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Effect of Site Specific Nitrogen Management Approaches on Content, Uptake and Use efficiency of Nitrogen in Rice under Different Systems of Establishment

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ABSTRACT

Nitrogen content of rice was significantly affected by successive stages of plant growth (Table 1). During early stages of growth it showed the highest content and with increase in age of plants decreased due to dilution effect resulting significant contribution towards higher dry matter production. The nitrogen uptake by plant however increased with the growth of the crop. At all growth stages, STCR approach recorded higher N content (2.909 per cent at 30 DAS/T, 0.688 and 1.139per cent at harvest in straw and grain respectively), uptake (around 15.82 kg ha^{-1} at 30DAS/T and at harvest it was 56.50 and 82.03 kg ha^{-1} in straw and grain, respectively), Agronomic use efficiency (5.64 kg kg^{-1}), Apparent N recovery efficiency (0.24 kg kg^{-1}), grain and straw yield (7183 and 8314 kg ha^{-1}) as compared to other nitrogen management approaches like RDF, STL and LCC. On the similar lines, Among systems of establishment, SRI recorded higher nitrogen content and uptake thereby recorded 56.11 and 49.26 per cent higher grain and straw yield over aerobic system (4975 and 5948 kg ha^{-1}), whereas it was 8.24 and 9.54 per cent over conventional system (7219 and 8105 kg ha^{-1}). The nature of response from varied level of N application indicate linear relationships with > 95 per cent dependency still the higher degree of relation like quadratic was found best fit as the data relayed still higher than relative to an extent of > 96 per cent for the study made in different years.

Key words: *Content, Nitrogen, SSNM, STCR, Use efficiency, Uptake*

INTRODUCTION

Nitrogen occupies a unique position among the essential nutrient elements required for plant growth, as it is an integral component of many essential plant compounds like chlorophyll, amino acids, enzymes, vitamins and hormones[2]. It directly influences the growth, development, yield and quality of rice. By and large, the soils in India are deficient in nitrogen, response to it is much pronounced. When nitrogen application is not synchronized with crop demand, losses from the soil plant system are large leading to varying degree of low fertilizer use efficiency.

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There is a need to synchronize nitrogen fertilizer application with plant to optimize nutrient use for getting sustainable yield apart from minimizing environmental pollution. Hence, nitrogen recommendations must consider crop demand and also supply capacity of the soil indicating decisions regarding improvement in use efficiency begin at the field scale.

Although India has made considerable advances in agricultural research, but still the blanket recommendation of cultivation practices for adoption over larger areas are in vogue which restricts efficient use either to enhance productivity or to reduce the yield gap for different regions. It is therefore suggested that fertilizer application should be based on local variations of field sites. A new concept, called site specific nutrient management approach provides timely application of fertilizer at optimal rates to fill the deficit between the nutrient needs of crop and nutrient supplying capacity of soil. Based on this approach, rice yield and fertilizer efficiency can been improved significantly. Soil test crop response studies takes into account spatial variability and help to generate fertilizer adjustment equations and calibration charts for recommending fertilizers on the basis of soil test for achieving targeted yield of crops[10]. Soil test approach for fertilizer application is reported to establish a proper balance of nutrients in medium to high fertile lands by eliminating any nutrient deficiency in plant[8]. Leaf N status of rice is closely related to photosynthetic rate and biomass production, also it is a sensitive indicator of changes in crop nitrogen demand within a growing season. The leaf colour chart (LCC) used to rapidly assess leaf greenness status and thereby guide the application of fertilizer nitrogen to maintain optimal greening *vis a vis* an optimal leaf nitrogen content, which can be vital for achieving high rice yield with effective nitrogen management.

In recent years, methods of rice cultivation have been developed to use water more efficiently. Two prominent systems among them are system of rice intensification (SRI) and aerobic method as an alternative to traditional transplanting system. A field experiment was conducted to study the yield response and N dynamics by different site specific nitrogen management approaches in rice establishment systems.

MATERIAL AND METHODS

A field experiment was conducted during the *kharif* 2014 and 2015 at College of Agriculture, Navile, Shivamogga comes under Southern Transition Zone (Zone-7) of Karnataka. The geographical reference point of experimental site was 13^0 58' to 14^0 1' North latitude and 75^0 34' to 75^0 42' East longitude with an altitude of 650 m above the mean sea level. The experiment was laid out in spilt plot design with three rice systems of establishment as main plots (aerobic, system of rice intensification and conventional) and nitrogen management approaches as subplots [Soil test and crop response (STCR), Soil test Based on lab (STL), Leaf colour chart (LCC) and Recommended fertilizers (RDF)] forming 12 treatment combinations with three replications. The main plots were prepared according to desired environment/ecosystem and the subplots were maintained under each main plot. The variety used in the experiment was KRH-4. Twelve days old seedlings were carefully planted (single seedling hill^{-1}) at a spacing of 25 x 25 cm in SRI system, two seeds were dibbled per spot at a spacing of 25 x 25 cm accounting seed rate of five kg ha^{-1}. After ten days of sowing, only one seedling was maintained by removing the excess seedling and necessary gaps were filled during the time in case of aerobic system. Twenty one day old seedlings were planted (one seedling hill^{-1}) at a spacing of 20 cm x 15 cm in conventional system.

A common dose of FYM @ 10 tonnes ha^{-1} was incorporated uniformly into the soil two weeks before planting for all systems of establishment. For all the treatment plots, a common dose of 20 kg $ZnSo_4$ ha^{-1} was applied at the time of sowing/transplanting. The quantity of different major fertilizer used under different approaches are mentioned below, for STCR approach under all the system of establishment the quantity of major plant nutrients were calculated with a target yield of 80 q ha^{-1} by using following target yield equations for Bhadra Command Area[1].

$FN = 2.981\ T - 0.30\ SN\ (KMnO_4 - N)$

$FP_2O_5 = 1.232\ T - 0.786\ SP_2O_5$ (Bray's P_2O_5)

$FK_2O = 1.173\ T - 0.155\ SK_2O\ (NH_4OAC - K_2O)$

Where,

T = Targeted yield (80 q ha^{-1}) i.e. 80 q ha^{-1}

FN = Nitrogen supplied through Fertilizer (kg ha^{-1})

SN = Initial available Nitrogen in soil (kg ha^{-1})

FP_2O_5 = Phosphorous supplied through Fertilizer (kg ha^{-1})

SP_2O_5 = Initial available P_2O_5 in soil (kg ha^{-1})

FK_2O = Potassium supplied through Fertilizer (kg ha^{-1})

SK_2O = Initial available K_2O in soil (kg ha^{-1})

Accordingly, the quantity of nitrogen was 175 and 176 kg ha[1], wherein phosphorus and potassium levels stood at 55 and 56 kg ha^{-1} in 2014 and 2015, respectively. In STL approach amount of fertilizer was calculated using soil test rating. Since for rice crop recommended dose of nitrogen is 100 kg ha^{-1} and the soil of the experimental area was low in available nitrogen, hence in accordance with table, +12.5 kg ha^{-1} is added along with recommended dose, considering their status, for phosphorus and potassium no change is made in the level of application (50 kg ha^{-1}). Leaf colour chart approach plots received a uniform dose of 14 kg nitrogen ha^{-1} as a basal dose for all the systems of establishment. Further, nitrogen is supplied to the crop based on LCC value of four and below[2]. Readings started from 14 days in SRI and conventional systems after transplanting and from 21 days in aerobic system at an interval of three days until first flowering. Nitrogen @ 25 kg ha^{-1} was applied for SRI and conventional systems and 20 kg ha^{-1} was applied in aerobic system at each LCC reading value of four and below. The total quantity of nitrogen used in the LCC based approach is 134 in case of aerobic and 164 kg ha^{-1} in SRI and conventional systems in both the year of experiment. Recommended dose of fertilizer is 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} as per the package of practice of 2010, University of Agricultural Sciences, Bangalore.

Other cultural practices were taken as per the recommendation and requirement of the crop. N content of the crop was determined at regular intervals of 30 days after sowing or transplanting. Further, uptake was calculated based on content and dry matter.

Different nitrogen use efficiencies were calculated for drawing more validity of the data. Since in the experiment without N application plots were not there, recommended fertilizers level which is the lowest is taken and compared. In interaction effects, compared to the recommended levels of fertilizer of the respective systems, efficiencies were calculated. Agronomic N use efficiency is the ratio of grain yield with N application minus grain yield without N application to quantity of N application and was used to describe the capability of yield increase per kilogram pure N. Apparent N recovery efficiency is the ratio that total plant N uptake with N application minus total plant N uptake without N application, then divided by N application. Physiological N use efficiency is the ratio of yield increase with N application to total plant N uptake increased with N application and it reflected the use efficiency of N absorbed by rice plant. Partial factor productivity is the simple ratio of yield obtained under fertilized plot to quantity of fertilizer applied. Further to decide upon the nature of response from varied level of N application through different approaches, regressions were calculated followed by simple, quadratic and exponential natures of curves.

RESULTS AND DISCUSSION

Nutrient content in rice

Nitrogen content of rice was significantly affected by successive stages of plant growth (Table 1). At 30 DAS/T, it showed the highest N content and with increase in age of plants decreased due to dilution effect resulting significant contribution towards higher dry matter production in comparison to absorption and mobilization. Lal and Mahapatra[6], reported that N content in plants decreases with increased age as N is absorbed vigorously at early stages of growth due to greater cell division and accumulation of protein at panicle primordial stage and after flowering the rate of absorption decreases due to decreased root activity and increased dry weight of plants. Among different system of establishment, SRI system achieved higher nitrogen content at all the growth stages compared to aerobic and conventional systems. In the present study, N content at 30DAT was 2.857per cent and at harvest it reduced to 0.699 and 1.188per cent in straw and grain (Fig. 2), respectively. Among different nitrogen management approaches, STCR approach recorded higher N content at all the growth stages (Table 1), as it achieved highest of 2.909per cent at 30 DAS/T, 0.688 and 1.139per cent at harvest in straw and grain respectively. It might be due to favorable soil conditions paving way for better absorption and mobilization in tune with growth and activity of roots. The result corroborates the findings of Janaki Rama[4].

Nutrient uptake in rice

The nitrogen uptake by plant however increased with the growth of the crop (Table 2). Systems of establishment differed significantly on nutrient uptake. Significantly higher nitrogen uptake noticed at 30, 60 and 90DAS/T under conventional system (17.60, 65.35 and 127.86 kg ha^{-1}) compared to aerobic (6.78, 15.94 and 45.56 kg ha^{-1}) and SRI systems (14.68, 50.62 and 82.20 kg ha^{-1}), whereas at harvest (Fig.2) it was higher under SRI system. At harvest the nitrogen uptake was more in grain (92.63 kg ha^{-1}) as compared to straw (62.00 kg ha^{-1}). Alternate wetting and drying might have improved the soil aeration and thus root activity to improve the uptake of nutrients under SRI. Increased root dry matter and root volume might have exploited more soil volume for nutrient absorption[11]. N uptake was higher in conventional though yields in SRI were always higher[16]. These findings indicated that plant spacing could contribute to the N uptake pattern but could not regulate the amount of absorbed N in rice plants until harvest. The rhizosphere is a favorable site for nitrification and shown that NO_3 accounts for 15 to nearly 40 per cent of N uptake by rice plants both under submerged conditions and also in SRI with proper water management[5].

Among different nitrogen management approaches, STCR approach recorded higher nitrogen uptake from 30 DAS/T to harvest (around 15.82 kg ha^{-1} at 30DAS/T, 55.95 kg ha^{-1} at 60 DAS/T, 98.23 kg ha^{-1} at 90 DAS/T and at harvest it was 56.50 and 82.03 kg ha^{-1} in straw and grain, respectively). This helped in translocation of photosynthate along with sufficient minerals and thus associated with maximum biomass and yield. Fageria and Baliger[3], reported that in cereals including rice, N accumulation is associated with dry matter production and yield of shoot and grain. Tsujimoto *et al*.[12], reported that average mineralizable N (at depths of 0 to 30 cm) was linearly related to rice grain yield irrespective of management practices. To obtain higher yields of rice plants soil N fertility was crucially important as supported by higher application on N fertilization to soil. At oxidized sites, nitrification by ammonium-oxidizing bacteria and nitrite-oxidizing bacteria could proliferate if a substantial amount of NH_4 is supplied as seen in case of site specific applications[7].

Yield response of rice

SRI system of rice establishment achieved significantly higher grain (7767kg ha^{-1}) and straw (8878 kg ha^{-1}) yield (Table 4). System of rice intensification (SRI) recorded 56.11 and 49.26 per cent higher grain and straw yield over aerobic system (4975 and 5948 kg ha^{-1}), whereas it was 8.24 and 9.54 per cent over conventional system (7219 and 8105 kg ha^{-1}). The increase in the grain and straw yield in SRI system is due to less phyllochron aged seedlings helping for proper establishment with very good root system, Opt intake of nitrogen and other nutrients, significantly higher number of productive tillers m^{-2} followed by growth and yield parameters supported by mineral elements. The study corroborates the findings of Viraktamath[14], and Vijay Mahantesh[13].

Among different nitrogen management approaches, STCR approach recorded higher grain and straw yield (7183 and 8314 kg ha^{-1}) as compared to other nitrogen management approaches like RDF (6196 and 6977 kg ha^{-1}), STL (6393 and7588 kg ha^{-1}) and LCC (6785 and 7697 kg ha^{-1}) (Table 4).Hence, adoption of STCR approach recorded 15.92 and 19.17 per cent higher grain and straw yield over RDF approach. Similarly, 12.36 and 9.56 per cent over STL and 5.86 and 8.01 per cent over LCC approaches. Through STCR approach the quantity of nitrogen, phosphorous and potassium applied were 175, 54 and 50 kg ha^{-1}, respectively for target yield of 8000 kg. In the experimental plots of STCR approach an average of 7183 kg ha^{-1} was achieved. However, as could be seen from the interaction table STCR approach in SRI system of establishment achieved a highest yield of 8348 kg over two years mean data. Hence, reasonably envisaged target yield is achieved by employing STCR approach. Though interaction effect was not significant, yield variations do exist among the interaction treatments. Highest grain yield was noticed in SRI system of establishment with STCR approach (8348 kg ha^{-1}). It was closely followed by SRI system of establishment with LCC (7914 kg ha^{-1}) or conventional system of establishment with STCR (7922 kg ha^{-1}) approach of N management (Table 4).

Response trends in rice

Theory on crop N uptake and allocation allows the determination of many diagnostic tools as Nitrogen indexes of use efficiencies (Table 3). Agronomic N use efficiency (AE_N) indicated that the capability of yield increase per kilogram pure N declined remarkably with increasing N application. Among nitrogen management approaches higher AE_N was recorded by STCR approach (5.64 kg kg^{-1}) as compared to STL (1.74 kg kg^{-1}) and LCC approaches (3.75 kg kg^{-1}). In all three systems of establishment, STCR approach recorded higher values of use efficiency. During the vegetative growth period of all the crop species in general, plant N concentration decreases monotonically because of either the ontogenetic decline in leaf area per unit of plant mass or the remobilization of N from shaded leaves at the bottom of the canopy to well illuminated leaves at the top. Yet the growth, dry matter makes the differentiation towards yield. The results are in conformity with the findings of Zhang *et al.*[15].

Apparent N recovery efficiency (RE_N) was the primary index to describe the characteristics of N uptake and utilization in rice. Most researchers considered that this description accorded with the fact of rice production. In the present study among nitrogen management approaches, STCR recorded higher RE_N (0.24 kg kg^{-1}) as compared to STL (0.10 kg kg^{-1}) and LCC (0.16 kg kg^{-1}) approaches (Table 4.42). Here again, systems of establishment with STCR approach recorded higher values of use efficiency. Quanbao *et al.*[9], showed that RE_N was increased with increasing of N application in sandy soil while it was increased first and reach to the maximum under 225 kg ha^{-1} N application, then declined significantly under 300 kg ha^{-1} N application in clay soil. It indicated that soil type also plays a dominant role.

On the other hand, among different nitrogen management approaches, STL approach recorded higher Physiological N use efficiency (33.03 kg kg^{-1}) as compared to LCC (27.75 kg kg^{-1}) and STCR (24.32 kg kg^{-1}) approaches (Table 4.42).Consistency of results was not noticed in interaction effects. It showed that yield increased per kilogram N accumulated in rice plant was decreased with increasing N application. Similarly, partial factor productivity found higher under RDF approach of nitrogen management (61.96 kg kg^{-1}) as compared to STL (56.82 kg kg^{-1}), LCC (50.63 kg kg^{-1}) and STCR (41.04 kg kg^{-1}) approaches (Table 3).

The nature of response from varied level of N application obtained is presented in Fig. 1. Among the relationships developed, though linear relationships holds the key with > 95 per cent dependency still the higher degree of relation like quadratic was found best fit as the data relayed still higher than relative to an extent of > 96 per cent for the study made in different years. To strengthen the above fact the simple relationship based on factor partitioning is calculated and indicated in table 7. It is learnt from the data that each kg of additional N an efficiency of 11.76 to 15.70 kg grain yield ha^{-1} realized over recommended indicating the positive strength to substantiate the degree of relationship.

Table 1: Nitrogen content of rice as influenced by systems of establishment and nitrogen management approach at different growth stages

Treatments	Nitrogen content (%)								
	30 DAS/T			60 DAS/T			90 DAS/T		
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
Systems of establishment (S)									
S_1 – Aerobic	2.606	2.694	2.650	1.185	1.216	1.200	0.975	1.001	0.988
S_2 – SRI	2.817	2.898	2.857	1.395	1.454	1.425	1.049	1.102	1.076
S_3 – Conventional	2.434	2.494	2.464	1.070	1.108	1.089	0.883	0.899	0.891
S.Em±	0.087	0.082	0.060	0.039	0.033	0.026	0.018	0.012	0.011
C.D. (*p*=0.05)	NS	NS	0.195	0.153	0.131	0.084	0.070	0.046	0.035
Nitrogen management approaches (N)									
N_1 – STCR	2.865	2.953	2.909	1.377	1.424	1.401	1.050	1.085	1.067
N_2 – STL	2.529	2.621	2.575	1.144	1.180	1.162	0.942	0.972	0.957
N_3 – LCC	2.689	2.757	2.723	1.240	1.300	1.270	1.001	1.029	1.015
N_4 – RDF	2.392	2.449	2.421	1.107	1.133	1.120	0.883	0.917	0.900
S.Em±	0.047	0.079	0.046	0.027	0.024	0.018	0.023	0.020	0.015
C.D. (*p*=0.05)	0.139	0.233	0.131	0.081	0.070	0.052	0.069	0.060	0.044
Interaction (SxN)									
S_1N_1	2.858	2.941	2.900	1.333	1.387	1.360	1.040	1.077	1.058
S_1N_2	2.511	2.608	2.559	1.130	1.153	1.142	0.957	0.977	0.967
S_1N_3	2.683	2.767	2.725	1.183	1.230	1.207	1.003	1.033	1.018
S_1N_4	2.370	2.460	2.415	1.093	1.093	1.093	0.901	0.915	0.908
S_2N_1	3.153	3.267	3.210	1.610	1.677	1.643	1.133	1.190	1.162
S_2N_2	2.712	2.825	2.768	1.283	1.323	1.303	1.015	1.075	1.045
S_2N_3	2.930	3.002	2.966	1.467	1.533	1.500	1.087	1.120	1.103
S_2N_4	2.473	2.497	2.485	1.220	1.283	1.252	0.960	1.023	0.992
S_3N_1	2.585	2.651	2.618	1.187	1.210	1.198	0.977	0.987	0.982
S_3N_2	2.363	2.430	2.397	1.017	1.064	1.041	0.853	0.863	0.858
S_3N_3	2.453	2.503	2.478	1.071	1.136	1.103	0.913	0.933	0.923
S_3N_4	2.333	2.390	2.362	1.007	1.023	1.015	0.787	0.813	0.800
S.Em±	0.081	0.136	0.079	0.047	0.041	0.031	0.040	0.035	0.027
C.D. (*p*=0.05)	NS	NS	NS	NS	NS	0.089	NS	NS	NS
CV (%)	5.35	8.74	7.30	6.69	5.62	6.16	7.18	6.10	6.65

DAS/T: Days after sowing/ transplanting, NS: Non Significant

Table 2: Nitrogen uptake of rice as influenced by systems of establishment and nitrogen management approaches at different growth stages

Treatments	Nitrogen uptake (kg ha^{-1})								
	30 DAS/T			60 DAS/T			90 DAS/T		
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
Systems of establishment (S)									
S_1 – Aerobic	6.67	6.89	6.78	15.72	16.17	15.94	44.97	46.15	45.56
S_2 – SRI	14.47	14.90	14.68	49.57	51.67	50.62	80.05	84.35	82.20
S_3 – Conventional	17.36	17.83	17.60	64.28	66.42	65.35	126.57	129.15	127.86
S.Em±	0.76	0.41	0.43	3.06	3.04	2.15	3.74	4.56	2.95
C.D. (*p*=0.05)	2.97	1.60	1.40	12.00	11.93	7.03	14.67	17.90	9.61
Nitrogen management approaches (N)									
N_1 – STCR	15.55	16.10	15.82	55.05	56.85	55.95	96.74	99.72	98.23
N_2 – STL	12.03	12.44	12.23	38.75	39.92	39.34	79.20	81.45	80.33
N_3 – LCC	13.30	13.61	13.45	45.58	48.10	46.84	89.82	92.33	91.08
N_4 – RDF	10.45	10.68	10.57	33.37	34.12	33.75	69.69	72.70	71.20
S.Em±	0.70	1.05	0.63	3.44	3.51	2.46	6.08	6.65	4.50
C.D. (*p*=0.05)	2.07	3.11	1.80	10.21	10.42	7.04	18.07	19.75	12.92
Interaction (SxN)									
S_1N_1	7.72	7.94	7.83	19.85	20.67	20.26	50.77	52.50	51.63
S_1N_2	6.42	6.66	6.54	13.63	13.95	13.79	43.58	44.53	44.05
S_1N_3	6.98	7.19	7.08	16.60	17.25	16.93	47.42	48.82	48.12
S_1N_4	5.56	5.78	5.67	12.79	12.79	12.79	38.11	38.77	38.44
S_2N_1	18.84	19.52	19.18	69.66	72.73	71.19	89.74	95.12	92.43
S_2N_2	12.91	13.45	13.18	42.73	43.89	43.31	75.99	80.38	78.18
S_2N_3	14.76	15.15	14.95	54.86	57.56	56.21	85.19	87.96	86.58
S_2N_4	11.35	11.48	11.41	31.02	32.50	31.76	69.29	73.95	71.62
S_3N_1	20.08	20.83	20.46	75.63	77.16	76.40	149.72	151.54	150.63
S_3N_2	16.75	17.21	16.98	59.90	61.92	60.91	118.04	119.44	118.74
S_3N_3	18.16	18.49	18.32	65.28	69.50	67.39	136.86	140.22	138.54
S_3N_4	14.44	14.80	14.62	56.30	57.09	56.69	101.66	105.39	103.53
S.Em±	1.21	1.81	1.09	5.95	6.07	4.25	10.53	11.52	7.80
C.D. (*p*=0.05)	NS	NS	NS	NS	NS	12.20	NS	NS	NS
CV (%)	16.32	23.77	20.49	23.88	23.51	23.69	21.75	23.04	22.43

DAS/T: Days after sowing/ transplanting, NS: Non Significant

Table 3: Agronomic efficiency of added N (AE_N), recovery efficiency of added N (RE_N), physiological efficiency of added N (PE_N) and partial factor productivity (PFP_N) of rice as influenced by systems of establishment and nitrogen management approaches

Treatments	AE_N (kg kg^{-1})			RE_N (kg kg^{-1})			PE_N (kg kg^{-1})			PFP_N (kg kg^{-1})		
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
Nitrogen management approaches (N)												
N_1 – STCR	5.64	5.63	5.64	0.23	0.25	0.24	23.36	25.28	24.32	40.82	41.27	41.04
N_2 – STL	1.75	1.74	1.74	0.10	0.11	0.10	28.03	38.04	33.03	56.47	57.18	56.82
N_3 – LCC	3.68	3.81	3.75	0.16	0.16	0.16	28.91	26.59	27.75	50.26	51.00	50.63
N_4 – RDF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	61.56	62.37	61.96
Interaction (SxN)												
S_1N_1	3.22	3.17	3.20	0.17	0.18	0.18	17.68	25.92	21.80	29.96	30.37	30.16
S_1N_2	1.03	1.00	1.02	0.05	0.07	0.06	21.47	21.97	21.72	42.61	43.31	42.96
S_1N_3	2.50	2.75	2.63	0.13	0.14	0.13	31.00	25.32	28.16	37.42	38.27	37.84
S_1N_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	46.78	47.59	47.19
S_2N_1	6.06	6.06	6.06	0.29	0.31	0.30	20.78	20.49	20.64	47.47	47.94	47.70
S_2N_2	2.04	2.04	2.04	0.17	0.16	0.17	12.48	24.29	18.38	66.46	67.18	66.82
S_2N_3	3.82	3.82	3.82	0.22	0.20	0.21	18.16	18.82	18.49	58.76	59.36	59.06
S_2N_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	72.48	73.29	72.88
S_3N_1	7.65	7.65	7.65	0.24	0.26	0.25	31.63	29.43	30.53	45.03	45.50	45.27
S_3N_2	2.18	2.18	2.18	0.08	0.09	0.08	50.12	67.86	58.99	60.33	61.05	60.69
S_3N_3	4.72	4.87	4.80	0.13	0.14	0.14	37.56	35.63	36.59	54.60	55.38	54.99
S_3N_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	65.42	66.23	65.82

Table 4: Grain yield, straw yield, harvest index and test weight of rice as influenced by systems of establishment and nitrogen management approaches

Treatments	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})			Harvest Index (HI)		
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
System of establishment (S)									
S_1 – Aerobic	4933	5018	4975	5948	5949	5948	0.46	0.46	0.46
S_2 – SRI	7726	7807	7767	8882	8875	8879	0.47	0.47	0.47
S_3 – Conventional	7132	7219	7175	8177	8032	8105	0.47	0.47	0.47
S.Em±	78	89	59	296	275	202	0.01	0.01	0.01
C.D. (*p*=0.05)	307	351	194	1164	1079	659	NS	NS	NS
N management approaches (N)									
N_1 – STCR	7144	7222	7183	8362	8266	8314	0.46	0.47	0.46
N_2 – STL	6353	6433	6393	7584	7593	7588	0.46	0.46	0.46
N_3 – LCC	6735	6835	6785	7687	7707	7697	0.47	0.47	0.47
N_4 – RDF	6156	6237	6196	7044	6909	6977	0.47	0.47	0.47
S.Em±	182	192	132	303	313	218	0.01	0.01	0.01
C.D. (*p*=0.05)	540	570	379	900	929	625	NS	NS	NS
Interaction (S X N)									
S_1N_1	5242	5314	5278	6481	6490	6486	0.45	0.45	0.45
S_1N_2	4794	4872	4833	5894	5903	5899	0.45	0.45	0.45
S_1N_3	5014	5128	5071	5939	5948	5943	0.46	0.46	0.46
S_1N_4	4678	4759	4719	5478	5454	5466	0.46	0.47	0.46
S_2N_1	8308	8389	8348	9474	9483	9479	0.47	0.47	0.47
S_2N_2	7477	7558	7517	8870	8879	8875	0.46	0.46	0.46
S_2N_3	7874	7954	7914	8939	8982	8960	0.47	0.47	0.47
S_2N_4	7248	7329	7288	8246	8155	8201	0.47	0.47	0.47
S_3N_1	7881	7962	7921	9131	8824	8977	0.46	0.47	0.47
S_3N_2	6787	6868	6828	7987	7996	7992	0.46	0.46	0.46
S_3N_3	7317	7421	7369	8183	8192	8188	0.47	0.48	0.48
S_3N_4	6542	6623	6582	7408	7117	7263	0.47	0.48	0.48
S.Em±	315	332	229	525	542	378	0.02	0.02	0.01
C.D. (*p*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	8.26	8.61	8.44	11.85	12.32	12.09	8.28	6.61	7.48

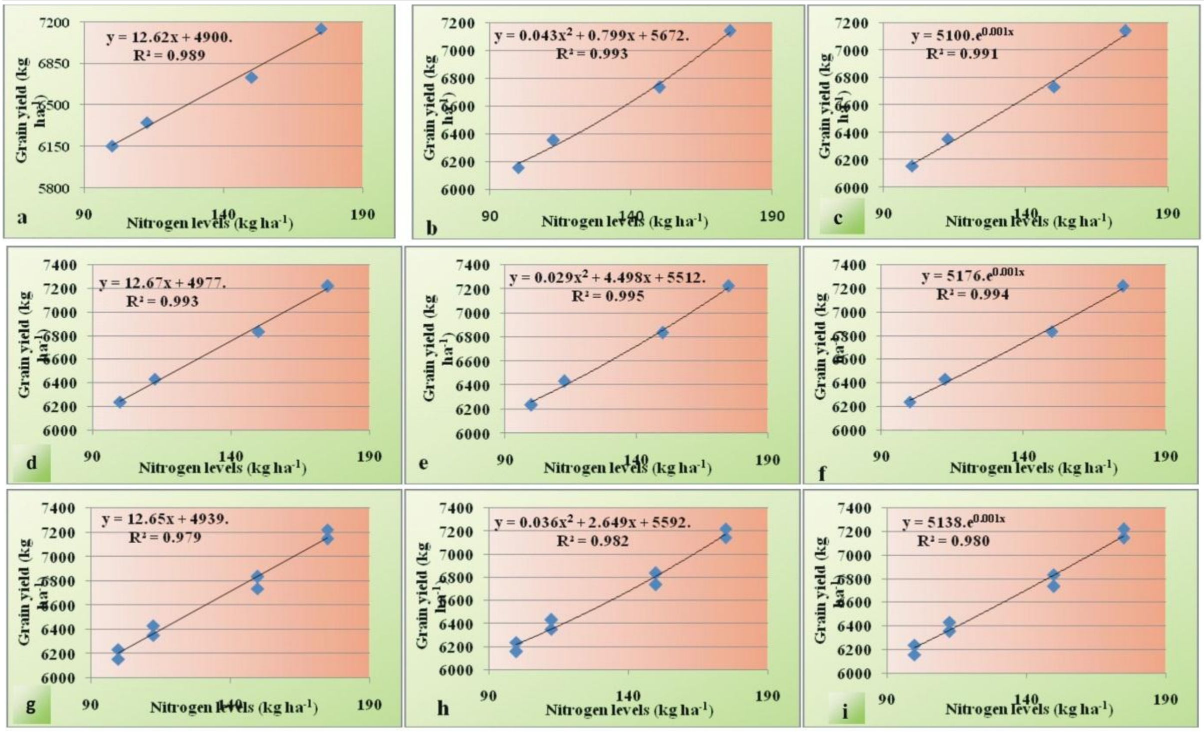

Fig. 1: Yield trends for different nitrogen levels through simple regression for different systems of establishment

(a, b and c indicates linear, polynomial and exponential representation of yield under aerobic system; d, c and f represent SRI system; g, h andi represents conventional system)

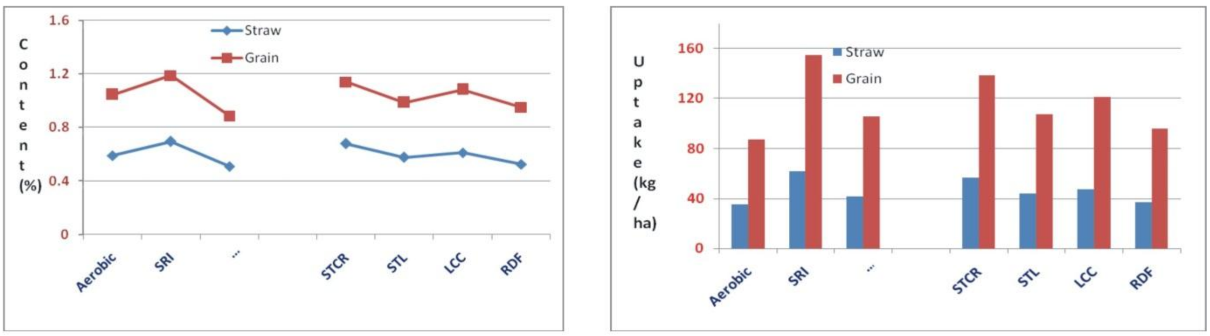

Fig. 2: Nutrient content and uptake of nitrogen as affected by method of planting and nitrogen management approaches

Table 5: Response of additional yield variations above recommended fertilizer

N levels	2014	2015	Mean	Additional yield over recommended	Additional yield per kg of additional N added	Additional B:C ratio
100	6155.92	6236.92	6196.42	-	-	-
112.5	6352.63	6432.63	6392.63	196.21	15.70	13.16
150	6734.65	6834.54	6284.60	188.18	11.76	9.85
175	7143.72	7221.71	7182.72	986.3	13.15	11.02

CONCLUSION

The results of the present investigation permit to infer that SRI system of establishment with with STCR based N management performed better followed by LCC approach.

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