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Nitrogen availability and uptake as influenced by time of application and N sources in semi-dry rice (*Oryza sativa*)

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ABSTRACT

Nitrogen uptake and N availability at different phenological stages of semi-dry rice was studied in a field experiment with time of N application as main plot treatment and sources of N as subplot treatments for two consecutive rabi seasons of 2009-10 and 2010-11 respectively in sub-split plot design. Results revealed that time of N application and sources of N had profound influence on the soil available N status and N uptake at different stages of crop growth. Available N in the soil increased up-to panicle initiation stage and then started declining as the growth advanced. The available N status was the highest with application of N in 4 equal splits at 5-10 days after emergence (DAE), 20-25 DAE, 40-45 DAE and 60-65 DAE. Among the sources, neem cake blended urea maintained high available N status in the soil at all phenological stages compared to other slow release forms of urea. Prilled urea maintained lower N status in the soil during both the years of study. Time of N application greatly influence the N uptake in semi dry rice. On an average, the N uptake was 28.3, 40.6, 55.3 and 81.7 kg ha^{-1} at 60, 75, 90 DAE and at harvest respectively. The treatment received half the portion of N at 20-25 DAE recorded the lowest uptake. With regard to different N source, neem cake blended urea recorded the highest uptake and prilled urea recorded the lowest uptake at all the phenological stages. The better uptake of N with minimum N losses and optimum N supply throughout the crop stage resulted in better growth and yield attributes. The highest grain yield was recorded in neem cake blended urea applied in four equal splits (3752 and 3872 kg ha^{-1}) during first and second year respectively. The study conclusively proved that physical blending of urea in four equal splits from 5-10 DAE to 60-65 DAE enhanced the N availability, N uptake and productivity in semi dry rice.

***Keywords*: N availability, N uptake, sources of N, semi-dry rice and time of N application**

Semi dry rice refers to rice which is sown on dry seed bed as an upland crop taking advantage of monsoon rains. At fourth or fifth leaf stage, when the rainfall intensifies or sufficient water is released from the tank or irrigation projects, the field is converted to wet land rice. The major barrier in improving the productivity of rice in this system is inefficient use of important plant nutrients especially N. Occurrence of diametrically opposite environment, both upland and lowland condition during the growth cycle of semi-dry rice, requires precise nitrogen management technology which is different from that of upland and lowland systems. Semi-dry rice fits very well during the short growing periods as in the case of delayed monsoon and in pre and post flood periods in the flood prone rice growing areas.

In recent years there has been a shift from transplanting to direct seeding.This shift was principally driven by waterscarcity issues and expensive labour component for transplanting under acute farm labour shortage (Chauhan, 2012). Direct-seeding of rice has the potential to provideseveral benefits to farmers and the environment overconventional practices of puddling and transplanting. Directseeding helps reduce water consumption by about 30% (0.9million liters acre^{-1}) as it eliminates raising of seedlings in anursery, puddling, transplanting under puddled soil andmaintaining 4-5 inches of water at the base of the transplanted seedlings (Joshi *et al*., 2013). In the conventional rice cultivation practiced in irrigated areas, rice crop's life cycle occurs completely under anaerobic condition. In semi-dry system part of the rice crop's life cycle passes under aerobic conditions and part under anaerobic conditions,it usually results in different nutrient dynamics than the transplanting (Farooq *et al*.,2011). In direct seeding, availability of several nutrientsincluding N, P, S and micronutrients such as Zn and Fe, ilikely to be a constraint (Ponnamperuma, 1972). In addition,loss of N due to denitrification, volatilization and leaching is likely to be high than in conventional transplanting (Singh and Singh, 1988). To compensate for the higher losses and lower availability of N from soil mineralization at the early stage in semi dry rice (Kumar and Ladha, 2011), requires precise N management. The loss of N is prevented and increase in yield can be obtained by adopting the agronomical practices such as use of ammoniacal form of fertilizers, placement, split application and use of slow release nitrogenous fertilizers. Therefore, a field experiment was conducted to study the time of N application and

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sources on N availability and uptake and yield in semi dry rice.

MATERIALS AND METHODS

The experiment was conducted for two consecutive *rabi* seasons of 2009-10 and 2010-11years, respectively to study the influence of time of N application and sources on N availability and uptake semi dry rice. The soil texture of the experimental field was well drained sandy loam in texture with pH 5.2 and 5.6 with available N 235 kg ha^{-1}and 224 kg ha^{-1}, available $P_2O_5$20.8 kg ha^{-1}and 20.4 kg ha^{-1} and available K_2O 192 kg ha^{-1} and 195.5 kg ha^{-1}at the start of the experiment during 2009-10 and 2011-12, respectively. A medium duration (110-115 days) semi-dry rice variety 'PMK-1' having a yield potential of 3.2t ha^{-1} was used in the study. The experiment was laid out in split plot design with time of N application as main plot and sources of nitrogen as sub-plot treatment. Main plot treatments were 1/3rd N 20-25 DAE (days after emergence) +1/3rd N 40-45 DAE+1/3rdN 60-65 DAE (M_1),1/2 N 20-25 DAE+1/4th N 40-45 DAE+ 1/4th N 60-65 DAE (M_2), 1/4th N 20-25 DAE +1/2 N 40-45 DAE +1/4th N 60-65 DAE (M_3) and 1/4th N 5-10 DAE +1/4th N 20-25 DAE +1/2 N 40-45 DAE +1/4th N 60-65 DAE(M_4), respectively. The sub-plot treatments were prilled urea (S_1), ureagypsum (S_2), rock phosphate coated urea (S_3), coal tar coated urea (S_4) and neem cake blended urea (S_5), respectively. The Plot size adopted was 5m × 3m. Seeds @ 100 kg ha^{-1} was sown on receipt of rainfall in lines at 20 cm apart after opening small furrows and later covered with soil properly.

Crop emergence was observed at six days after sowing (DAS). Since there was no subsequent rainfall for the next few days, for ensure uniform germination and subsequent crop establishment, a light irrigation was provided 2 DAS to all experimental plots. Thereafter, the crop was maintained purely under rain-fed condition up to 45 DAE. From 45 DAE onwards, the field was maintained at submergence condition and irrigation was given at one day after disappearance of ponded water until 10 days prior to harvest. The crop was fertilized with 100, 50 and 50 kg ha^{-1} of N, P_2O_5 and K_2O, respectively. The recommended full dose of P_2O_5 and half the dose of K_2O were applied at10 DAE. Remaining half of K_2O was applied at 25 DAE. Nitrogen was applied as per the treatment schedule.

Growth attributing characters *viz*. plant height, tillers per square meter and leaf area index were recorded at 90 DAE. Leaf area index was computed by using the formula outlined by Palanisamy and Gomez (1974). Dry matter production (DMP) was recorded at 60, 75 and 90 DAE and at harvest. Soil samples were collected and analyzed for available N at 60, 75 and 90 DAE and at harvest. The plant samples were analyzed for N content at 60, 75,90 DAE and at harvest and corresponding uptake was recorded by multiplying the N content with DMP. Yield attributing characters like panicles per square meter, grains per panicle, 1000 grain weight and grain yield were recorded at harvest. The data was analyzed using ANOVA and the least significant difference (LSD) values at 5% level of significance were calculated and used to test the significant difference between treatment means.

RESULTS AND DISCUSSION

Effect on growth attributes

The growth attributes were significantly influenced by both time and sources of N application (Table 1). Application of N in 4 equal splits at 5-10, 20-25, 40-45 and 60-65 DAE (M_4) produced significantly taller plants, higher tiller per square meter and LAI. The increase in growth attributes in M_4 might be primarily due to enhanced vegetative growth with more nitrogen supply to plant as evident from the data on N availability and N uptake. The treatment which received heavy dressing of N at early stages (M_2) registered lower growth attributes because of greater loss of N as denitrification and volatilization (Gobrial, 1980), which resulted in the deficiency of N at flowering through accelerated senescence of lower leaves, death of tillers and narrow and short leaves as reported by De Datta (1981). Sources also significantly influenced the growth attributes. Neem cake blended urea recorded significantly taller plants, higher tiller per square meter and LAI; this was followed by rock phosphate coated urea (S_3). The gradual release of nitrogen from the neem cake blended might have exerted a beneficial effect on the growth characters. The result is in conformity with the findings of Umashankar *et al*. (2005). Prilled urea (S_1) recorded lower values for the growth attributes compared to all coated fertilizers. The reason for the production of more tillers and LAI in coated fertilizers was attributed tocontinuous and steady supply of N which promoted the initiation of more number of tillers and higher leaf production. Similar results were also reported by Reddy (1988).

The rate of dry matter production (DMP) was its peak between 60 DAE and 90 DAE (Table 2). Higher DMP was observed in M_4 throughout the crop growth while the lowest DMP was noticed in M_2. Sources of N had perceptible effect on DMP at all the stages. Neem cake blended urea favoured increased DMP than other coated fertilizers and prilled urea. At harvest it recorded a DMP of 11098 kg ha^{-1}.The resultis in agreement with the finding of Umashankar *et al*. (2005). The increased DMP in neem cake blended urea may be attributed to regular and consistent supply of available N to rice plants throughout the growth period. Prilled urea at harvest recorded a DMP of 9899 kg ha^{-1}, which was attributed to the increased N losses and reduced N availability and uptake (Table 3, 4). Maiti *et al*. (2007) also made similar observation and reported that prilled urea recorded lower DMP at harvest compared to granular urea. Irrespective of time of N application, neem cake blended urea recorded the highest DMP which was distinctly superior to other coated fertilizers and prilled urea. Similarly, all the sources of N registered higher DMP when they are applied in four equal splits (M_4S_5). This was attributed to the need based N application at critical stages of the crop growth. Moreover, due to the remarkable degree of nitrification inhibition by the alkaloid nimbidin present in the neem cake reduced the N losses associated with the rice soil ecology (Bhalla and Devi Prasad, 2008) and resulted in the absorption of N by rice for a longer period. The lowest dry matter accumulation was observed when N was applied @ 50 per cent at 20-25 DAE, 25 per cent at 40-45 DAE and 25 per cent at 60-65 DAE in the form of prilled urea. This was attributed to reduced plant height, LAI and lesser number of tillers.

Effect on N availability in the soil

Time and sources of N had profound influence on the availability of N at different stages. Available N in the soil increased up to 60 DAE (panicle initiation stage) and then started declining as the growth advanced (Table 3). This might be due to increase in the uptake of N by the rice crop. Application of N in four equal splits (M_4) recorded higher amount of available N at all the stages of crop growth. This might be due to its fractional application and associated reduced leaching, volatilization and denitrification. A drastic reduction in N status was noticed in M_2at all the stages. This might be due to the fact that heavy dressing of N at the early stages which was subjected to various losses associated with the rice soil. The result is in conformity with the findings of Ghobrial (1980). Neem cake blended urea maintained high available N in soil at all the stages. Rock phosphate coated urea (S_3) was more efficient in maintaining available N in soil compared to urea gypsum. Prilled urea maintained lower N status in the soil at all stages of crop growth. The interaction was found to be significant only at 75 DAE during both the years of study. Maximum soil N status was observed in treatment which received neem cake blended urea in four equal splits followed by rockphosphate coated urea in four equal splits. The high available N in neem cake blended and rock phosphate coated urea applied plots revealed that slow release N fertilizers and nitrification inhibitors increased the retention of fertilizer N as ammonium in soil and did not release their entire N during the cropping season (Ahmed and Baroova, 1992; Bhardwaj and Singh,1993).

Effect on N uptake

The N uptake was significantly influenced by the time and sources of N during both the years. The N uptake was progressively increased from establishment to maturity (Table 4). A linear relationship between increased dry matter production and N uptake was reported by Fagi and De Datta (1981). On an average, the N uptake was 28.3, 55.3 and 81.7 kg/ha at 60 DAE, 75 DAE, 90 DAE and at harvest. The highest N uptake was observed when N applied in four equal splits. The highest N uptake in M_4 was due to higher tilleringability, high LAI, vigorous root development and high water uptake which increased the photosynthetic rate in rice leaves with high N content, which altogether resulted in higher DMP. The lowest uptake was noticed in M_2which might be due to lesser growth and DMP resulted from inadequate supply of N. Among the sources, the highest uptake was noticed in neem cake blended urea (S_5) at all the growth stages. At flowering stagethe increase in N uptake observed in neem cake blended urea over prilled urea was 20 % and over coal tar coated urea was 12.14% respectively. The interaction effect was significant only at 60 DAE and 90 DAE. However, the highest N uptake was observed when N was applied in the form of neem cake blended urea in four equal splits (M_4S_5) followed by rock phosphate coated urea in four equal splits at all stages. This might be due to its slow release pattern, obviously aided in keeping the N in ammonical form, which was readily utilized by the rice crop with similar preference as nitrate. Further ammonical form of N was subjected to minimum leaching loss which resulted in continuous and steady supply of N to the rice crop (Velu and Ramanathan, 1985), and thereby increased the uptake and utilization of N by rice.

Effect on yield attributes

The time of N application and sources of N significantly influenced the yield attributes.

Table 1: Effect of time of N application and sources on plant height, tillers and leaf area index at 90 DAE (pooled of 2years)

Time of N application	Plant height (cm)						Tillers per square meter						Leaf area index					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	89.8	97.2	103.9	94.3	108.1	98.7	431	448	464	445	476	453	3.96	4.11	4.20	4.06	4.28	4.12
M_2	83.4	88.6	94.2	86.2	98.3	90.1	412	430	444	420	462	434	3.79	3.88	3.90	3.96	4.11	3.93
M_3	97	101.4	108.1	99.3	114.4	104.0	448	469	494	469	518	480	4.15	4.24	4.18	4.18	4.61	4.27
M_4	101.4	110.7	114.7	108.4	115.6	110.2	461	483	530	462	534	494	4.32	4.49	4.45	4.45	4.69	4.48
Mean	92.9	99.5	105.2	97.1	109.1	100.8	438	458	483	449	498	465	4.06	4.18	4.18	4.16	4.42	4.20
			LSD (0.05)						**LSD (0.05)**						**LSD (0.05)**			
M			**3.2**						**13.0**						**0.06**			
S			**2.0**						**8.0**						**0.04**			
S at M			**3.9**						**15.0**						**0.06**			
M at S			**4.8**						**19.0**						**0.08**			

Table 2: Effect of time of N application and sources on DMP at 60, 75, 90 DAE and at harvest (pooled data of 2 years)

Time of N application	DMP (kg ha^{-1}) 60DAE						DMP (kg ha^{-1}) 75 DAE						DMP (kg ha^{-1}) 90 DAE						DMP (kg ha^{-1}) Harvest					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	2325	2975	3357	2869	3750	3055	4334	4833	5470	4734	5834	5041	7465	8477	8914	8340	9443	8528	9741	10229	11185	10126	11388	10534
M_2	2176	2560	3192	2488	3364	2756	3623	3970	4479	3832	5170	4215	7029	7659	8094	7341	8943	7813	9427	9714	10293	9604	10552	9918
M_3	2466	3126	3561	2805	3977	3187	4443	5037	5561	5034	5990	5213	7741	8757	9347	8512	9621	8796	10094	10770	11319	10302	11627	10822
M_4	3098	3541	4126	3342	4212	3664	4855	5342	6105	5213	6174	5538	7961	8919	9670	8658	9781	8998	10334	11033	11588	10759	11776	11098
Mean	2516	3051	3559	2876	3826	3166	4314	4796	5404	4703	5793	5002	7549	8453	9006	8213	9447	8534	9899	10437	11096	10198	11336	10593
			LSD (0.05)						**LSD (0.05)**						**LSD (0.05)**						**LSD (0.05)**			
M			**110**						**208**						**140**						**443**			
S			**147**						**196**						**137**						**157**			
S at M			**194**						**296**						**273**						**314**			
M at S			**256**						**438**						**282**						**356**			

Note: M_1- 1/3rd N 20-25 DAE + 1/3rd N 40-45 DAE + 1/3rd N 60-65 DAE, M_2- 1/2 N 20-25 DAE + 1/4th N 40-45 DAE + 1/4th N 60-65 DAE, M_3-1/4th N 20-25 DAE + 1/2 N 40-45 DAE + 1/4th N 60-65 DAE and M_4- 1/4th N 5-10 DAE + 1/4th N 20-25 DAE + 1/2 N 40-45 DAE + 1/4th N 60-65 DAE, S_1- prilled urea, S_2- urea gypsum,S_2-rock phosphate coated urea, S_4- coal tar coated urea and S_5-neam cake blended urea.

Table 3: Effect of time of N application and sources on N availability at 60 ,75 , 90 DAE and at harvest (pooled of 2 years)

Time of N application	N availability (kg ha^{-1}) 60DAE						N availability (kg ha^{-1})75 DAE						N availability (kg ha^{-1})90 DAE						N availability (kg ha^{-1}) harvest					
	S1	**S2**	**S3**	**S4**	**S5**	**Mean**	**S1**	**S2**	**S3**	**S4**	**S5**	**Mean**	**S1**	**S2**	**S3**	**S4**	**S5**	**Mean**	**S1**	**S2**	**S3**	**S4**	**S5**	**Mean**
M_1	253	257	267	255	273	261	239	246	257	242	264	250	220	227	235	223	242	229	204	211	218	208	222	213
M_2	248	255	263	249	268	257	239	241	251	238	256	245	215	222	229	220	235	224	197	204	211	198	216	205
M_3	260	270	277	265	281	271	248	256	264	252	270	258	226	236	244	231	252	238	209	218	223	213	226	218
M_4	266	273	282	270	285	275	253	262	269	257	274	263	232	241	248	238	256	243	214	222	230	219	235	224
Mean	258	264	273	260	277	266	245	251	261	247	266	254	223	232	239	236	246	234	206	214	221	210	225	215
	LSD (0.05)						**LSD (0.05)**						**LSD (0.05)**						**LSD (0.05)**					
M	**3**						**4**						**6**						**4**					
S	**2**						**5**						**4**						**5**					
S at M	**NS**						**8**						**NS**						**NS**					
M at S	**NS**						**4**						**NS**						**NS**					

Table 4: Effect of time of N application and sources on N uptake at 60, 75, 90 DAE and at harvest (pooled of 2 years)

Time of N application	N uptake (kg ha^{-1}) 60DAE						N uptake (kg ha^{-1}) 75 DAE						N uptake (kg ha^{-1}) 90 DAE						N uptake (kg ha^{-1}) harvest					
	S1	**S2**	**S3**	**S4**	**S5**	**Mean**	**S1**	**S2**	**S3**	**S4**	**S5**	**Mean**	**S1**	**S2**	**S3**	**S4**	**S5**	**Mean**	**S1**	**S2**	**S3**	**S4**	**S5**	**Mean**
M_1	22.0	26.8	30.1	25.8	32.6	27.5	33.8	36.8	41.1	35.7	44.3	38.3	49.8	55.7	56.9	53.0	59.3	54.9	74.0	80.0	86.9	76.7	88.9	81.3
M_2	20.9	24.3	29.0	23.2	31.2	25.7	29.1	32.8	37.9	31.2	42.5	34.7	46.5	50.1	53.8	49.5	56.7	51.3	71.5	74.8	79.8	73.5	84.2	76.7
M_3	22.7	29.2	32.2	26.5	35.2	29.2	37.6	42.6	48.2	41.4	49.2	43.8	50.9	55.9	59.8	55.2	61.9	56.7	74.0	83.2	87.3	80.0	91.4	83.2
M_4	25.8	30.0	34.2	28.1	36.6	30.9	40.0	43.7	50.8	42.1	51.0	45.5	52.9	57.6	61.7	56.5	62.2	58.2	78.7	84.5	89.9	82.5	92.1	85.5
Mean	22.9	27.6	31.4	25.9	33.9	28.3	35.1	38.9	44.5	37.6	46.8	40.6	50.0	54.8	58.1	53.5	60.0	55.3	74.6	80.6	86.0	78.2	89.1	81.7
	LSD (0.05)						**LSD (0.05)**						**LSD (0.05)**						**LSD (0.05)**					
M	**1.5**						**3.5**						**2.4**						**3.1**					
S	**2.6**						**2.9**						**2.8**						**4.1**					
S at M	**3.3**						**NS**						**3.6**						**NS**					
M at S	**2.5**						**NS**						**4.7**						**NS**					

Table 5: Effect of time of N application and sources on yield attributes of semi dry rice (pooled data of 2 years)

Time of N application	Sources of N																	
	Panicles per square meter						No. of grains per panicle						1000 grain weight					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	199	217	225	216	233	218	73.4	78.8	85.6	76.6	89.2	80.7	25.6	25.6	25.3	24.8	24.5	25.2
M_2	185	196	212	195	219	201	68	76.5	82.2	74.2	85.7	77.3	25.7	25.8	25.0	25.3	24.7	25.3
M_3	207	219	235	209	242	222	78.9	83.9	88.9	81.8	87.1	84.1	25.6	25.4	25.2	25.6	24.6	25.3
M_4	227	235	237	226	243	234	83	88.5	94.1	85.3	94.3	89.04	25.7	25.3	25.1	25.3	24.9	25.3
Mean	205	217	227	212	234	219	75.8	81.9	87.7	79.5	89.1	82.8	25.7	25.5	25.3	25.3	24.7	25.3
	LSD (0.05)						**LSD (0.05)**						**LSD (0.05)**					
M	**7**						**3.2**						**NS**					
S	**8**						**1.7**						**0.41**					
S at M	**8**						**3.3**						**NS**					
M at S	**11**						**4.2**						**NS**					

Table 6: Effect of time of N application and sources on grain yield of semi dry rice

Time of N application	Sources of N											
	Grain yield kg ha^{-1} (2009-10)						Grain yield kg ha^{-1} (2010-11)					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	3030	3141	3213	3195	3468	3210	2800	3177	3546	3112	3634	3254
M_2	2854	3058	3172	2886	3318	3058	2665	2947	3411	2857	3547	3085
M_3	3194	3387	3430	3357	3652	3404	3151	3376	3813	3244	3862	3489
M_4	3307	3363	3637	3234	3752	3459	3245	3576	3754	3443	3872	3578
Mean	3096	3237	3363	3168	3548	3283	2965	3269	3631	3164	3629	3352
	LSD (0.05)						**LSD (0.05)**					
M	**118**						**108**					
S	**179**						**159**					
S at M	**161**						**116**					
M at S	**187**						**150**					

Application of N in four equal splits at 5-10 DAE, 20-25 DAE, 40-45 DAE and 60-65 DAE recorded higher number of panicles per square meter and grains per panicle than three splits. Being a varietal character thousand grain weight was not significantly influenced by the treatments. The treatment M_2 even though received 50% of N at 20-25 DAE, which could not have been fully utilized by the crop due to various losses. This has led to reduction in yield components (Table 5). Neem cake blended urea (S_5) provided continuous and steady supply of N into the soil solution to match the required absorption pattern of rice plant to meet the physiological processes which in turn produced higher number of panicles and grains per panicle. Prilled urea produced lesser number of panicles and grains per panicle might be due to reduction in the availability of N in soil (Table 3) and its utilization at different critical stages of crop growth (Table 4). The interaction of neem cake blended urea applied in four splits (M_4S_5) producing more number of panicles per square meter and grains per panicle was ascribed to the increased availability and uptake of N.

Effect on grain yield

Grain yield was distinctly influenced by time of N application and sources of N (Table 6). The treatment which received N in 4 equal splits registered higher grain yield which was comparable with M_3.The yield increase was due to favorable influence on growth and yield attributes. Similarly among the sources neem cake blended urea recorded higher grain yield which was on par with rock phosphate coated urea. The increased grain yield in neem cake blended urea and rock phosphate urea might be due to reduced losses of N and better uptake and due to higher growth and yield attributes. Several workers (Reddy and Shinde, 1981; Joshi *et al*., 1982; Kumar and Shivay, 2009) have reported that application of neem cake blended urea resulted in higher rice yield than prilled urea application. Rock phosphate coated urea (S_3) also gave significantly higher yield, could be partially to the slow release of N to plants and partially to the synergistic effect of P and N. The result is in line with the findings of Manickam *et al*. (1986). Interaction had brought out that irrespective of sources of N, application of 50% of N in two equal splits, one at mid tillering and another 25 % at maximum tillering stage (M_4) or entire 50 % at maximum tillering stage (M_3) were found highly favorable for higher productivity. Similar observations were also made by Moorthy and Mittra (1990).

In semi-dry system part of the rice crop's life cycle passes under aerobic conditions and part under anaerobic conditions so for higher N availability and uptake, application of N in four equal splits at 5-10 DAE, 20-25 DAE, 40-45 DAE and 60-65 DAE was found to be best. Among the sources, neem cake blended urea was found to superior in maintaining soil N status and higher uptake throughout the crop growth. The study conclusively proved that physical blending of urea with powdered neem cake and applied in four equal splits was found to be superior for maintaining higher available N in the soil, increased uptake and productivity and sustainability in semi-dry rice.

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