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RESEARCH ARTICLE

Effect of graded nutrient levels and time of nitrogen application on performance of rice under SRI

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SUMMARY

Field experiments were conducted for two consecutive *Kharif* seasons of 2005 and 2006 at Agricultural College farm, Naira, Srikakulam district,A.P. on sandy clay loam soil with an objective of optimization of agro-techniques for higher productivity of rice under SRI in North Coastal Zone of Andhra Pradesh. The treatments comprised of four graded nutrient levels assigned to main plots and four time of nitrogen application practices assigned to sub plots tried in split plot design. The highest stature of growth, yield attributes, lesser spikelet sterility , higher grain yield and more returns were obtained with the application of 100-50-50 kg ha^{-1} N, P_2O_5, K_2O and these parameters were at their minimum with the supply of 60- 30 - 30 kg ha^{-1} of N, P_2O_5, K_2O. The increase in yield with supply of 100- 50 - 50 kg ha^{-1} N, P_2O_5, K_2O (N_3), compared to supply of 60- 30 - 30 kg ha^{-1} N, P_2O_5, K_2O (N_1) was 15.1 and 15.4 per cent, during 2006 and 2007, respectively. Similarly, the highest stature of growth, yield attributes, lesser spikelet sterility, higher grain yield and more returns were produced with the supply of nitrogen fertilization in three splits as 1/3 basal + 1/3 at active tillering +1/3 at panicle initiation (T_1). While these parameters were the lowest with split application of nitrogen dose as ½ at active tillering + ½ at panicle imitation without basal application (T_4) and increase in yield with (T_1) compared to (T_4) was 10.6 and 14.4 per cent, during 2006 and 2007, respectively under SRI.

Key Words : Rice, SRI, Graded levels of nutrients, Time of N application, Yield attributes, Grain yield, Returns

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Plateau in rice yields coupled with restrictions on area expansion, availability of water, labour and the need to achieve projected targets of about 140 million tons by 2020 are the major challenges facing Indian rice researchers. The increase in rice productivity, therefore, needs to be achieved through adoption of suitable and newer technologies. The system of rice intensification (SRI) is an important tool in this direction and offers opportunities to researchers and farmers to expand the yield potentials already existing in the rice genome (Stoop *et al.,* 2002). It is also a new sustainable methodology for increasing the productivity of irrigated rice through a change in plant, soil, water and nutrient management resulting in both improvement of soil health and increased yields supported by greater root growth and the soil microbial abundance and diversity. The system of rice intensification (SRI) has been recently introduced to India and is slowly gaining momentum. It has been field tested in the state of Andhra Pradesh by the state department of Agriculture and District Agricultural Advisory and Transfer of Technology centers of Acharya N.G. Ranga Agricultural University. Scientists and farmers dealing with SRI are of the opinion that the high productivity under SRI calls for adoption of greater nutrient supply as the Indian soils are low in organic matter and nutrient status.

Nitrogen supply is known to affect both dry matter production and its effective partitioning and tillering in rice. Higher nitrogen supply favours the dry matter accumulation

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in foliage rather than in economic sink. Sub optimal level of nutrient supply subdues the dry matter accrual in source system. Thus, optimum nitrogen supply is very much essential for effective partitioning of accumulated dry matter to saleable parts/economical parts. Therefore, nitrogen application should be moderate and timely, in order to prevent excessive development of vegetative growth at the cost of panicle and grain development. Moreover, nitrogen is a costly input in crop production. It is, therefore, necessary that it should be applied in such a way that the various losses are minimized and the maximum efficiency can be realized. In this context, the present study was undertaken with the objectives to determine the level of fertilizer application and time of nitrogen application for higher productivity under SRI cultivation.

MATERIAL AND METHODS

Field experiments were conducted for two consecutive *Kharif* seasons of 2005, 2006 at Agricultural College farm, Naira, Srikakulam district, Andhra Pradesh (18.24^o N latitude and 83.84^o E longitude). The soils were sandy clay loam in texture, low in organic carbon and available nitrogen, medium in available phosphorus and available potassium. In both the years the test variety of rice tried was Swarna (MTU 7029). Experiment was conducted in a Split Plot Design with three replications. The treatments comprised of four graded nutrient levels assigned to main plots [N_1 : 60 – 30 - 30 kg N, P_2O_5 and K_2O ha^{-1} ; N_2: 80 – 40 - 40 kg N, P_2O_5 and K_2O ha^{-1} ;N_3 : 100 – 50 - 50 kg N, P_2O_5 and K_2O ha^{-1} and N_4 : 120 – 60 - 60 kg N, P_2O_5 and K_2O ha^{-1}] and four time of nitrogen application practices to sub plots [T_1: 1/3 as basal + 1/3 at active tillering + 1/3 at panicle initiation (3 splits); T_2 : ¼ as basal+ ¼ at active tillering + ¼ at panicle initiation + ¼ at flowering (4splits) ; T_3 : No basal application, 1/3 at active tillering + 1/3at panicle initiation + 1/3rd at flowering (3 splits) and T_4 : No basal application, ½ at active tillering + ½ at panicle initiation (2 splits)]. The nursery was prepared with raised beds of 1.5 m width and of convenient length. Bold and healthy seeds were soaked for 12 hours and incubated in moist gunny cloth for 24 hours. A fine thin layer of well decomposed farm yard manure (FYM) was spread over the seed bed and then the sprouted paddy seed was broadcasted uniformly. After broadcasting the seeds, a thin layer of sieved FYM was again spread over the bed surface to cover the seed and water was sprinkled everyday for keeping the soil moist and also for better seedling stand. Coconut palm leaves were also used for covering the beds for retention of soil moisture. The recommended nutrient dose of N, P_2O_5 and K_2O (80-60-50 kg ha^{-1}) was applied as per the treatments. The experiments were provided uniform plant protection and cultural management practices throughout the period of crop growth.

Data on growth were collected from ten randomly marked hills at flowering stage. Dry matter production at harvest was recorded from ten randomly marked hills, samples were air-dried and then oven dried at 60^{o}C to a constant weight and expressed as kg ha^{-1}. The number of ear bearing tillers were counted from tagged plants, averaged to compute productive tillers hill^{-1} and expressed as panicles m^{-2} ,ten randomly selected panicles were counted, averaged and expressed as number of grains per panicle and filled grains per panicle at maturity stage. Thousand grains randomly drawn from the composite sample of grain yield of net plot in each treatment (dried to 14 % moisture content), were weighed and expressed in grams. Grain from the net plot was thoroughly sun dried to 14 per cent moisture content, weighed and expressed in kg ha^{-1}. The relationship of economic yield to the total biological yield was expressed as harvest index (HI). Nitrogen content of grain and straw was analysed separately using modified microkjeldahl method and crude protein was estimated by multiplying total N with factor 5.95. Economic parameters like gross returns, net returns and rupee returned rupee^{-1} invested were worked out treatment – wise taking prevailing market rates for different inputs and out puts. Data were analyzed using ANOVA and the significance was tested by Fisher's least significance difference ($p= 0.05$).

RESULTS AND DISCUSSION

The results of the present study as well as relevant discussions have been presented under following sub heads:

Effect of graded levels of nutrients on performance of rice under SRI:

Growth of rice as indicated by the plant height, leaf area index, total number of tillers m^{-2} , dry matter production at flowering and at harvest were influenced by graded levels of nutrients. The highest stature of growth parameters plant height, leaf area index, total number of tillers m^{-2} and dry matter production were produced with the nutrient level of 100-50-50 kg ha^{-1} N, P_2O_5 , K_2O which were comparable with those produced with 120–60-60 kg ha^{-1} of N, P_2O_5 , K_2O nutrients (N_4) and significantly superior to other two nutrient levels tried. It could be attributed to the fact that higher nutrient levels might have accelerated the synthesis of more chlorophyll and amino acids and stimulated the cellular activity, which is useful for the process of cell division and meristimatic growth, resulting in the enhanced growth stature. Similar results of increase in growth stature of with increased nutrient levels have been reported by Singh and Namdeo (2004) and Dwivedi *et al.* (2006). The shortest plants were noticed with the supply of 60- 30 - 30 kg ha^{-1} of N, P_2O_5, K_2O (N_1), which were however, at par with 80- 40 - 40 kg ha^{-1} of N, P_2O_5 , K_2O (N_2). Reduced stature of growth parameters of rice was noticed with 60-30-30 kg ha^{-1}of N, P_2O_5 , K_2O, which was obviously due to supply of insufficient dose of nutrients, denying satisfactory level of growth, probably due to retarded cell division and multiplication, as was also opined by Singh and singh (1999) (Table 1).

The highest stature of yield attributes *viz*., number of panicles m^{-2}, total number of grains $panicle^{-1}$ and number of filled grains $panicle^{-1}$ was recorded with supply of 100- 50 - 50 kg ha^{-1} N, P_2O_5 , K_2O however, which were comparable with those produced with 120–60-60 kg ha^{-1} of N, P_2O_5 , K_2O nutrients (N_4) and significantly superior to other two nutrient levels tried. The elevated stature might be presumably due to the concomitant supply of primary nutrients and translocation of photosynthates efficiently to sink, contributing to the better development of yield contributing characters. These results are in conformity with those of Kundu *et al*.(2004), Raju and Suneetha Devi (2005). These parameters were lowest with the supply of 60- 30 - 30 kg ha^{-1} of N, P_2O_5 , K_2O (N_1), which were however, at par with 80- 40 - 40 kg ha^{-1} of N, P_2O_5 , K_2O (N_2). The lowest stature of yield attributes of rice under SRI was noticed with lowest dose of nutrient supply (Table 2). Similar results of poor yield attributing characters with lower doses of major nutrients was documented by Sharma *et al*.(1990).

Thousand grain weight of rice did not differ significantly either with the graded nutrient levels during both the years of investigation. Spikelet sterility of rice was the lowest with the supply of 100- 50- 50 kg ha^{-1} N, P_2O_5 , K_2O (N_3), which was comparable with the supply of 120 - 60 - 60 kg ha^{-1} N, P_2O_5 , K_2O (N_4) and significantly lower than with the other two nutrient levels tried. The highest value of spikelet sterility was

Table 1 : Growth parameters of rice under SRI at Flowering and dry matter production at harvest as influenced by graded nutrient levels and varied time of nitrogen application

Treatments	Plant height (cm)		Leaf area index		Total tillers m^{-2}		DMP (kg ha^{-1})		DMPH (kg ha^{-1})	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Nutrient levels										
N_1	93.5	87.4	3.11	2.63	758	544	10006	9587	10136	9845
N_2	94.5	88.9	3.37	2.78	776	565	10139	9663	10508	10102
N_3	101.0	95.8	4.04	3.52	818	605	12255	11530	13436	12845
N_4	98.5	94.6	3.86	3.20	805	595	11894	10972	12731	12141
S.E. ±	0.92	1.17	0.12	0.10	6.94	9.91	366	292	379	441
CD (P=0.05)	3.2	4.1	0.42	0.38	24	27	1268	1009	1312	1526
Time of nitrogen application										
T_1	106.2	98.0	4.64	3.77	835	620	12185	11732	13470	12703
T_2	102.4	95.9	4.35	3.48	825	599	11758	11221	12456	11892
T_3	90.3	87.3	2.91	2.57	756	551	10665	9717	10908	10590
T_4	88.7	85.5	2.80	2.31	741	540	9686	9282	9977	9748
S.E. ±	0.89	0.35	0.10	0.07	8.99	6.62	365	282	224	272
C.D. (P=0.05)	2.4	1.4	0.28	0.21	26	19	1067	823	654	796

Table 2 : Yield attributes of rice under SRI as influenced by graded nutrient levels and varied time of nitrogen application

Treatments	Panicles m^{-2}		Total grains $panicle^{-1}$		Number of filled grains $panicle^{-1}$		1000 grain weight (g)		Spikelet sterility (%)	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Nutrient levels										
N_1	357	341	169	174	112	107	18.38	17.77	28.65	38.20
N_2	368	352	173	182	130	118	18.57	18.22	25.45	35.61
N_3	448	411	211	214	180	171	19.67	19.02	14.65	21.06
N_4	438	388	209	210	175	163	19.04	18.73	16.77	22.98
S.E. ±	16.57	9.19	8.26	8.71	12.07	10.94	0.29	0.35	1.25	1.64
CD (P=0.05)	57	32	29	30	42	37	NS	NS	4.32	5.67
Time of nitrogen application										
T_1	460	410	214	212	187	172	19.45	19.33	12.62	19.06
T_2	431	392	208	209	176	161	19.11	18.93	15.59	23.48
T_3	361	350	170	181	124	116	18.65	17.94	27.39	36.49
T_4	354	340	169	179	119	110	18.45	17.75	29.92	38.81
S.E. ±	11.54	6.59	5.76	5.03	9.35	7.38	0.17	0.23	0.83	1.24
CD (P=0.05)	34	19	17	15	27	22	NS	NS	3.27	4.84

NS=Non-significant

recorded with the supply of 60- 30 - 30 kg ha^{-1} N, P_2O_5 , K_2O (N_1), which was however, at par with 80- 40 - 40 kg ha^{-1} N, P_2O_5 , K_2O (N_2).

During both the years of study, grain yield of rice was significantly influenced by supply of graded nutrient levels and it was increased significantly with increase in nutrient levels from N_1 to N_3. Grain yield of rice was the highest with the supply of 100- 50 - 50 kg ha^{-1} N, P_2O_5, K_2O (N_3), which was comparable with the supply of 120 - 60 - 60 kg ha^{-1} N, P_2O_5 , K_2O (N_4) and significantly higher than with the other two nutrient levels tried. The lowest grain yield was obtained with the supply of 60- 30 - 30 kg ha^{-1} N, P_2O_5, K_2O (N_1), which was however, at par with 80- 40 - 40 kg ha^{-1} N, P_2O_5, K_2O (N_2). The increase in yield with supply of 100- 50 - 50 kg ha^{-1} N, P_2O_5, K_2O (N_3), compared to supply of 60- 30 - 30 kg ha^{-1} N, P_2O_5, K_2O (N_1) was15.1 and 15.4 per cent during 2006 and 2007, respectively (Table 3). The improvement in yield with (N_3), was due to better availability and uptake of nutrients, which in turn lead to efficient metabolism. High level of biomass accrual and efficient translocation of photosynthates from source to sink might be responsible for the production of elevated level of yield structure. Rice plants when grown under saturated condition develop more hairy, branched secondary adventitious roots near the root-soil interface in order to absorb dissolved oxygen in the oxidized layer and take up more nutrients resulting in higher yields. These results are in accordance with those of Mulugeta Seyoum and Heluf Gebrekidan (2005) and Dwivedi *et al*.(2006).Harvest index of rice and protein content of grain was not significantly influenced either by varied time of nitrogen application tried, during both the years of study.

The highest gross and net returns were found with supply of 100- 50- 50 kg ha^{-1} N, P_2O_5, K_2O (N_3) followed by with application of 120-60-60 kg ha^{-1} N, P_2O_5, K_2O (N_4), 80-40-40 kg ha^{-1} N, P_2O_5, K_2O (N_2) and 60-30-30 kg ha^{-1} N, P_2O_5, K_2O (N_1), with significant disparity between any two of them and the lowest gross returns were obtained with N_1 (Table 3). This could be attributed to the higher yield of grain and straw with higher levels of nutrients. These economic returns were the lowest with the lowest level of nutrient supply (60-30-30 kg ha^{-1} N, P_2O_5, K_2O) due to poor performance of the crop. Similar results have been reported by Uprety (2008) and Anjugam *et al*. (2008).

Effect of time of nitrogen application on performance of rice under SRI:

Time of nitrogen application exerted significant influence on the growth parameters of rice *viz*., plant height, leaf area index, total number of tillers m^{-2} dry matter production at flowering and at harvest (Table 1). The highest stature of growth parameters were produced with the supply of nitrogen fertilization in three splits as 1/3 basal + 1/3 at active tillering +1/3 at panicle initiation (T_1), followed by supply of nitrogen in four splits of 1/4th each at basal, active tillering, panicle initiation and flowering (T_2), three splits of 1/3rd each at active tillering, panicle initiation and flowering (T_3) and ½ each at active tillering and panicle imitation (T_4), with significant disparity between any two of them .While these growth characters were the lowest with split application of nitrogen dose as ½ at active tillering + ½ at panicle imitation without basal application (T_4), during both the years of study. The split application of nitrogen reduced the denitrification and leaching losses in rice fields and thereby increased growth stature. This was mainly because, nitrogen applied at three splits maintained the continuous supply of nitrogen to the crop, which might have matched with the growth stage of crop

Table 3 : Grain yield, H I, protein content of grain and returns of rice under SRI as influenced by graded nutrient levels and varied time of nitrogen application

Treatments	Grain yield (kg ha^{-1})		Harvest index (%)		Protein content of grain (%)		Gross returns (Rs ha^{-1})		Net returns (Rs ha^{-1})	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Nutrient levels										
N_1	6888	6554	49.06	49.13	5.34	5.54	52507	49950	40289	37732
N_2	7136	6665	49.14	49.14	5.55	5.63	54383	50739	41478	37991
N_3	7927	7564	49.14	49.14	6.11	5.99	60412	57804	47135	44528
N_4	7684	7372	49.14	49.14	5.97	5.88	58558	56182	44751	42375
S.Em ±	154	194	0.59	0.78	0.03	0.04	239	197	81.1	59.3
CD (P=0.05)	534	675	NS	NS	NS	NS	920	760	312	228
Time of nitrogen application										
T_1	7795	7522	49.14	49.14	6.54	6.42	59420	57265	46270	44273
T_2	7646	7341	49.13	49.14	6.28	6.25	58276	55948	45136	42875
T_3	7144	6716	49.14	49.14	5.18	5.21	54447	51338	41454	38346
T_4	7049	6577	49.14	49.14	4.97	5.16	53719	50124	40726	37131
S.Em ±	105.7	134.7	0.34	0.49	0.02	0.03	166	222	59.8	43.9
CD (P=0.05)	308	393	NS	NS	NS	NS	648	534	234	172

NS=Non-significant

resulting in more leaf area and dry matter production. These results are in concurrence with the findings of Singh and Singh (1999).

Split application of nitrogen exerted significant influence on yield attributes of rice *viz.*, number of panicles m^{-2}, total number of grains $panicle^{-1}$ and number of filled grains $panicle^{-1}$ (Table 2). The highest stature of the yield attributes *i.e.*, more number of panicles m^{-2} with more number of total and filled grains $panicle^{-1}$ was attained with split application of nitrogen as 1/3 basal + 1/3 at active tillering + 1/3 at panicle initiation (T_1). However, which was comparable with application of nitrogen ¼basal, ¼ at active tillering, ¼th at panicle initiation and ¼ at flowering (T_2) and significantly higher than with other two times of nitrogen application tried. The lowest number of tillers m^{-2} was registered with supply of nitrogen ½ each at active tillering and panicle imitation (T_4), which was however, at par with the nitrogen supply in three splits of 1/3rd each at active tillering, panicle initiation and flowering (T_3). This may be attributed to the fact that nitrogen use efficiency in rice crop will be maximum when it is applied in three splits at different growth stages than applied in two splits; thereby the yield attributes were the highest with T_1. Similar results have been reported by Singh and Singh (1999). Application of highest rates of fertilizer nitrogen in one or two splits resulted in excessive vegetative growth coupled with lower supply of carbohydrates for grain filling and hence, resulted in production of less number of filled grains per panicle. This might be the reason that lowest stature of yield attributes recorded when nitrogen applied in two splits (T_4). These findings are in conformity with Jee and Mahapatra. (1989).

Thousand grain weight of rice did not differ significantly with the varied time of nitrogen application, during both the years of investigation. The lowest spikelet sterility was recorded with the supply of nitrogen in three splits of 1/3rd each at basal, active tillering and panicle initiation (T_1), followed by supply of nitrogen in four splits of 1/4 th each at basal, active tillering, panicle initiation and flowering (T_2), three splits of 1/3rd each at active tillering, panicle initiation and flowering (T_3) and ½ each at active tillering and panicle imitation (T_4), with significant disparity between any two of them and the highest spikelet sterility was noticed under T_4 (Table 2).

Grain yield of rice was significantly influenced by varied time of nitrogen application during both the years of study (Table 3). The highest grain yield was recorded with the supply of nitrogen in three splits of 1/3rd each at basal, active tillering and panicle initiation (T_1), which was comparable with the application of nitrogen ¼basal, ¼ at active tillering , ¼th at panicle initiation and ¼ at flowering (T_2) and significantly higher than with other two times of nitrogen application tried. The lowest grain yield was produced with the supply of nitrogen ½ each at active tillering and panicle imitation (T_4), which was however, at par with the nitrogen supply in three splits of 1/3rd each at active tillering, panicle initiation and flowering (T_3). The increase in yield with (T_1) compared to (T_4) was10.6 and 14.4 per cent, respectively during 2006 and 2007, respectively. This might be due to the fact that split application of nitrogen to rice under SRI will maintain the constant nutrient content at different growth stages thereby there is improvement in the stature of growth as well as yield attributes, resulting in higher grain and straw yields. Application of nitrogen in two splits *i.e.* ½ at active tillering + ½ at panicle initiation, without basal application recorded the lowest grain and straw yields of rice under SRI, which indicates the importance of nitrogen nutrition to rice crop right from basal to panicle initiation. These results are in accordance with those of Chandra (1997) and Singh (2006).Harvest index of rice and protein content of grain was not significantly influenced either by varied time of nitrogen application tried, during both the years of study.

The highest gross returns and net returns were realized with the supply of nitrogen in three splits of 1/3rd each at basal, active tillering and panicle initiation (T_1), followed by supply of nitrogen in four splits of 1/4th each at basal, active tillering, panicle initiation and flowering (T_2), three splits of 1/3rd each at active tillering, panicle initiation and flowering (T_3) and ½ each at active tillering and panicle imitation (T_4), with significant disparity between any two of them and the lowest gross returns were registered with T_4 (Table 3). This was due to the higher grain and straw yield of rice obtained with better nitrogen management practice *i.e.*, application of nitrogen in three splits as 1/3 basal+1/3 at active tillering +1/3 at panicle initiation. The poorest performance of rice was recorded with T_4 (no basal, ½ at active tillering and ½ at panicle initiation) and the lowest yield level has obviously resulted in the poor economic returns. Application of nitrogen in three splits proved beneficial over two splits, for obtaining higher economic returns. Similar trend of economic returns under SRI have been reported earlier by Uprety (2008) and Parpavani and Jayaraj (2008).

It can be inferred that, the highest stature of growth, yield attributes, lesser spikelet sterility, higher grain yield and more returns were obtained with the application of 100-50-50 kg ha^{-1} N, $P_2 0_5$, $K_2 0$ among four graded nutrient levels and with the supply of nitrogen fertilization in three splits as 1/3 basal + 1/3 at active tillering +1/3 at panicle initiation among four time of nitrogen application practices under SRI.

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