.91	77.67	79.64
N_2	29.98	28.63	36.65	35.30	64.96	66.86	83.60	88.85	79.36	82.98
N_3	29.97	29.55	37.32	36.06	66.70	68.96	86.81	91.87	83.14	85.86
N_4	30.78	29.84	37.82	36.93	67.92	69.89	86.92	93.98	86.04	87.59

Table.7 Periodic root volume (cc $hill^{-1}$) as influenced by establishment methods and nitrogen levels under aerobic condition
Periodic observation, Days After Sowing (DAS)

Treatment	15		30		60		90		At harvest	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Establishment methods										
E_1	5.67	4.78	6.45	6.85	16.25	17.10	21.63	22.36	17.56	17.48
E_2	5.52	4.82	7.23	7.45	17.63	18.48	20.57	21.85	16.32	16.73
E_3	4.28	3.82	6.85	6.56	19.45	19.62	23.67	23.67	17.50	17.67
E_4	3.76	3.94	6.76	6.66	18.62	18.92	22.23	22.59	16.00	17.82
E_5	4.78	4.63	7.17	7.24	18.74	19.45	24.46	24.32	17.62	18.48
SEm±	0.053	0.072	0.084	0.126	0.429	0.406	0.552	0.417	0.451	0.268
CD (0.05)	0.17	0.24	0.27	0.41	1.40	1.32	1.80	1.36	NS	0.87
Nitrogen Levels										
N_1	2.79	2.41	6.43	5.49	17.71	16.17	21.50	20.28	15.71	15.64
N_2	3.02	2.84	6.72	6.62	18.01	18.22	22.29	22.28	16.70	17.46
N_3	3.21	3.22	7.05	7.53	18.29	19.48	22.79	23.92	17.39	18.13
N_4	3.39	3.53	7.37	8.17	18.54	20.99	23.47	25.35	18.19	19.31
SEm±	0.064	0.060	0.091	0.117	0.332	0.372	0.350	0.294	0.384	0.354
CD (0.05)	0.18	0.18	0.26	0.34	NS	1.07	1.01	0.85	1.11	1.02

Table.8 Periodic root volume (cc hill[-1]) as influenced by establishment methods and nitrogen levels under anaerobic condition Periodic observation, Days After Sowing (DAS)

Treatment	15		30		60		90		At harvest	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Establishment methods										
E_1	7.07	7.18	11.95	12.25	17.25	22.78	27.63	27.76	23.12	23.18
E_2	11.02	10.32	12.73	12.78	23.63	23.98	26.57	27.45	22.00	22.23
E_3	7.08	7.32	12.35	12.06	24.85	24.95	29.17	28.97	23.00	22.77
E_4	7.06	7.34	12.16	12.06	24.12	24.32	28.23	28.29	22.13	22.98
E_5	10.28	10.13	12.67	13.34	24.24	25.75	29.76	30.32	24.35	25.89
Nitrogen Levels										
N_1	7.79	7.91	11.93	10.99	23.71	22.17	27.00	26.28	20.79	20.74
N_2	8.67	7.94	11.99	11.98	24.01	24.22	27.79	27.78	22.70	22.86
N_3	8.72	8.72	12.95	12.97	24.29	25.48	28.29	29.92	23.39	23.63
N_4	8.89	9.03	12.97	13.97	24.59	26.99	28.87	30.95	24.19	24.71

Fig.1 Periodic root length- spread ratio as influenced by establishment methods and nitrogen levels under aerobic condition (mean of 2016& 2017)

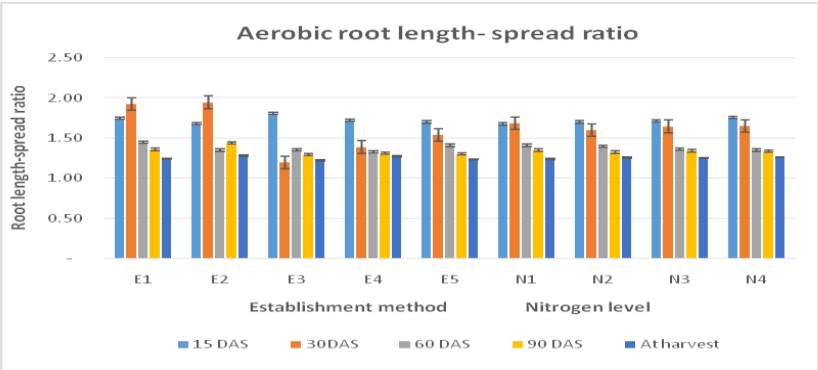


Fig.2 Periodic root length - spread ratio as influenced by establishment methods and nitrogen levels under anaerobic condition (mean of 2016 & 2017)

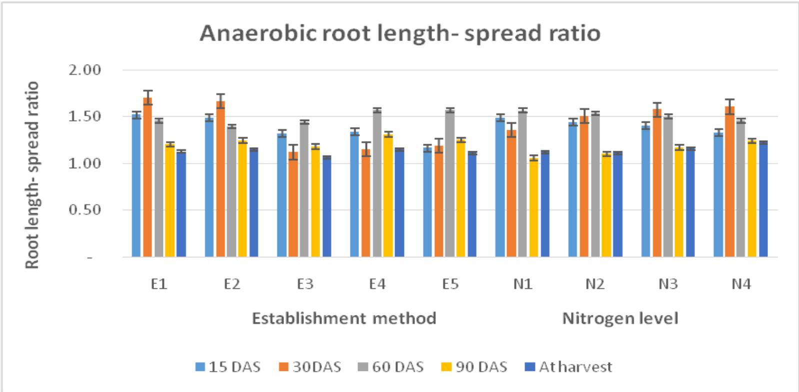


Fig.3 Periodic shoot-root ratio as influenced by establishment methods and nitrogen levels under aerobic condition (mean of 2016& 2017)

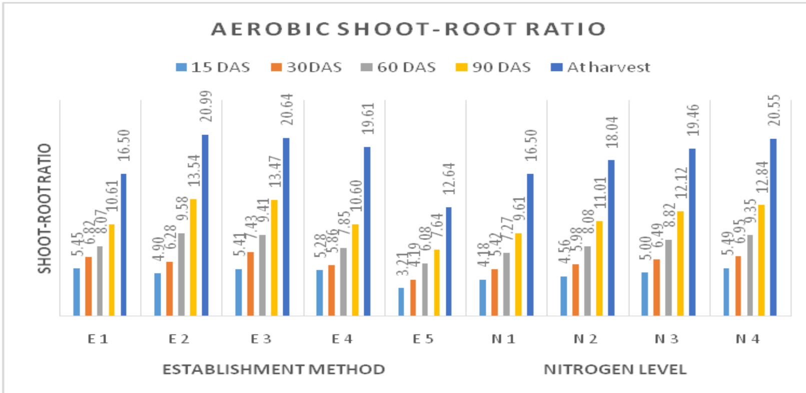
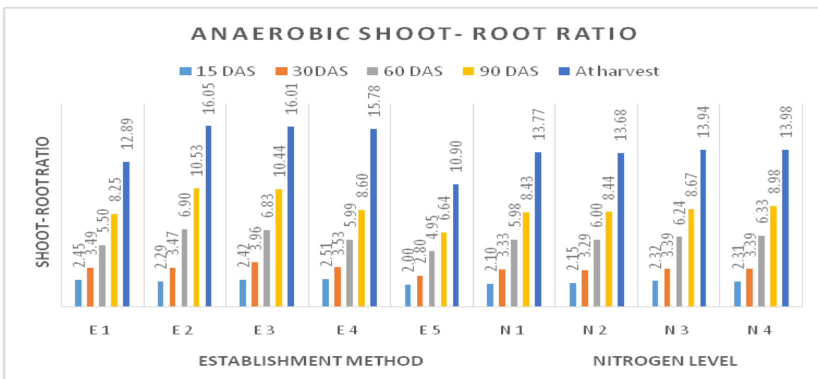


Fig.4 Periodic shoot-root ratio as influenced by establishment methods and nitrogen levels under anaerobic condition (mean of 2016 & 2017)



However, the dry weight was more when same treatment was employed under anaerobic puddle condition weighing 120.5 and 125.0 g m^{-2} up by 17.5 and 13.5 % in 2016 and 2017, respectively. Application of nitrogen registered higher root dry weight with increasing N- levels up to 90 DAS and decreased at harvest. The values at 120 kg N/ha under, aerobic and anaerobic conditions were 68.9 and 78.7 and 86.9 and 94.0 g m^{-2} in 2016 and 2017, respectively. The reduction in root traits at harvest is due to degeneration of roots and crop senescence process.

Root volume ($hill^{-1}$)

Higher root dry weight also resulted in higher root volume at all the periods of observation. It was also higher under anaerobic condition than aerobic one (Table 7 & 8). Volume increased up to 90 DAS and decreased at harvest. Among the methods the roots in treatment E5, occupied more volume, and higher values of 24.5 and 24.3 cc in 2016 and 2017 under aerobic and 28.9 and 29.2 cc under anaerobic condition were measured at 90 DAS during respective years of study. Root dry weight increased with successive dose of nitrogen. It was 70.0 and 72.1 g m^{-2}in 2016 under aerobic and 86.0 and 87.6 g m^{-2} under anaerobic during the same period. Similar higher values have also been reported by Upendra Rao *et al.,* (2016)

Shoot-root ratio

Shoot-root ratio was found to increase with advancement of age (Fig. 3& 4). Treatment direct seeding in aerobic condition as punji (dibbling- spot seeding) at 20 cm x 20 cm spacing observed significantly the highest (20.56 and 21.41) shoot-root ratio at harvest in 2016 and 2017, respectively but it was at par with (E_3) where 2-3 seedlings were transplanted 20 cm x 20 cm spacing with 2- 3 seedlings hill^{-1} at 2 leaf stage. The trend is indicative of more of shoot growth when the seed were sown with higher density. The shoot-root ratio increased with each incremental doses of nitrogen and highest shoot-root ratio of 20.69 was observed in 1st year and 20.40 in 2nd year at harvest when 120kg N ha^{-1} applied.

Under anaerobic methods of transplanting, the highest (15.00 in 2016 and 17.09 in 2017) shoot-root ratio was recorded in E_2 at harvest, respectively. Among the nitrogen levels, 120kg N ha^{-1} recorded maximum (13.15 and 14.80) shoot-root ratio in both the years of study at harvest.

In conclusion the aerobic rice variety displayed its adaptive ability in aerobic hydrological situation by measuring higher root traits of length, spread and length-spread ratio. Rice traditionally adapted to anaerobic flooded condition, in spite of released as aerobic rice, the variety showed its competitive ability to respond to puddle-flooded condition and produced more root dry weight and root volume**.** It also responded to increased level of nitrogen application up to 120 kg/ha in both the situations. Further, the changed root architecture under both the situations is indicative of crops response to altered physical condition and establishment methods. Transplanting under un puddle un flooded water regime can be an option in the areas where water is not sufficient enough to raise the rice crop successfully under puddle flooded condition with comparable yield.

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