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Studies on root growth, yield and NPK uptake of rice as influenced by different establishment techniques and N-levels

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Abstract
A field experiment was conducted for two consecutive years 2015-16 and 2016-17 at Agricultural Research Station, Ragolu, Andhra Pradesh, with four establishment techniques Viz., dry direct sown rice, aerobic rice, machine planting and normal (manual) planting as main plots and five nitrogen levels (90,120,150,180 and 210 kg ha^{-1}) as sub plots in a split plot design on sandy clay loam soil. The study revealed that among crop establishments of rice root volume, root dry weight, uptake of N, P and K at harvest, grain yield and straw yield of rice was significantly higher with machine planting and these parameters were the lowest with aerobic rice. Among the nitrogen levels studied, the maximum root volume, root dry weight, uptake of N, P and K at harvest, grain yield and straw yield of rice were recorded with application of nitrogen @ 210 kg N ha^{-1} and were comparable with application of 180 and 150 kg N ha^{-1} during both the years of study.

Keywords: Rice, crop establishment techniques, N levels, NPK uptake, root growth and yield

Introduction
Rice is a staple food crop for about 3 billion people, mostly living in Asia (Zhang *et al*., 2009) [18]. India is the second largest producer and consumer of rice in the World. The area under rice crop in our country is about 43.95 million ha with a production of 106.54 million tonnes and productivity of 2424 kg ha^{-1} (Ministry of Agriculture, 2014) [7]. With the current population growth rate, the rice requirement of India by the year 2025 would be around 125 million tonnes (Kumar *et al*., 2009). Rice production under current inputs and technology is likely to fail to meet the projected demand (Leeper, 2010). Though the conventional method of rice establishment is the best to achieve good yields (Sandhya Kanthi *et al*., 2014) [10], labour crisis, reduced water availability and other disadvantages associated with this method at present forced to identify alternate methods of rice establishment which saves energy, water and time without reduction in yield. Nutrient management must be sound and effective for achieving the production targets on sustainable basis. As nitrogen is the king pin of rice nutrition, optimum nitrogen management is highly imperative to realize the full potential of improved methods of crop establishment because of variations in N dynamics under different establishment methods. As the information on nitrogen requirement of rice under varied establishment techniques for realizing optimum yield is meagre, the present experiment was under taken to study the effect of different establishment techniques and nitrogen levels on root growth, Nutriet uptake and yield of rice.

Material and Methods
The present investigation was undertaken during 2015-16 and 2016-17 at Agricultural Research Station, Ragolu in North coastal agro climatic zone of Andhra Pradesh, situated at $18^0.24^'$ N latitude, $83^0.84^'$ E longitude and at an altitude of 27.0 m above the mean sea level. The experimental soil was sandy clay loam in texture, neutral in reaction, low in organic carbon, low in available nitrogen, medium in available phosphorus and potassium. The experiment was laid out in a split plot design, replicated thrice with four crop establishment techniques as main plots and five nitrogen levels as sub plots. The main plot treatments consisted of (i) Dry direct sown rice (ii) Aerobic rice (iii) Planting with machine and (iv) Normal planting. The subplot treatments consisted of five nitrogen levels (90, 120, 150, 180 and 210 kg N ha^{-1}). The cultivar used in the study for rice was MTU 1001(vijetha).
Nitrogen in the form of urea was applied as per the treatments in three equal splits as one third basal, one third at active tillering and one third at panicle initiation stage. A common dose of

60 kg $P_2 O_5$ and 50 kg K_2O ha^{-1} was applied uniformly through single super phosphate and muriate of potash, respectively. Entire dose of phosphorus was applied as basal. Whole potassium was applied in 2 splits as basal and 1/3 at panicle initiation stage along with urea. A common dose of $ZnSO_4$ @ 20 kg ha^{-1} was applied to all the treatments uniformly as basal.

The sowing of dry direct sown rice(DDS rice) and aerobic rice was done in lines in the non puddled and non flooded soil at a spacing of 20 x10 cm. Nursery was raised in trays for planting with machine technique on the same day of sowing of dry direct sown rice and aerobic rice. Tray nursery was used to suit mechanical transplanting. Seedlings from tray nursery of 14 days age were machine transplanted to ensure uniform depth and seedlings per hill at a spacing of 30cm x 18cm. Nursery was raised on thoroughly puddled and levelled nursery bed for normal planting method of establishment, on the same day of sowing of dry direct sown rice and aerobic rice. Nursery was raised upto the age of 25 days and transplanted manually at a spacing of 20 cm x 15 cm. In direct seeded rice and transplanting rice, weeds were controlled by applying pendimethalin @ 2.5 litres ha^{-1} within 2 days of sowing and transplanting of rice and bispyribac sodium @250 ml ha^{-1} at 30 days after sowing and 25 days after transplanting of rice, respectively. The left over weeds were removed by 2 hand weedings in direct seeded rice techniques and 1 hand weeding in transplanted rice techniques respectively.

The observations on Root volume was recorded at flowering stage by water displacement technique (Bridgit and potty, 2002) [2]. Five plants were uprooted carefully with the roots in each plot and then separated from the stem portion from first node of the plants. The roots scooped along with soil and whole plant were washed in running water carefully and detached from the nodal bases. Any excess moisture adhering on the surface of the roots was removed wiping with blotting paper. Then, the volume of the roots was measured by volume displacement method and expressed as cc $hill^{-1}$. For recording root dry weight (g/hill), root samples were dried in shade and then in hot-air oven till a constant weight is arrived and expressed in g $hill^{-1}$. The crop was harvested manually with the help of sickle when the grain almost matured and the straw had turned yellow and data on grain and straw yield was recorded. The plant samples collected at harvest were analysed for N uptake (microkjeldahl method), P uptake (vanadomolybdate phosphoric yellow colour method) and K uptake (flame photometry).All the data were subjected to analysis of variance (ANOVA) as per the standard procedures. The comparison of treatment means was made by critical difference (CD) at P=0.05.

Results and Discussions

Root Volume (cc $hill^{-1}$)

The root volume measured at flowering stage was significantly influenced by both crop establishment techniques and nitrogen levels during both the years of study and the interaction effect of crop establishment techniques and nitrogen levels was not significant during both the years (Table 1).

Among the establishment techniques, it was observed that, root volume was superior with machine planting over other establishment techniques and it was on par with normal planting during both the years of study. Lowest root volume was observed with aerobic rice and it was on par with DDS rice and normal planting. As reported by Upendra rao *et al.* (2016) [17] plants grown under continuous flooding on well prepared field, where the mechanical resistance was lowest, the root volume was more as compared to reduced water regimes.

During both the years of experimentation, nitrogen levels significantly affected the root volume measured at flowering stage. Maximum root volume recorded with 210 kg N ha^{-1}. However the root volume showed significant increase with increasing nitrogen level upto 150 kg N ha^{-1} only and further increase in N level did not influence the root volume conspicuously. Whereas the root volume was lowest with the application of N @ 90 kg N ha^{-1}.

Root Dry weight (g $hill^{-1}$)

Root dry weight recorded at flowering stage was significantly influenced by both crop establishment techniques and nitrogen levels during both the years, however their interaction was found not significant during both the years (Table 1).

Among the establishment techniques, it was observed that, root dry weight was significantly superior in planting with machine as compared to other establishment techniques and it was on par with normal planting during both the years of study. Lowest root dry weight was observed with aerobic rice. Less intra plant competition would have enabled the plants to have more physiological activity in planting with machine. Also wider inter row spacing and more soil area was available for foraging in planting with machine thus leading to improved root growth. This is in accordance with the observations of Singh *et al*. (2015a) [14].

During both the years of experimentation, nitrogen levels significantly affected the root dry weight measured at flowering stage. Root dry weight showed significant increase with increasing nitrogen level from 90 to 150 kg $ha^{-1}$and further increase in N level did not influence the root dry weight conspicuously. The higher root dry weight with increasing N level might be due to continuous supply of adequate nitrogen which helped to achieve better growth and development of root system in rice crop throughout crop growth period.

Nitrogen Uptake by Rice

During both the years, nitrogen uptake by grain at harvest was significantly higher with machine transplanted rice than aerobic rice and it was comparable with that of normal planting and DDS rice. Whereas DDS rice recorded significantly higher N uptake in grain over aerobic rice (Table 2).

Similarly, nitrogen uptake in straw was also significantly higher with machine transplanted rice and it was comparable with that of normal planting and DDS rice in 2015 and normal planting only in 2016. There was no significant difference between DDS rice and normal planting in nitrogen uptake of straw and were resulted in significantly higher N uptake in straw over aerobic rice (Table 2).

Among the establishment techniques, Perceptible differences were observed with regard to nutrient uptake during both the years of study. Nitrogen uptake by rice crop at harvest was highest in planting with machine followed by normal planting. This might be due to better environment available around eco-rhizosphere as a result of thorough pulverisation of soil under a thin film of water and transplanting of younger seedlings in such an ideal environment might have enabled the rice crop to absorb native as well as applied nutrients. Similar results were also reported by Parameswari and Srinivas (2014) [8] and Sahu *et al*. (2015) [11].

During both the years of study, the N uptake by grain, straw and total N uptake at harvest was the highest with application of 210 kg N ha^{-1}. However, the difference in N uptake between the N levels was measurable upto application of N @ 150 kg ha^{-1} only and further increase in N level did not influence the N uptake conspicuously. The lowest N uptake was registered with nitrogen level @ 90 kg N ha^{-1} during both the years of experimentation. The higher nitrogen uptake at higher levels of nitrogen might be due to enhanced level of nitrogen supply. This proportionately increased the pool of available nitrogen at the root zone that inturn enabled greater absorption by rice crop. Further, the uptake being the product of nutrient content and drymatter accumulation, the increase in N uptake by the crop at higher dose of nitrogen might be due to increased grain and straw yields. Similar results are also reported by Sandhya Kanthi *et al.* (2014) [10] and Singh *et al.* (2015a) [14].

Phosphorus Uptake by Rice

Phosphorus uptake by rice crop (grain +straw) at harvest was significantly influenced by both crop establishment techniques and nitrogen levels and their interaction was not significant during both the years (Table 2).

The maximum total (grain +straw) phosphorus uptake 23.3 kg N ha^{-1} in 2015 and 24.5 kg ha^{-1} in 2016 was recorded in planting with machine rice which was on par with normal planting and it was significantly higher than DDS rice and aerobic rice Similar trend was observed in phosphorus uptake by grain and straw also. This might be due to good stand establishment of transplanted crop with better availability of nutrients. These results are in close proximity with those of Parameswari and Srinivas (2014) [8] and Surekha *et al.* (2015) [16].

Among the N levels, irrespective of years of investigation, there was an increase in uptake of phosphorus with each increment of nitrogen applied. The phosphorus uptake by rice grain, straw and total phosphorus uptake at harvest was maximum at 210 kg N ha^{-1}. However, it was measurable upto 150 kg N ha^{-1} during both the years, which was significantly superior to all the lower levels of nitrogen. The significant increase in P uptake at higher nitrogen levels might be due to more root proliferation and vigorous seedling growth and their foraging ability which helps in augmenting phosphorus uptake from soil. These results are in close conformity with those of Bhanu prakash *et al.* (2013) [1] and Singh *et al.* (2015a) [14].

Potassium Uptake by Rice

Crop establishment techniques and nitrogen levels influenced the potassium uptake by rice grain, straw and total uptake at harvest during both the years. However, the interaction was non significant in both the years of study. (Table 2).

The maximum uptake of total potassium (102.4 kg ha^{-1} in 2015 and 105.3 kg ha^{-1} in 2016) was recorded in planting with machine but it was on par with normal planting and it was significantly superior to DDS rice and aerobic rice during both the years. Potassium uptake by rice grain and straw also followed similar trend as that of total K uptake at harvest. The increase in K uptake with transplanting methods (planting with machine and normal planting) might be due to decreased weed competition in transplanted rice which might have induced the uptake of applied nutrients as well as soil nutrients. These results are in close conformity with those of Sandhya kanthi *et al*. (2014) [10] and Surekha *et al.* (2015) [16].

There was a progressive increase in K uptake by rice grain, straw and total uptake at harvest with the increase in nitrogen levels from 90 to 210 kg N ha^{-1}and the highest K uptake was recorded with 210 kg N ha^{-1}. However the difference in K uptake between the N levels was measurable upto application of N @ 150 kg N ha^{-1} only. Further increase in N level did not influence K uptake conspicuously whereas the K uptake was lowest with the application of N@ 90 kg ha^{-1}. The increase in K uptake with increasing levels of nitrogen might have stimulated more vegetative growth and increased the foraging capacity of roots which inturn lead to increased uptake of potassium. These results are in accordance with the findings of Singh *et al.* (2015a) [14] and Singh *et al.* (2015b) [15].

Yield

Grain and straw yield of rice was significantly influenced by both crop establishment techniques and nitrogen levels, while their interaction was non significant during both the years (Table1). Among the crop establishment techniques, the highest grain and straw yields were recorded in planting with machine, but it was comparable with normal planting and DDS rice and significantly superior to aerobic rice. The grain and straw yields were significantly lowest with aerobic rice over other crop establishment techniques during both the years. It was observed that different planting methods caused marked variations in grain and straw yields of rice. Higher yield under transplanting methods might be due to better enhanced stature of yield attributing characters through optimum utilisation of resources which had direct bearing on the production of higher grain and straw yield. Lower yields under direct seeding (aerobic rice and dry direct sowing) is attributed to excessively higher competition with weeds and dense population per unit area. Plant density plays a major role in determining the efficiency of solar energy conversion to plant product per unit of land area. Excess plant population than required creates competition for various growth resources, either spatially or temporally and thus results in sub-optimal performance of the crop under a given environment. These results are in confirmation with the findings of Senthil kumar (2015) [12], Islam *et al.* (2016) [4] and Meena *et al.* (2017) [6].

Regardless of crop establishment techniques, there was a progressive increase in grain and straw yield of rice with the increase in nitrogen levels from 90 to 210 kg N ha^{-1}. Among N levels the highest grain and straw yields were recorded with 210 kg N ha^{-1}. However, the difference in grain and straw yields between the N levels was measurable upto application of N@150 kg ha^{-1} only and further increase in N level did not augment the grain and straw yields conspicuously. However, the grain and straw yields were lowest with the application of N@ 90 kg ha^{-1}. The linear response observed with grain and straw yield was supported by similar trends recorded with all growth and yield attributing characters studied. This suggests that nitrogen nutrition is important for both source and sink development. Higher straw yield with higher levels of nitrogen might be attributed to higher drymatter and plant height. Nitrogen is the constituent of chlorophyll, which inturn, might have resulted in accumulation of photosynthates in vegetative portion of plants and ultimately enhanced the plant growth in transplanting techniques. These results are in conformity with those of Singh *et al*. (2015) [13] and Prathibha sree *et al*. (2016) [9].

It can be concluded that root volume, root dry weight at flowering, and NPK uptake at harvest was significantly higher in rice established through machine planting compared to aerobic rice and DDS rice and found at par to conventional planting. Whereas grain yield, straw yield were significantly higher by machine planting over aerobic rice only and found to be at par to DDS rice and normal planting. There was a progressive increase in root volume, root dry weight at flowering, and NPK uptake at harvest, grain yield and straw yield with increase in N application from 90 to 210 kg ha^{-1}, However the difference in these parameters was measurable upto application of N @ 150 kg ha^{-1} only.

Table 1: Root growth and yield of rice as influenced by crop establishment techniques and N-levels during kharif 2015-16 and 2016-17

Treatments	**Root volume (cc/hill)**		**Root dry weight (g/hill)**		**Grain yield (kg ha^{-1})**		**Straw yield (kg ha^{-1})**	
	2015	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Crop establishment techniques								
M_1:Dry direct sown rice	35.73	36.02	13.38	13.60	6194	6421	7341	7511
M_2 : Aerobic rice	35.03	35.43	12.93	13.10	5283	5645	6631	6820
M_3 : Planting with machine	38.71	39.27	14.98	15.16	6572	6954	7728	8177
M_4 : Normal planting	36.97	37.13	14.54	14.60	6308	6636	7441	7739
SEm±	0.73	0.70	0.29	0.31	147	155	158	179
CD(P=0.05)	2.51	2.42	0.99	1.09	508	536	547	618
CV%	7.7	7.3	8.1	8.6	9.3	9.4	8.4	9.2
Nitrogen levels (kg ha^{-1})								
N_1:90	32.97	33.40	13.08	13.38	4848	4947	6074	6367
N_2:120	35.24	35.30	13.47	13.67	5881	6262	7128	7342
N_3:150	37.35	38.05	14.27	14.35	6409	6722	7578	7820
N_4:180	38.35	38.54	14.41	14.47	6597	6984	7763	8043
N_5:210	39.14	39.53	14.56	14.70	6713	7155	7883	8238
SEm±	0.63	0.82	0.26	0.23	140	158	152	166
CD(P=0.05)	1.81	2.36	0.74	0.67	404	455	438	477
CV%	6.1	7.7	6.4	**5.7**	8.0	8.7	7.2	7.6
Interaction	NS	NS	NS	**NS**	NS	NS	NS	NS

Table 2: NPK uptake of rice grain, straw and total uptake at harvest as influenced by crop establishment techniques and N-levels

Treatments	**N uptake of grain (kg ha^{-1})**		**N uptake of straw (kg ha^{-1})**		**Total N uptake (kg ha^{-1})**		**P uptake of grain (kg ha^{-1})**		**P uptake of straw (kg ha^{-1})**		**Total P uptake (kg ha^{-1})**		**K uptake of grain (kg ha^{-1})**		**K uptake of straw (kg ha^{-1})**		**Total K uptake (kg ha^{-1})**	
	2015	**2016**	**2015**	**2015**	**2016**	**2015**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Crop establishment techniques																		
M_1:Dry direct sown rice	66.9	71.3	37.9	41.8	104.8	113.1	12.2	13.1	8.6	9.1	20.9	22.2	18.9	19.7	79.8	86.4	98.7	106.2
M_2 : Aerobic rice	54.6	59.7	32.8	36.2	87.4	95.8	11.1	11.8	8.0	8.2	19.1	20.0	17.2	17.9	70.1	72.7	87.3	90.6
M_3 : Planting with machine	73.9	80.0	40.4	47.1	114.3	127.1	13.6	14.5	9.6	10.0	23.3	24.5	21.1	21.8	90.8	97.5	111.9	119.3
M_4 : Normal planting	69.0	75.0	39.3	43.8	108.4	118.8	13.3	14.1	9.5	9.7	22.8	23.7	20.5	21.5	87.3	93.8	107.8	115.4
SEm±	2.1	2.2	1.2	1.4	3.2	3.3	0.3	0.4	0.3	0.3	0.5	0.5	0.5	0.6	2.1	2.1	2.4	2.6
CD(P=0.05)	7.3	8.7	4.2	4.8	11.2	11.4	1.0	1.2	0.9	0.9	1.6	1.7	1.6	1.9	7.4	7.4	8.2	8.9
CV%	12.3	12.0	12.5	12.8	12.1	11.3	9.2	10.2	11.3	10.9	8.3	8.2	9.4	10.6	10.1	9.4	9.1	9.2
Nitrogen levels (kg ha^{-1})																		
N_1:90	49.2	51.7	29.2	33.4	78.4	85.2	10.8	11.5	7.6	7.8	18.3	19.4	17.4	18.2	69.7	74.7	87.1	92.8
N_2:120	61.7	68.0	36.1	40.4	98.8	107.8	11.9	12.8	8.3	8.6	20.3	21.5	18.9	19.9	79.8	84.5	98.8	104.4
N_3:150	70.0	76.2	39.3	44.1	109.4	120.8	12.9	13.7	9.4	9.6	22.5	23.3	19.7	20.6	84.4	90.8	104.1	110.5
N_4:180	73.6	79.5	40.8	45.9	114.4	125.3	13.4	14.1	9.6	9.9	22.9	23.9	20.0	20.9	87.3	93.1	107.4	114.0
N_5:210	75.0	82.0	42.6	47.3	117.6	129.4	13.8	14.7	9.8	10.2	23.6	24.9	20.9	21.7	88.8	95.0	109.6	117.5
SEm±	2.1	2.2	1.1	1.2	3.0	3.1	0.3	0.4	0.2	0.2	0.4	0.6	0.4	0.5	1.8	1.5	1.7	2.0
CD(P=0.05)	6.2	6.2	3.3	3.6	8.6	9.0	1.0	1.0	0.6	0.7	1.2	1.7	1.3	1.3	5.0	4.4	5.0	5.8
CV%	11.2	10.4	10.4	10.4	9.9	9.5	9.3	9.4	8.4	8.5	7.0	9.1	7.9	7.7	7.4	6.0	6.0	6.5
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

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