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RESEARCH ARTICLE :

Yield, nutrient uptake and agronomic fertilizer use efficiency (FUE) of different varieties of aerobic rice (*Oryza sativa* L.) with different N, P and K fertigation levels

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SUMMARY : A field experiment was conducted at Water Technology Centre, College farm, Rajendranagar, Hyderabad during *Kharif,* 2015 to study the "Response of different varieties of aerobic rice (*Oryza sativa* L.) under drip fertigation levels." The experiment was conducted with three main treatments and four sub treatments. The main treatments were three rice varieties (RNR 15048, MTU 1010 and Anagha) and the sub treatments were four different fertigation levels (S_0: Control, S_{75}:90-45-30 kg N-P_2O_5-K_2O ha^{-1}, S_{100}:120-60-40 kg N-P_2O_5-K_2O ha^{-1}, S_{125}:150-75-50- N-P_2O_5-K_2O ha^{-1}. Drip irrigation was scheduled once in 3 days based on daily data of USWB class 'A' pan evaporimeter at 1.5 Epan. The amount of total irrigation water used including effective rain fall (277 mm) for different varieties were Anagha (9720 m^3), MTU 1010 (9910 m^3) and RNR 15048 (10110 m^3) through drip irrigation. The differences in amount of water used were different for different varieties due to the differences in their crop growth period. The crop growth period noticed was 131, 139 and 151 days for Anagha, MTU 1010 and RNR 15048, respectively. The data on grain yield (kg ha^{-1}), straw yield (kg ha^{-1}), uptakes of N, P and K at different growth stages were recorded. Along with that agronomic fertilizer use efficiency (FUE) was calculated.

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KEY WORDS :
Aerobic rice, Drip fertigation, Pan evaporimeter, Effective rainfall, Uptakes, Agronomic fertilizer use efficiency

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BACKGROUND AND OBJECTIVES

A new concept of reducing water requirements for rice is ''aerobic rice'' in which rice isgrown like an upland crop with high inputs and supplementary irrigation when rainfall isinsufficient (Bouman, 2001).Further, Asia is considered to be "RICE BOWL" of the world and produces more calories and carbohydrates per hectare than any other cereals in India (Lu and Chang, 1980). Geometric growth of population and arithmetic increase in food grain productionleave a vast gap in food supply. In India, rice is grown in

an area of 45 million ha annually with a production of 106.19 million t, with an average productivity of 2976 kg ha^{-1} during 2013-2014 (Indiastat, 2013-2014).Aerobic rice production is a revolutionary way of growing rice in well-drained, non-puddled, and non-saturated soils without ponded water. This system uses input-responsive specialized rice cultivars and complementary management practices to achieve at least 4-6 t ha^{-1} using only 50-70% of the water required for irrigated rice production. This is recommended in areas where water is too scarce or expensive to allow traditional irrigated rice cultivation. Lowland rice in Asia has relatively higher water inputs. As water is becoming a scarce commodity nowadays, it is necessary to find ways and means of using the available water resources in a judicious manner to attain maximum productivity per unit quantity of water. In drip irrigation, water is provided most efficiently at right time and practically near the root zone of the crop. Generally, between 15 to 60 per cent of the fraction of the soil alone is wetted. It enables precise application of water and nutrients at precise zone avoiding soil erosion and drain of water by deep percolation. Drip irrigation could also be used for close spaced row crops of high return wherever water scarcity would be the major constraint. Though the initial cost would be more, the payback period for many commercial crops like sugarcane, banana, vegetables, cotton, etc., was within two years.

Irrigation is scheduled through drip to maintain the soil water content near field capacity in the root zone. Another advantage of the drip irrigation is the application of nutrients through fertigation, which could reduce the total amount of nutrients needed by the rice crop thereby increase in nutrient use efficiency. Fertigation is the application of water and fertilizers simultaneously to the crops only to the wetted root volume where the active roots are concentrated through micro irrigation systems *i.e*, drip, microjets or micro sprinklers. Fertigation allows adapting the amount and concentration of the applied nutrients in order to meet the actual nutritional requirement of the crop throughout the growing season for maximum yield and production quality. It is specific for each crop and climate and is to be determined in different experiments.

RESOURCES AND METHODS

A field experiment was conducted at Water Technology Centre, College farm, Rajendranagar, Hyderabad during *Kharif*, 2015 to study the response of different varieties of aerobic rice (*Oryza sativa* L.) under drip fertigation levels**.** The experiment was conducted with three main treatments and four sub treatments. The main treatments were three rice varieties (RNR 15048, MTU 1010 and Anagha) and the sub treatments were four different fertigation levels (S_0: Control, S_{75}:90-45-30 kg N-P_2O_5-K_2O ha^{-1}, S_{100}:120-60-40 kg N-P_2O_5-K_2O ha^{-1}, S_{125}: 150-75-50- N-P_2O_5-K_2O ha^{-1}).

The experimental soil was sandy clay loam in texture, slightly alkaline in reaction, non-saline, low in organic carbon and available nitrogen, medium in available phosphorous and high in available potassium. The mean weekly maximum (RH-II) and minimum relative humidity (RH-I during the crop growing period varied from) 73 to 95.28 % and 39.5 to 75.42 %, respectively, during *Kharif*, 2015 and 369.9 mm of rainfall was received in 26 rainy days. The mean bright sunshine hours per day varied from 1.77 to 8.25. The average wind speed varied from 0.1 to 11.34 km h^{-1} in 2015. With respect to pan evaporation, mean pan evaporation ranged 2.7 to 7.98 mm day^{-1} in 2015. The seasonal cumulative pan evaporation during the crop period of *Kharif*, 2015 was 687.6 mm.

Out of the varieties chosen, RNR 15048 is recently released by Professor Jayashankar Telangana State Agricultural University as Telangana Sona and is gaining wider popularity among farming community. Hence, there is a need to generate the data on this new variety in different management practices. Hence, this variety was included. The other variety MTU 1010 is a widely accepted, cold tolerant, bold seeded variety in both Telangana and Andhra Pradesh state and was found to perform better under aerobic conditions than other popular varieties. Hence, this variety was included under the study. The third variety Anagha is a variety specially released for growing under aerobic conditions by U.A.S, Bangalore. To test its suitability under Telangana, this variety was also included under the present study.

OBSERVATIONS AND ANALYSIS

Data on grain yield (kg ha^{-1}), straw yield (kg ha^{-1}), uptakes of N, P and K (kg ha^{-1}) at different growth stages were recorded. Along with yield and uptakes of plant samples, the economics also worked out for the aerobic

cultivation.

The grain yield ranged from 1103 to 2578 kg ha^{-1} and the data was represented in Table 1. Among all varieties, Anagha recorded significantly the highest grain yield followed by MTU 1010 and RNR 15048. The varieties MTU 1010 and RNR 15048 were observed to be on par to each other. Anagha, recorded 38.75 % and 46.10 % higher grain yield than MTU 1010 and RNR 15048, respectively. Among the NPK fertigation levels, S_{125} recorded significantly the highest grain yield followed by S_{100}, S_{75} and S_0, respectively. The S_{75}, S_{100} and S_{125} have recorded 21.6 %, 39.8 % and 60.4 % higher grain yield over control (S_0).Among interactions, higher grain yield was recorded by Anagha at S_{125} followed by the same variety at $S_{100,}$at S_{75} and MTU 1010 at S_{125}. The lowest was recorded by RNR 15048 at S_0 which was on par with MTU at $S_{0.}$ It was noticed that under aerobic cultivation, among the varieties tested, Anagha was observed to perform better over other two varieties. As it is the variety specially released for aerobic cultivation, it could adopt to aerobic conditions better than the other two varieties. Katsura and Nakaide (2011) found that the varieties with greater sink activity and source capacity per plant during the ripening period could produce larger grain weight under aerobic culture.

The straw yield ranged from 2501 to 6378 kg ha^{-1}. Among all varieties, Anagha recorded significantly higher grain yield followed by MTU 1010 and RNR 15048. Anagha, recorded 51.88% and 60.22% higher straw yield than MTU 1010 and RNR 15048, respectively. Among the NPK fertigation levels, S_{125} has recorded significantly the highest straw yield followed by S_{100}, S_{75} and S_0, respectively. The S_{75}, S_{100} and S_{125} have recorded 19.9 %, 41.7 % and 67.8 % higher straw yield over control (S_0). Among the interactions, significantly the highest straw yield was observed by Anagha at S_{125} followed by the same variety at S_{100} .The lowest was recorded by MTU at S_0 which was on par with RNR 15048 at S_0. Increase in straw yield with increase in NPK / N fertilizer doses was also reported by Rakesh *et al*. (2012) and Reddy *et al.* (2012).

The data on nitrogen uptake of aerobic rice at 30, 60, 90 and at harvest (grain + straw) is presented in Table 2. Nitrogen uptake was significantly influenced by the

Table 1: Effect of different levels of NPK fertigation levels on grain yield (kg ha^{-1}) of different varieties of rice at final harvest under aerobic cultivation during *Kharif*, 2015

Varieties	Fertigation levels*				Mean
	S_0	S_{75}	S_{100}	S_{125}	
RNR 15048	1103	1226	1504	1606	1360
MTU 1010	1177	1376	1481	1692	1432
Anangha	1382	1852	2136	2578	1987
Mean	1221	1485	1707	1959	
	Main (V)**	Sub (S)	V at same S	S at same V	
S.E.±	59	45	78	90	
CD (P=0.05)	233	134	163	215	
RNR 15048	2508	2708	3285	3682	3046
MTU 1010	2501	2979	3311	4062	3213
Anangha	3406	4404	5332	6378	4880
Mean	2805	3364	3976	4707	
	Main (V)	Sub (S)	V at same S	S at same V	
S.E.±	136	120	181	206	
C.D. (P=0.05)	527	309	378	491	

* S_0= Control (No N, P_2O_5,K_2O), S_{75} = 90-45-30 kg N, P_2O_5,K_2O ha^{-1},
S_{100} = 120-60-40 kg N, P_2O_5,K_2O ha^{-1}, S_{125} = 150-75-50 kg N, P_2O_5,K_2O ha^{-1}
** Main (V) = Main treatments (Rice varieties); Sub (S) = Sub treatments (Fertigation levels)
Interactions = Main treatments x Sub treatments (Rice varieties x fertigation levels)

varieties, fertigation levels and their interactions at all the growth stages studied. It was observed that the nitrogen uptake of aerobic rice continued to increase from 30 DAS to harvest.

Table 2: Effect of different levels of NPK fertigation levels on N uptake (kg ha^{-1}) of different varieties of rice at 30, 60, 90 DAS and at final harvest under aerobic cultivation during *Kharif*, 2015

Varieties	Fertigation levels*				Mean
	30 DAS				
	S_0	S_{75}	S_{100}	S_{125}	
RNR 15048	0.42	0.68	0.82	0.95	0.72
MTU 1010	0.23	0.55	0.90	0.62	0.58
Anangha	0.62	1.02	1.36	1.70	1.18
Mean	0.42	0.75	1.03	1.09	
	Main (V)**	Sub (S)	V at same S	S at same V	
S.E.±	0.05	0.05	0.08	0.08	
C.D. (P=0.05)	0.21	0.14	0.17	0.20	
	60 DAS				
RNR 15048	4.62	6.54	9.93	12.16	8.31
MTU 1010	4.88	6.16	10.63	12.28	8.49
Anangha	7.82	12.42	16.77	28.07	16.27
Mean	5.77	8.37	12.44	17.50	
	Main (V)	Sub (S)	V at same S	S at same V	
S.E.±	0.8	1.0	1.8	1.8	
C.D. (P=0.05)	3.3	3.0	3.7	4.0	
	90 DAS				
RNR 15048	7.6	10.5	14.1	16.5	12.2
MTU 1010	9.0	10.7	19.2	22.1	15.3
Anangha	20.8	30.5	51.9	73.6	44.2
Mean	12.5	17.2	28.4	37.4	
	Main (V)	Sub (S)	V at same S	S at same V	
S.E.±	1.1	1.3	2.2	2.2	
C.D. (P=0.05)	4.2	3.8	4.7	5.0	
	Total uptake (Grain+Straw)				
RNR 15048	28.5	37.9	46.4	53.9	41.7
MTU 1010	33.4	39.5	49.8	69.3	48.0
Anangha	53.6	77.3	102.4	138.0	92.8
Mean	38.5	51.6	66.2	87.1	
	Main (V)**	Sub (S)	V at same S	S at same V	
S.E.±	2.3	1.5	2.6	3.2	
C.D. (P=0.05)	6.3	3.1	5.4	7.8	

* S_0= Control (No N, P_2O_5,K_2O), S_{75} = 90-45-30 kg N, P_2O_5,K_2O ha^{-1},
S_{100} = 120-60-40 kg N, P_2O_5,K_2O ha^{-1}, S_{125} = 150-75-50 kg N, P_2O_5,K_2O ha^{-1}
** Main (V) = Main treatments (Rice varieties); Sub (F) = Sub treatments (Fertigation levels)
Interactions = Main treatments x Sub treatments (Rice varieties x fertigation levels)

At 30 DAS, nitrogen uptake ranged from 0.23 to 1.70 kg ha^{-1}. Among all varieties, Anagha (1.18 kg ha^{-1}) recorded significantly the highest nitrogen uptake followed by RNR 15048 (0.72 kg ha^{-1}) and MTU 1010 (0.58 kg ha^{-1}). Anagha recorded 63.88% and 1.03 times more nitrogen uptake than RNR 15048 and MTU 1010, respectively. Among the NPK fertigation levels, S_{125} (1.09 kg ha^{-1}) recorded significantly the highest nitrogen uptake followed by S_{100} (1.03 kg ha^{-1}), S_{75} (0.75 kg ha^{-1}) and S_0 (0.42 kg ha^{-1}) respectively. When compared to S_{125}, there was a difference of 5.82%, 45.33% and 1.59 times decreased nitrogen uptake in $S_{100,}$ S_{75} and S_0, respectively. Among interactions, higher nitrogen uptake was observed by Anagha at S_{125} (1.70 kg ha^{-1}) followed by Anagha at S_{100} (1.36 kg ha^{-1}), Anagha at S_{75} (1.02 kg ha^{-1}), RNR 15048 at S_{125} (0.90 kg ha^{-1}), MTU 1010 at S_{100} (0.82 kg ha^{-1}), RNR 15048 at S_{100} (0.82 kg ha^{-1}), RNR 15048 at S_{75} (0.62kg ha^{-1}), RNR 15048 at S_{75} (0.55 kg ha^{-1}), RNR 15048 at S_0 (0.55 kg ha^{-1}), RNR 15048 at S_0 (0.42 kg ha^{-1}) and MTU 1010 at S_0 (0.23 kg ha^{-1}).

At 60 DAS, nitrogen uptake ranged from 4.62 to 28.07 kg ha^{-1}. Among all varieties, Anagha (16.27 kg ha^{-1}) recorded significantly the highest nitrogen uptake followed by MTU 1010 (8.49kg ha^{-1}) which was on par with RNR 15048 (8.31 kg ha^{-1}). When compared to Anagha, there was a difference of 91.63% and 95.78% decreased nitrogen uptake by MTU 1010 and RNR 15048, respectively. Among the NPK fertigation levels, S_{125} (17.50 kg ha^{-1}) recorded significantly higher nitrogen uptake followed by S_{100} (12.44 kg ha^{-1}), S_{75} (8.37 kg ha^{-1}) and S_0 (5.77 kg ha^{-1}), respectively. The S_{75} and S_0 were observed to be on par to each other. When compared to S_{125}, there was a difference of 40.67%, 1.9 times and 2.03 times decreased nitrogen uptake in $S_{100,}$ S_{75} and S_0, respectively. Among interactions, higher nitrogen uptake was observed in Anagha at S_{125} (28.07 kg ha^{-1}) followed by Anagha at S_{100} (16.77 kg ha^{-1}), Anagha at S_{75} (12.42kg ha^{-1}), MTU 1010 at S_{125} (12.28 kg ha^{-1}), MTU 1010 at S_{125} (12.16 kg ha^{-1}), RNR 15048 at S_{100} (10.63 kg ha^{-1}), RNR 15048 at S_{100} (9.93kg ha^{-1}), RNR 15048 at S_{75} (6.54 kg ha^{-1}), RNR 15048 at S_{75} (6.54 kg ha^{-1}), MTU 1010 at S_{75} (6.16 kg ha^{-1}), MTU 1010 at S_0 (4.88 kg ha^{-1}) and RNR 15048 at S_0 (4.62 kg ha^{-1}).

At 90 DAS, nitrogen uptake was ranged from 7.6 to 73.6 kg ha^{-1}. Among all varieties, Anagha (44.2 kg ha^{-1}) recorded higher nitrogen uptake followed by RNR 15048 (8.49kg ha^{-1}) and MTU 1010 (8.31kg ha^{-1}). The varieties RNR 15048 and Anagha were found to be on par to each other. When compared to Anagha, there was a difference of 1.88 times and 2.62 times decreased nitrogen uptake in RNR 15048 and MTU 1010 respectively. There was a significant difference found between varieties. Among the NPK fertigation levels, S_{125} (37.4 kg ha^{-1}) recorded significantly the highest nitrogen uptake followed by S_{100} (28.4 kg ha^{-1}), S_{75} (17.2 kg ha^{-1}) and S_0 (12.5 kg ha^{-1}). When compared to S_{125}, there was a difference of 31.69%, 1.17 times and 1.99 times decreased nitrogen uptake in $S_{100,}$ S_{75} and S_0, respectively. Among interactions, significantly the highest nitrogen uptake was observed in Anagha at S_{125} (73.6 kg ha^{-1}) followed by Anagha at S_{100} (51.9 kg ha^{-1}), Anagha at S_{75} (30.5 kg ha^{-1}), and the lowest was noticed in RNR 15048 at S_0 (4.62 kg ha^{-1}) which was on par with MTU 1010 at S_0 and RNR 15048 and MTU 1010 at S_{75}.

At harvest, total uptake of N (by grain + straw) ranged from 28.5 to 138.0 kg ha^{-1}. Among all varieties, Anagha (92.8 kg ha^{-1}) recorded significantly the highest nitrogen uptake followed by MTU 1010 (48.0 kg ha^{-1}) and RNR 15048 (19.23kg ha^{-1}). The RNR 15048 and MTU 1010 were on par to each other. Anagha recorded 93.33% and 1.22 times higher nitrogen uptake than RNR 15048and MTU 1010., respectively. With increase in fertigation levels from S_0 to S_{125}, there was a linear increase in N total uptake. Among the NPK fertigation levels, S_{125} (87.1 kg ha^{-1}) recorded significantly the highest nitrogen uptake followed by S_{100} (66.2 kg ha^{-1}), S_{75} (51.6 kg ha^{-1}) and S_0 (38.5 kg ha^{-1}), respectively. The S_{125} recorded 31.57%, 68.79% and 1.27 times higher nitrogen uptake than $S_{100,}$ S_{75} and S_0, respectively. Among interactions, higher nitrogen uptake was observed in Anagha at S_{125} (138 kg ha^{-1}) followed by Anagha at S_{100} (102.4 kg ha^{-1}), Anagha at S_{75} (77.3 kg ha^{-1})and significantly the lowest was recorded by RNR 15048 at S_0 (28.5 kg ha^{-1}).

Increase in fertigation levels from S_0 to S_{125} through fertigation has facilitated the availability of nutrients regularly throughout the active vegetative and reproductive stages and resulted in higher dry matter production and N content at all the growth stages and ultimately resulted in linear increase in uptake of N with increase in fertigation levels. Among the varieties, Anagha appears to have the more potential to uptake more nutrients when compared to the other two varieties tested.

The data on phosphorus uptake (kg ha^{-1}) of aerobic rice at 30, 60, 90and at final harvest (straw+ grain) is

presented in Table 3. The phosphorus uptake of aerobic rice was significantly influenced by the treatments at all stages except non-significant influence of interactions on P uptake at 30 DAS. It was observed that the phosphorous uptake of aerobic rice continued to increase from 30 DAS to harvest.

Table 3: Effect of different levels of NPK fertigation levels on P uptake (kg ha^{-1}) of different varieties of rice at 30, 60, 90 DAS and at final harvest under aerobic cultivation during *Kharif* 2015

Varieties	Fertigation levels*				Mean
	S_0	S_{75}	S_{100}	S_{125}	
30 DAS					
RNR 15048	0.14	0.28	0.44	0.47	0.33
MTU 1010	0.09	0.21	0.33	0.43	0.26
Anangha	0.18	0.35	0.55	0.65	0.43
Mean	0.14	0.28	0.44	0.51	
	Main (V)**	Sub (S)	V at same S	S at same V	
S.E.±	0.02	0.02	0.04	0.04	
C.D. (P=0.05)	0.06	0.07	NS	NS	
60 DAS					
RNR 15048	1.6	4.2	6.4	7.9	5.0
MTU 1010	1.3	3.4	4.9	7.7	4.3
Anangha	2.6	6.5	9.9	14.5	8.4
Mean	5.6	4.7	7.1	10.0	
	Main (V)	Sub (S)	V at same S	S at same V	
S.E.±	0.2	0.3	0.6	0.5	
C.D. (P=0.05)	0.7	0.9	1.1	1.1	
90 DAS					
RNR 15048	2.0	5.3	9.0	11.6	7.0
MTU 1010	1.9	4.8	6.8	11.6	6.3
Anangha	2.8	9.3	13.7	19.8	11.4
Mean	2.3	6.5	9.8	14.3	
	Main (V)	Sub (S)	V at same S	S at same V	
S.E.±	0.3	0.4	0.8	0.7	
C.D. (P=0.05)	1.2	1.3	1.6	1.6	
Total uptake (Grain+Straw)					
RNR 15048	4.7	11.5	17.0	23.9	14.3
MTU 1010	4.9	12.7	16.1	25.7	14.8
Anangha	8.4	21.6	33.3	48.0	27.8
Mean	6.0	15.3	22.2	32.5	
	Main (V)**	Sub (S)	V at same S	S at same V	
S.E.±	0.9	0.8	1.3	1.5	
C.D. (P=0.05)	3.5	2.3	2.8	3.4	

* S_0= Control (No N, P_2O_5,K_2O), S_{75} = 90-45-30 kg N, P_2O_5,K_2O ha^{-1},
S_{100} = 120-60-40 kg N, P_2O_5,K_2O ha^{-1}, S_{125} = 150-75-50 kg N, P_2O_5,K_2O ha^{-1}
** Main (V) = Main treatments (Rice varieties); Sub (F) = Sub treatments (Fertigation levels)
Interactions = Main treatments x Sub treatments (Rice varieties x fertigation levels)

At 30 DAS, uptake of P ranged from 0.09 to 0.65 kg ha^{-1}. Among varieties, Anagha has recorded the highest P uptake (0.43 kg ha^{-1}) which was significantly higher than RNR 15048 (0.33 kg ha^{-1}) and MTU 1010 (0.26 kg ha^{-1}). Among NPK fertigation levels, the highest P uptake was observed in S_{125} (0.51 kg ha^{-1}) which was significantly higher than S_{100} (0.44 kg ha^{-1}), S_{75} (0.28 kg ha^{-1}) and S_0 (0.14 kg ha^{-1}). The S_{75}, S_{100}, S_{125} have recorded 2 times, 3.14 times and 3.64 times higher P uptake over control (S_0). Among interactions, the highest uptake of P was observed by Anagha at S_{125} (0.65 kg ha^{-1}) followed by Anagha at S_{100} (0.55 kg ha^{-1}), RNR 15048 at S_{100} (0.47 kg ha^{-1}). The lowest uptake of P was observed by MTU 1010 at S_0 (0.09 kg ha^{-1}).

At 60 DAS, uptake of P ranged from 1.3 to 14.5 kg ha^{-1}. Among varieties, Anagha has recorded the highest P uptake (8.4 kg ha^{-1}) which was significantly higher than RNR 15048 (5.0 kg ha^{-1}) and MTU 1010 (4.3 kg ha^{-1}). Among NPK fertigation levels, the highest P uptake was observed in S_{125} (10.0 kg ha^{-1}) which was significantly higher than S_{100} (7.1 kg ha^{-1}), S_{75} (4.7 kg ha^{-1}) and S_0 (1.83 kg ha^{-1}). The S_{75}, S_{100}, S_{125} have recorded 2.57 times, 3.87 times and 5.46 times higher P uptake over control (S_0). Among interactions, significantly the highest uptake of P was observed in Anagha at S_{125} (10.0 kg ha^{-1}) followed by Anagha at S_{100} (9.9 kg ha^{-1}), RNR 15048 at S_{125} (7.9 kg ha^{-1}), MTU 1010 at S_{125} (7.7kg ha^{-1}). Significantly, the lowest uptake of P was observed in MTU 1010 at S_0 (1.3 kg ha^{-1}) followed by RNR 15048 at S_0 (1.6 kg ha^{-1}). Anagha even at lower levels of fertigation like at S_{100} has recorded higher uptake of P (9.9 kg ha^{-1}) than at higher level of fertigation for other varieties like RNR 15048 at S_{125} (7.9 kg ha^{-1}) and MTU 1010 at S_{125} (1.3 kg ha^{-1}) .

At 90 DAS, uptake of P ranged from 1.9 to 19.8 kg ha^{-1}. Among varieties, Anagha has recorded the highest P uptake (11.4 kg ha^{-1}) which was significantly higher than RNR 15048 (7.0 kg ha^{-1}) and it was on par with MTU 1010 (4.3 kg ha^{-1}). Among NPK fertigation levels, the highest P uptake was observed in S_{125} (14.3 kg ha^{-1}) which was significantly higher than S_{100} (9.8 kg ha^{-1}), S_{75} (6.5 kg ha^{-1}) and S_0 (2.3 kg ha^{-1}). The S_{75}, S_{100}, S_{125} have recorded 2.83 times, 4.26 times and 6.22 times higher uptake of P over control (S_0). Among interactions, significantly the highest uptake of P was observed by Anagha at S_{125} (19.8 kg ha^{-1}) followed by Anagha at S_{100} (13.7 kg ha^{-1}), RNR 15048 at S_{125} (11.6 kg ha^{-1}), MTU 1010 at S_{125} (7.7kg ha^{-1}). Significantly the lowest uptake of P was observed in MTU 1010 at S_0 (1.9 kg ha^{-1}) followed by RNR 15048 at S_0 (2.0 kg ha^{-1}). The same trend which was observed at 60 DAS was noticed at 90 DAS and at final harvest.

At harvest, uptake of P ranged from 4.7 to 48 kg ha^{-1}. Among varieties, Anagha has recorded the highest P uptake (27.8 kg ha^{-1}) which was significantly higher than RNR 15048 (14.8 kg ha^{-1}) and it was on par with MTU 1010 (4.3 kg ha^{-1}). Among NPK fertigation levels, the highest P uptake was observed in S_{125} (32.5 kg ha^{-1}) which was significantly higher than S_{100} (22.5 kg ha^{-1}), S_{75} (15.3 kg ha^{-1}) and S_0 (6.0 kg ha^{-1}). The S_{75}, S_{100}, S_{125} have recorded 2.55 times, 3.7 times and 5.42 times higher uptake of P over control (S_0).Among interactions, significantly the highest uptake of P was observed in Anagha at S_{125} (48.0 kg ha^{-1}) followed by Anagha at S_{100} (33.3 kg ha^{-1}), RNR 15048 at S125 (25.9 kg ha^{-1}), MTU 1010 at S_{125} (23.9 kg ha^{-1}). Significantly the lowest uptake of P was observed in MTU 1010 at S_0 (4.9 kg ha^{-1}) and it was on par with RNR 15048 at S_0 (4.7 kg ha^{-1}).

Increase in fertigation levels from S_0 to S_{125} through fertigation has facilitated the availability of nutrients regularly throughout the active vegetative and reproductive stages and resulted in higher dry matter production and P content at all the growth stages and ultimately resulted in linear increase in uptake of P with increase in fertigation levels. Among the varieties, Anagha appears to have the more potential to uptake more nutrients when compared to the other two varieties tested.

The data on potassium uptake (kg ha^{-1}) of aerobic rice at 30, 60, 90and at final harvest (straw+ grain) is presented in Table 4. The potassium uptake of aerobic rice was significantly influenced by the treatments at all stages except 30 DAS. It was observed that the potassium uptake of aerobic rice continued to increase from 30 DAS to harvest.

At 30 DAS, uptake of K ranged from 0.20 to 0.78 kg ha^{-1}. Among varieties, Anagha has recorded the highest K uptake (0.58 kg ha^{-1}) which was significantly higher than RNR 15048 (0.42 kg ha^{-1}) and MTU 1010 (0.39 kg ha^{-1}). Among NPK fertigation levels, the highest K uptake was observed in S_{125} (0.64 kg ha^{-1}) which was on par with S_{100} (0.56 kg ha^{-1}) and it was significantly higher than S_{75} (0.41 kg ha^{-1}) and S_0 (0.26 kg ha^{-1}). The S_{75}, S_{100}, S_{125} have recorded 57.7%, 2.15 times and 2.46 times higher K uptake over control (S_0). Among interactions, the highest uptake of K was observed in Anagha at S_{125}(0.78 kg ha^{-1}) followed by Anagha at S_{100}

(0.68 kg ha^{-1}), RNR 15048 at S_{100} (0.59 kg ha^{-1}). The lowest uptake of P was observed in MTU 1010 at S_0 (0.20 kg ha^{-1}) followed by RNR 15048 at S_0 (0.26 kg ha^{-1}).

At 60 DAS, uptake of K ranged from 3.1 to 16.9 kg ha^{-1}. Among varieties, Anagha has recorded the highest

Table 4: Effect of different levels of NPK fertigation levels on K uptake (kg ha^{-1}) of different varieties of rice at 30, 60, 90 DAS and at final harvest under aerobic cultivation during *Kharif*, 2015

Varieties	Fertigation levels*				Mean
	S_0	S_{75}	S_{100}	S_{125}	
			30 DAS		
RNR 15048	0.26	0.34	0.51	0.59	0.42
MTU 1010	0.20	0.34	0.48	0.54	0.39
Anangha	0.31	0.54	0.68	0.78	0.58
Mean	0.26	0.41	0.56	0.64	
	Main (V)**	Sub (S)	V at same S	S at same V	
S.E.±	0.02	0.02	0.03	0.03	
C.D. (P=0.05)	0.06	0.06	NS	NS	
			60 DAS		
RNR 15048	4.3	5.0	7.5	8.7	6.4
MTU 1010	3.1	4.8	6.1	8.6	5.6
Anangha	5.7	8.0	13.3	16.9	11.0
Mean	4.4	5.9	9.0	11.4	
	Main (V)	Sub (S)	V at same S	S at same V	
S.E.±	0.3	0.3	0.5	0.5	
C.D. (P=0.05)	1.0	0.9	1.1	1.2	
			90 DAS		
RNR 15048	12.5	18.0	25.5	31.9	22.0
MTU 1010	11.4	16.7	22.2	31.4	20.4
Anangha	19.1	29.7	41.5	56.2	36.6
Mean	14.4	21.5	29.8	39.8	
	Main (V)	Sub (S)	V at same S	S at same V	
S.E.±	0.9	0.8	1.3	1.4	
C.D. (P=0.05)	3.3	2.2	2.7	3.3	
			Total uptake (Grain+Straw)		
RNR 15048	16.1	22.6	33.1	41.4	28.3
MTU 1010	13.7	19.9	29.6	40.6	26.0
Anangha	25.0	39.4	56.1	74.5	48.7
Mean	18.3	27.3	39.6	52.2	
	Main (V)**	Sub (S)	V at same S	S at same V	
S.E.±	1.4	1.1	1.9	2.2	
C.D. (P=0.05)	5.6	3.3	4.0	5.2	

* S_0= Control (No N, P_2O_5,K_2O), S_{75} = 90-45-30 kg N, P_2O_5,K_2O ha^{-1},
S_{100} = 120-60-40 kg N, P_2O_5,K_2O ha^{-1}, S_{125} = 150-75-50 kg N, P_2O_5,K_2O ha^{-1}
** Main (V) = Main treatments (Rice varieties); Sub (F) = Sub treatments (Fertigation levels)
Interactions = Main treatments x Sub treatments (Rice varieties x fertigation levels)

K uptake (16.9 kg ha^{-1}) which was significantly higher than RNR 15048 (6.4 kg ha^{-1}) and it was on par with MTU 1010 (5.6 kg ha^{-1}). Among NPK fertigation levels, the highest K uptake was observed in S_{125} (11.4 kg ha^{-1}) which was significantly higher than S_{100} (9.0 kg ha^{-1}), S_{75} (5.9 kg ha^{-1}) and S_0 (4.4 kg ha^{-1}). The S_{75}, S_{100}, S_{125} have recorded 34.1%, 2.05 times and 2.6 times higher K uptake over control (S_0). Among interactions, significantly the highest uptake of K was observed in Anagha at S_{125} (16.9 kg ha^{-1}) followed by Anagha at S_{100} (13.3 kg ha^{-1}), RNR 15048 at S_{125} (8.7 kg ha^{-1}) and it was on par with MTU 1010 at S_{125} (8.6 kg ha^{-1}). Significantly, the lowest uptake of K was observed in MTU 1010 at S_0 (3.1 kg ha^{-1}) followed by RNR 15048 at S_0 (4.3 kg ha^{-1}). Anagha at S_{100} (13.3 kg ha^{-1}) has recorded higher uptake of K, but RNR 15048 at S_{125}(8.7 kg ha^{-1}) and it was on par with MTU 1010 at S_{125} (8.6 kg ha^{-1}) which recorded the lower uptake of P at higher NPK fertigation level. This reveals the fact that, Anagha has the higher fertilizer use efficiency when compared to RNR 15048 and MTU 1010. Similar trend was followed in 60 DAS, 90 DAS and at final harvest.

At 90 DAS, uptake of K ranged from 13.7 to 74.5 kg ha^{-1}. Among varieties, Anagha has recorded the highest K uptake (48.7 kg ha^{-1}) which was significantly higher than RNR 15048 (28.3 kg ha^{-1}) and it was on par with MTU 1010 (26.0 kg ha^{-1}). Among NPK fertigation levels, the highest K uptake was observed in S_{125} (52.2 kg ha^{-1}) which was significantly higher than S_{100} (39.6 kg ha^{-1}), S_{75} (27.3 kg ha^{-1}) and S_0 (18.3 kg ha^{-1}). The S_{75}, S_{100}, S_{125} have recorded 49.2 %, 2.16 times and 2.86 times higher K uptake over control (S_0). Among interactions, significantly the highest uptake of K was observed in Anagha at S_{125} (74.5 kg ha^{-1}) followed by Anagha at S_{100} (56.1 kg ha^{-1}), RNR 15048 at S_{125} (41.4 kg ha^{-1}) and it was on par with MTU 1010 at S_{125} (40.6 kg ha^{-1}). Significantly, the lowest uptake of K was observed in MTU 1010 at S_0 (13.7 kg ha^{-1}) followed by RNR 15048 at S_0 (16.1 kg ha^{-1}).

Increase in fertigation levels from S_0 to S_{125} through fertigation has facilitated the availability of nutrients regularly throughout the active vegetative and reproductive stages and resulted in higher dry matter production and K contents at all the growth stages and ultimately resulted in linear increase in uptake of K with increase in fertigation levels. Among the varieties, Anagha appears to have the more potential to uptake more nutrients when compared to the other two varieties tested.

The fertilizer use efficiency of different varieties and fertigation levels was presented in the Table 5. It is expressed as increase in kg grain yield per kg NPK nutrients applied. Each one kg of nutrient contained 0.668 kg N, 0.146 kg P and 0.186 kg K.

Among all the varieties, the highest fertilizer use efficiency was recorded in Anagha (4.34 kg grain kg NPK nutrient) followed by MTU 1010 (1.82) and RNR 15048 (1.79) (Table 5). Anagha recorded 2.42 and 2.38 times higher agronomic FUE than MTU 1010 and RNR 15048. Among fertigation levels, S_{125} (3.28) has recorded the highest followed by S_{100} (2.70) and S_{75} (1.96). Among interactions, the highest fertilizer use efficiency was noticed by Anagha at S_{125} (5.32) followed by Anagha at S_{100} (4.20), Anagha at S_{75} (3.49), MTU 1010 at S_{125} (2.29), RNR 15048 at S_{125} (2.24). The lowest fertilizer use efficiency was observed in RNR 15048 at S_{75} (0.91) followed by MTU 1010 at S_{75} (1.48). The reason for getting higher agronomic fertilizer use efficiency in Anagha is due to higher grain yield recorded by this variety over other varieties. In addition, all the varieties responded positively to the fertigation level up to 125 %. Hence, relatively higher FUE was noticed in Anagha at S_{125} Similar results were also obtained by Bouman and Tuong, 2001 and Lu and Chang, 1980.

Table 5: Effect of different levels of NPK fertigation levels on fertilizer use efficiency of different varieties of rice under aerobic cultivation during *Kharif*, 2015 (increase in kg grain per kg nutrients applied)

Fertilizer use efficiency				
	Fertigation levels			
Varieties	S_{75}	S_{100}	S_{125}	Mean
RNR 15048	0.91	2.23	2.24	1.79
MTU 1010	1.48	1.69	2.29	1.82
Anagha	3.49	4.2	5.32	4.34
Mean	1.96	2.7	3.28	

Conclusion:

Thus, based on the yield attributes, nutrient uptakes and agronomic fertilizer use efficiency (FUE) it can be recommended to go for fertigation of NPK up to 125% level (150-75-50 kg $N\text{-}P_2O_5\text{-}K_2O$ ha^{-1}), applied in ten splits at weekly interval to aerobic rice from emergence to flowering stage. Among the varieties tested, Anagha was found to be more suitable for aerobic rice cultivation followed by MTU 1010 and RNR 15048. Taking in to consideration of economics, it is suggested to eliminate phosphorus from fertigation programme and go for fertigation of only N and K up to 125% through urea and potassium chloride (white) and better to go for soil application of phosphorus fertilizer as single basal dose to make the fertigation programme of aerobic rice as more economically viable.

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