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Evaluation of Crop Establishment Methods and Nitrogen Management Strategies on Realizing Yield Potential of Rice Hybrid ADTRH 1

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Abstract: Field experiments were conducted at wetland research farm, Tamil Nadu Agricultural University, Coimbatore India during Kharif 2002 and 2003 with a view to formulate a suitable crop establishment method and to optimize the nitrogen management practices for hybrid rice ADTRH 1. The experiments were laid out in split plot design replicated thrice with four crop establishment techniques in the main plots and seven N management practices in the sub plots. The results revealed that different crop establishment methods exerted a significant variation on the seed rate requirement and caused significant influence on growth and yield of hybrid rice. Seeding through one out of two holes (M_3) registered optimum seed rate of 28.03 and 27.59 kg ha^{-1} during 2002 and 2003, respectively. Except at the early stage of 40 DAS, there was no significant difference in plant height as influenced by establishment methods. Seeding through all the holes (M_1) with higher seed rate recorded significantly higher values of growth characters viz., LAI, tillers m^{-2}, DMP, productive tillers m^{-2} and grain yield which was comparable with transplanting (M_1) and seeding through one out of two holes (M_3). The influence of crop establishment methods on yield attributes like panicle length and 1000 grain weight were insignificant. The seeding through one out of three holes (M_4) registered significantly higher total number of grains, filled grains panicle^{-1} and lower sterility percentage as compared to rest of the establishment methods. Application of N based on Soil Test Crop Response (STCR) enhanced significantly the growth and yield attributing characters viz., plant height, LAI, DMP, total tiller m^{-2}, panicle length, productive tillers m^{-2}, total number of grains panicle^{-1} over the other N management practices and was on par with N application in four splits combined with green manure *Sesbania aculeata* at the rate of 6.25 t ha^{-1} application. STCR based N application recorded the highest sterility percentage whereas LCC based N application noticed the lowest sterility percentage. The treatment combination of seeding through one out of two holes with a seed rate of 28 kg ha^{-1} and N application based on STCR (M_3N_7) during both the years realize the targeted yield.

Key words: Crop establishment methods, nitrogen management, hybrid rice, yield

INTRODUCTION

Rice is grown around the globe in 113 countries spread over an area of 153 million hectares with estimated total production of 589 million tonnes. In the Indian context, the present level of production of rice from 85.50 million tonnes has to be increased to 114.4 million tonnes by 2030 (Paroda, 2001). The increasing demand for rice grain production has to be met by using limited available resources in a sustainable manner. Increasing the productivity of rice from current level of 2817 kg ha^{-1} is the immediate challenge to agricultural scientists. Hybrid rice cultivation is a technology option available for meeting this challenge. India is yet to fully exploit the technology which offers a 10-15% yield advantage over the best conventional inbred varieties (Li, 1981; Yang and Sun, 1982). Growing hybrid rice is a complex process since agronomic management of hybrid rice differs considerably from that of conventional inbred varieties in many respects. Establishment technique, plant density, nutrient requirement and management, water management etc., need to be standardized to achieve the reported yield potential of rice hybrids of different duration in various environments. Asian rice farmers are increasingly adopting wet seeding as an alternative crop establishment technique to transplanting for economic and technical reasons. However wet seeding in hybrid rice has not been contemplated so far due to increased seed requirement for direct seeding and consequent increase in the cost of production since the hybrid rice seed is a costly input. Yet

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wet seeding of hybrid rice may become a reality due to the same reasons as in conventional inbred varieties. The grain yield in wet seeding is also comparable to transplanting method and even higher under good management (De Datta, 1986). Economy in seed rate of wet seeded rice had been made possible through the intervention of drum seeder. Studies on optimization of seed rate for wet seeded short duration hybrid rice using drum seeder have not so far been taken up. When wet seeding of hybrid rice becomes popular a recommendation on seed rate has to be made available.

Nutrient requirement of hybrid rice especially nitrogen is higher than that of conventional inbred varieties. In order to minimize N-fertilizer use and to maximize nitrogen fertilizer efficiency for increasing rice yield, simple and reliable diagnostic tools are needed to inform farmers how much and how often to apply N fertilizers. Leaf green colour was calibrated very precisely to leaf N content (Tanno, 1998). Leaf Colour Chart (LCC) is a non-destructive tool for farmers to assess the leaf N status and to determine the time of top dressing to rice crop. Organic nutrition to rice is assuming significance in the context of an increasing concern about sustaining soil health with increasing use of inorganic on the one hand and expected shortage in N fertilizer for rice cultivation on the other hand (Mahapatra *et al.*, 1985). An integrated approach involving organic manures and chemical fertilizers will go a long way in building up of soil fertility on a permanent basis and the system will supply most of the nutrients in a judicious way. In this context, the present research was undertaken with the objectives of effect of different crop establishment methods and nitrogen management practices on the seed rate optimization, growth and yield of rice hybrid ADTRH1 under the Coimbatore region of Tamil Nadu, India.

MATERIALS AND METHOD

Field experiments were conducted during Kharif season of 2002 and 2003 in wetland research farm of Tamil Nadu Agricultural University, Coimbatore to evaluate the effect of crop establishment methods with various N management practices on the optimization of seed rate and yield of rice hybrid ADTRH1. The soil of the experimental field was moderately drained, deep clay loam in texture and taxonomically classified as *Typic Haplustalf*. The soil was low in available N, medium in available P and high in available K. The experiment was laid out in a split plot design replicated thrice. The main plot consisted of four establishment methods and sub-plots with seven levels of N management practices. The hybrid ADTRH1 is of short duration (105-115 days) suitable for Kharif season (June-September) with long slender grain.

The details of the treatments and the notations used are as follows.

Main plots: Crop establishment techniques

M_1 - Transplanting (15×10 cm)
M_2 - Drum seeding though all holes
M_3 - Drum seeding through one out of every two holes
M_4 - Drum seeding through one out of every three holes

Sub-plots: N managements

N_1 - Control (without N)
N_2 - 120 kg N ha^{-1} in four splits (1/6th N at 7 DAT, 1/3 rd at active tillering, 1/3 rd at panicle initiation, 1/6th at first flowering)
N_3 - Green manure application at the rate of 6.25 t ha^{-1} +120 kg N ha^{-1} in four splits
N_4 - 20 kg N ha^{-1} + N as per LCC cv. 4
N_5 - N application as per LCC cv. 4
N_6 - 100% N through organic manures (50% N as green manure + 15% N as Poultry manure + 20% N as FYM + 15% N as neem cake)
N_7 - Soil Test Crop Response (STCR) based N application for a yield target of 7 t ha^{-1}

The drum seeder holes were plugged with cellophane tape to impose the different seeding methods as described in M_3 and M_4 methods. Above ground biomass of *Sesbania aculeata* at the age of 40 days was harvested, weighed and applied to the respective plots as per treatment schedule. The green manure was spread uniformly and incorporated a week prior to transplanting. Seeds of hybrid ADTRH1 were treated with carbendazim at 2 g kg^{-1} of seeds against seed borne pathogens. After 24 h, the seeds were inoculated with Azospirillum at the rate of 600 g ha^{-1}. Then the seeds were soaked in water for 24 h and incubated in dark for 12 h to induce sprouting. The drum seeder developed by the Department of Agricultural Engineering, TNAU, Coimbatore for row seeding of pre-germinated paddy seeds on puddle soil was used for direct seeding. This machine permits uniform seeding at fairly low seed rates of 50-100 kg ha^{-1}. The eight row drum seeder was used for this purpose and it requires 9 kg of pulling force to operate. The machine weighs 11 kg with seed capacity of 8 kg (2 kg/hopper). Seeding output per day is about 1.0 ha with seeding labour requirement of 14 man h ha^{-1}. The seed rate was optimized by seeding through one out of every two holes and seeding through one out of three holes. The ADTRH1 seeds of 20 kg were sown in the wet nursery for raising seeding on the same day of direct seeding in the main field. The seedlings raised were transplanted at 24 days after sowing. The seedlings were transplanted at one seedling hill^{-1} adopting a spacing of 15×10 cm. The recommended dose of 120 kg N ha^{-1} for Kharif as per treatment was applied in equal splits on 30, 45, 70 and 95 DAS. Phosphorus at 50 kg ha^{-1} was applied basally to all the treatments. Potash at the rate of 50 kg ha^{-1} was applied in three equal splits on 30, 45 and 70 DAS along with the first three splits of fertilizer N. In LCC based N management treatments, the LCC values were recorded as per the standard procedure (IRRI, 1996) at weekly interval starting from 14 DAT to flowering for transplanted crop. In case of drum seeding the LCC values were recorded at weekly interval from 21 DAS. Whenever the LCC values were found to be below the critical level of four, recommended quantity of fertilizer N was applied.

Manure application: Nutrient content of different organic manures was analysed and based on the nitrogen content of different manures, the quantities required for the recommended dose were calculated on dry weight basis and applied to the respective plots one week before transplanting and incorporated well into the field. The quantities of organic manures added to substitute the recommended N are presented below:

*Quantity of organic manures added (t ha^{-1})

Sesbania aculeata (50 % N)	Poultry manure (15 % N)	Farmyard manure (20% N)	Neem cake (15% N)
3.38	0.72	6.10	0.50

*Quantity applied on dry weight basis

STCR based N application: Based on the soil available N, the required quantity of fertilizer to attain the targeted yield of 7 t ha^{-1} was calculated. The fertilizer prescription to attain specific yield targets based on soil available nutrient levels for the experimental field was as follows:

$$\text{Kharif season-FN} = 43.9\text{T}-0.52\ \text{SN}$$

Where:

FN - Fertilizer nitrogen (kg ha^{-1})
T - Targeted yield (t ha^{-1})
SN - Soil available nitrogen (kg ha^{-1})

Fertilizer N applied to attain yield target

Season	Soil available N (kg ha^{-1})	Targeted yield (t ha^{-1})	Required fertilizer N (kg ha^{-1})
Kharif 2002	227	71	89.00
Kharif 2003	223	7	191.00

Leaf Colour Chart (LCC) measurements: The colour of the single leaf was measured by holding the leaf colour chart vertically and placing the middle part of leaf 1 cm in front of colour strip for comparison (IRRI, 1996). During measurement, the leaf being measured was shaded with the body to avoid interference by sunlight intensity. Ten readings were taken for each plot and average was computed by rounding off to the nearest 0-5 to determine the need for N top dressing. The amount of N to be applied at different growth stages was as per the schedule given below (IRRI, 1996):

Crop growth stages	N to be applied (kg ha^{-1})
Transplanted crop	
Early growth sage (14-21 DAT)	30
Rapid growth stage (28-42 DAT)	45
Late growth stage (45 DAT-Flowering)	30
Direct seeded rice	
Early growth sage (21-35 DAS)	30
Rapid growth stage (35-56 DAS)	45
Late growth stage (56 DAS-Flowering)	30

High dose of 45 kg ha^{-1} was applied only once or twice during rapid growth stage. The N applied kg ha^{-1} in different management practices are given in Table 1-3.

Seed rate calibration: The drum seeder hopper was filled with a known weight of sprouted seeds and allowed to operate over the plot on a saturated soil condition. After

Table 1: N applied (kg ha^{-1}) in different N management for transplanting Kharif 2002 and 2003

Time of fertilizer application (DAT)		Kharif 2002					Kharif 2003				
		M_1N_1	M_1N_3	M_1N_4	M_1N_5	M_1N_7	M_1N_2	M_1N_3	M_1N_4	M_1N_5	M_1N_7
Basal (0)		30.00	-	20.00	-	047.25	30.00	-	20.00	-	47.75
7 DAT		-	20.00	-	-	-	-	20.00	-	-	-
Early growth	14	-	-	-	30.00	-	-	-	-	30.00	-
stages (EGS)	21	30.00	40.00	30.00	-	047.25	30.00	40.00	30.00	-	47.75
	28	-	-	-	-	-	-	-	-	-	-
Rapid growth	35	30.00	40.00	-	45.00	047.25	30.00	40.00	-	45.00	47.75
stages (RGS)	42	-	-	45.00	-	-	-	-	45.00	-	-
	49	-	-	-	-	-	-	-	-	-	-
Late growth	56	30.00	20.00	30.00	30.00	047.25	30.00	20.00	30.00	30.00	47.75
stages (LGS)											
Total (kg N ha^{-1})		120.00	120.00	125.00	105.00	189.00	120.00	120.00	125.00	105.00	191.00

Table 2: N applied (kg ha^{-1}) in different N management-Wet seeding-Kharif 2002

Time of fertilizer application (DAS)		M_2N_2	M_2N_3	M_2N_4	M_2N_5	M_2N_7	M_3N_2	M_3N_3	M_3N_4	M_3N_5	M_4N_7	M_4N_2	M_4N_3	M_4N_4	M_4N_5	M_4N_7
B (0)		-	-	20.00	-	-	-	-	20.00	-	-	-	-	20.00	-	-
EGS	21	30.00	20.00	-	30.00	47.75	30.00	20.00	-	30.00	47.75	30.00	20.00	-	30.00	047.75
	28	-	-	30.00	-	-	-	-	30.00	-	-	-	-	30.00	-	-
RGS	35	30.00	40.00	-	-	47.75	30.00	40.00	-	-	47.75	30.00	40.00	-	-	047.75
	42	-	-	45.00	45.00	-	-	-	45.00	45.00	-	-	-	45.00	45.00	-
	49	30.00	40.00	-	-	47.75	30.00	40.00	-	-	47.75	30.00	40.00	-	-	047.75
	56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LGS	63	-	-	30.00	30.00	-	-	-	30.00	30.00	-	-	-	30.00	30.00	-
	70	30.00	20.00	-	-	47.75	30.00	20.00	-	-	47.75	30.00	30.00	-	-	047.75
		120.00	120.00	125.00	105.00	191.00	120.00	120.00	125.00	105.00	191.00	120.00	120.00	125.00	105.00	191.00

B- Basal, EGS- Early Growth Stages, RGS- Rapid Growth Stages, LGS- Late Growth Stages

Table 3: N applied (kg ha^{-1}) in different N management-Wet seeding-Kharif 2003

Time of fertilizer application (DAS)		M_2N_2	M_2N_3	M_2N_4	M_2N_5	M_2N_7	M_3N_2	M_3N_3	M_3N_4	M_3N_5	M_4N_7	M_4N_2	M_4N_3	M_4N_4	M_4N_5	M_4N_7
B (0)		-	-	20.00	-	-	-	-	20.00	-	-	-	-	20.00	-	-
EGS	21	30.00	20.00	-	30.00	47.25	30.00	20.00	-	30.00	47.25	30.00	20.00	-	30.00	47.75
	28	-	-	30.00	-	-	-	-	30.00	-	-	-	-	30.00	-	-
RGS	35	30.00	40.00	-	-	47.25	30.00	40.00	-	-	47.25	30.00	40.00	-	-	47.75
	42	-	-	45.00	45.00	-	-	-	45.00	45.00	-	-	-	45.00	45.00	-
	49	30.00	40.00	-	-	47.25	30.00	40.00	-	-	47.25	30.00	40.00	-	-	47.75
	56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LGS	63	-	-	30.00	30.00	-	-	-	30.00	30.00	-	-	-	30.00	30.00	-
	70	30.00	20.00	-	-	47.25	30.00	20.00	-	-	47.25	30.00	30.00	-	-	47.75
		120.00	120.00	125.00	105.00	189.00	120.00	120.00	125.00	105.00	189.00	120.00	120.00	125.00	105.00	191.00

B- Basal, EGS- Early Growth Stages, RGS- Rapid Growth Stages, LGS- Late Growth Stages

sowing, the weight of the remaining seeds was recorded and difference in weight divided by the area sown gave the seed rate for the covered plot area. The moisture content of the seed used was calculated and the seed rate required is calculated at 14 and moisture content basis. From the above data, seed rate required for one hectare was calculated.

RESULTS AND DISCUSSION

Seed rate calibration: In general, direct seeded rice requires more quantity of seed rate than transplanted rice. In hybrid rice, where seed cost is relatively higher, optimization of seed rate is crucial. The quantity of seeds required for one hectare was calibrated by manipulating the seed holes in the drum seeder. The seeding through all the holes (M_1) registered seed rate of 69.09 and 68.43 kg ha^{-1} during 2002 and 2003 which was 245.45 and 242% higher than the seed rate adopted for transplanted crop (Table 4 and 5). Seeding through one out of every two holes registered seed rate of 28.03 and 27.59 kg ha^{-1} and the increase was 40.15 and 37.95% higher than transplanting. Seeding through one out of three holes recorded seed rate requirement of 17.43 and 16.58 kg ha^{-1} and it was 14.74 and 19.19% less over that of transplanted crop. Joseph (2001) also reported similar trend of seed rate usage under wet seeding by manipulating the seed holes in the drum seeder. Growth of wet seeded hybrid rice ADTRH 1 varied distinctly due to different seed rates adopted by manipulating the seed holes in terms of tiller production, dry matter production and leaf area index. Yield attributes like productive tillers and number of grains panicle^{-1} were also affected by seed rate leading to significant effect on grain yield.

Growth components: Tiller number per unit area registered a progressive increase from seeding through one out of three holes (M_4) to the seeding through all the holes (M_2). At all the stages of growth, seeding through all the holes (M_2) resulted in significantly higher tillers m^{-2} which was comparable with transplanting (M_1) and seeding through one out of two holes (M_3) (Table 6). Lowest number of tillers was noticed with seeding through one out of three holes (M_4). Plant density is the most important factor affecting tillering in any crop (Counce and Wells, 1991). Miller *et al.* (1991) has also reported similar trend of increasing tiller count with increasing plant densities. In wet seeding plant density is decided principally by seed rate and hence higher seed rate in the treatment M_2 led to higher plant density resulting in more tiller production. This results is in conformity with the findings of Sharma and Ghose (1998) who reported that seeding emergence and tiller numbers increased proportionately with increasing seed rate. Joseph (2001) also reported that adoption of seed rate of 24 kg ha^{-1} in wet seeding of CoRH2 hybrid rice resulted in more number of tillers m^{-2}

Table 4: Calibration of seed rate for ADTRH1 (2002)

Treatments	Area (ha)	Initial weight of seed (kg)	Weight of seeds after sowing (kg)	Difference in weight (kg)	Seed rate (kg ha^{-1})	% increase over M_1
M_1	-	-	-	-	20.00	-
M_2	0.0453	5.40	2.27	3.13	69.09	245.45
M_3	0.0453	5.40	4.13	1.27	28.03	40.15
M_4	0.0453	5.40	4.61	0.79	17.43	-14.74

Table 5: Calibration of seed rate for ADTRH1 (2003)

Treatments	Area (ha)	Initial weight of seeds (kg)	Weight of seeds after sowing (kg)	Difference in weight (kg)	Seed rate (kg ha^{-1})	% increase over
M_1	-	-	-	-	20.00	-
M_2	0.0453	5.6	2.50	3.10	68.43	242.15
M_3	0.0453	5.6	4.35	1.25	27.59	37.95
M_4	0.0453	5.6	4.84	0.76	16.78	-19.19

Table 6: Total tillers m^{-2} of rice hybrid ADTRH1 as influenced by Crop establishment methods and N management practices

	Kharif 2002				Kharif 2003			
Treatments	40 DAS	60 DAS	80 DAS	105 DAS	40 DAS	60 DAS	80 DAS	105 DAS
Establishment methods								
M_1	370	478	509	524	351	459	494	508
M_2	379	486	516	535	358	467	503	59
M_3	364	471	502	517	347	453	487	501
M_4	291	375	400	412	278	364	389	404
CD (0.05)	16	17	19	22	14	16	18	20
N Management								
N_1	201	273	290	305	194	265	283	294
N_2	366	470	505	512	344	447	488	500
N_3	417	532	565	586	399	521	548	562
N_4	376	483	510	520	356	461	498	509
N_5	362	466	496	503	340	442	482	495
N_6	304	391	429	456	290	377	415	439
N_7	430	553	576	595	414	537	565	583
CD (0.05)	18	19	20	25	16	18	21	22
M at N CD (0.05)	37	40	41	52	33	37	42	44
N at M CD (0.05)	36	38	40	50	32	41	41	43

than 20, 16 and 12 kg ha^{-1}. Santhi (1997) reported comparable tillers per unit area between wet seeded and transplanted crop. Nitrogen management practices exerted comparable tillers per unit area between wet seeded and transplanted crop. Nitrogen management practices exerted significant influence on number of tillers at various crop stages across seasons. Application of N based on Soil Test Crop Response (STCR) at all stages of crop in both the years recorded significantly higher tiller umbers and it was on par with the application of 120 kg N ha^{-1} plus green manure at the rate of 6.25 t ha^{-1} (N_2) during both the years. Promotion of tillering with high nutrient availability is an established process (Mandal *et al*., 1991). Hence higher nutrient availability in the STCR based N application and green manure plus nitrogen supply favoured higher tiller density as has been reported by earlier workers (Chau and Deshmukh, 1991). To maximize the productivity of hybrid rice, the maximum potential vegetative growth should be ensured with high rate of N fertilizer at early growth stages. In case of STCR based N application, higher dose of N applied in each split might have positively influenced the tiller production. Increased tiller production at higher N level of 200 kg ha^{-1} was reported in hybrid rice by Rajarathinam and Balasubramanian (1999). Timely availability of N in right proportion at the critical stages of the growth will help in profuse tillering as seen in various N management practices compared to control. Jiang *et al*. (1993) also reported that the content of ammonical N in the soil solution was positively correlated with the tillering ability in rice. Steady supply of N through four splits of the recommended dose combined with green manure synchoronizing with peak requirement of N to the crop might have resulted in considerable increase in tiller compared to other N management practices. Similar observation was reported by Ramamoorthy *et al*. (1997). An improvement in growth components due to green manuring was observed by Valarmathi (1994) and Shanmugam and Veerabadran (2000). Interaction effect of crop establishment methods and N management practices on tiller production of hybrid rice was significant at all the four stages of crop growth in both the seasons. Dry matter production varied significantly with the different establishment methods and N management practices. A positive and linear response was observed with dry matter production to the seed rate. Seeding through all the holes (M_2) registered maximum DMP of 2784 and 2621 kg ha^{-1} at 40 DAS, 6912 and 6636 kg ha^{-1}

Table 7: Influence of crop establishment and nitrogen management practices on DMP (kg ha^{-1}) of ADTRH1

	Kharif 2002				Kharif 2003			
Treatments	40 DAS	60 DAS	80 DAS	105 DAS	40 DAS	60 DAS	80 DAS	105 DAS
Establishment methods								
M_1	2723	6793	12134	14299	2575	6533	11805	13921
M_2	2784	6912	12305	14596	2624	6651	11992	14201
M_3	2675	6705	11976	14114	2530	6455	11637	13722
M_4	2138	5333	9545	11256	2041	5167	9327	11085
CD (0.05)	115	310	371	502	101	304	403	510
N management								
N_1	1379	3464	7430	9164	1234	3362	7124	8790
N_2	2707	6756	11962	13855	2533	6414	11570	13531
N_3	3084	7638	13394	15839	2975	7526	13075	15470
N_4	2781	6945	12090	14059	2620	6621	11825	13768
N_5	2678	6690	11741	13615	2519	6343	11428	13384
N_6	2248	5612	10172	12345	2150	5416	9856	11882
N_7	3183	7945	13642	16088	3068	7728	13454	15802
CD (0.05)	125	357	427	547	110	332	440	568
M at N CD (0.05)	257	727	869	1121	225	379	901	1158
N at M CD (0.05)	250	715	854	1095	220	664	880	1135

at 60 DAS, 12305 and 11963 kg ha^{-1} at 80 DAS and 14582 and 14129 kg ha^{-1} at harvest and it was on par with transplanting (M_1) and seeding through one out of two holes (M_3) during respective stages of the crop (Table 7). Increase in tiller production at higher seed rate caused more accumulation of DMP. Results on the positive and linear effect of seed rate on DMP by rice were reported by Reddy and Reddy (1991). No marked difference in DMP at all the growth stages due to the drum seeding and transplanting methods was reported by Santhi (1997). The application of N based on STCR (N_7) registered higher DMP at all the stages of crop growth and it was comparable with the application of 120 kg N ha^{-1} plus green manure (N_3). These results are in online with the findings of Stalin *et al*. (1999). The highest LAI in STCR based N application might have increased the amount of solar radiation intercepted and utilized by the plant which resulted in higher quantity of photosynthate production ultimately resulting in higher DMP. The higher N levels resulted in greater biomass at different growth stages of rice as reported by Schnier *et al*. (1990) and Thiyagarajan *et al*. (1994). Similarly, Balasubramanian (2002) reported higher plant height and DMP with STCR based N application in CoRH1 rice hybrid. Improvement in DMP with the application of N in four splits along with green manure could be attributed to optimum availability of N at the time when the crop is most responsive as reflected in increased LAI and number of tillers. Westcott and Mikkelson (1988) also reported that continuous release of N from the green manure into the soil solution matching the required absorption rate of the crop to enhance the DMP. Though the total quantity of N was less through green manure plus N applied in four splits, it produced biomass similar to that of STCR based N probably due to steady supply of N for a prolonged period of crop growth (Goos, 1985) and addition of other nutrients through green manure. Similar results have been reported by Buresh and DE Datla (1991). As a result of higher LAI and increased CO_2 exchange and due to synergistic influence of integrated use of green manure along with fertilizer N, the plant have become photosynthetically more active and contributed to greater biomass production (Siddeswaran, 1992; Somasundaram *et al*., 1996).

Plant height is a direct index to measure the growth and vigour of the plant. During both the years, the method of crop establishment showed significant influence on plant height at early stages of crop growth. At 40 DAS, the seeding through one out of every three holes (M_4) registered maximum plant height (36.93 and 35.28 cm) which was comparable with the seeding through one out of two holes (M_3) and seeding through all the holes (M_2) but was significantly higher than transplanting (M_1). At 60, 80 and 105 DAS, the method of establishment did not cause any significant difference in plant height. The nitrogen management practices significantly enhanced the plant height at all the stages during both the years. At all the stages of the crop significantly higher plant height was recorded with the N application based on STCR (N_7) and it was comparable with application of 120 kg N ha^{-1} plus green manure at the rate of 6.25 t ha^{-1}(N_3). Plant height generally tends to decrease with higher plant densities due to interplant competition for life (Palanimurugesan, 1997). In the present study, however, adoption of seeding through different holes with different seed rate did not cause any significant difference in plant height of wet seeded ADTRH1 hybrid rice (Table 8). Seed rate adopted in the study ranged from 16 to 70 kg ha^{-1} only unlike in the conventional inbred varieties where higher seed rates of 120-150 kg ha^{-1} were

Table 8: Influence of Crop establishment methods and N management on yield attributes of ADTRH1 during 2002

Treatments	Productive tillers m^{-2}	Panicle length (cm)	Total No. of grains $panicle^{-1}$	No. of filled grains $panicle^{-1}$	No. of ill-filled grains $panicle^{-1}$	Sterility (%)	1000 grain weight (g)
Establishment methods							
M_1	447	22.23	126.00	107.80	18.20	14.44	23.80
M_2	454	21.47	120.00	102.60	17.40	14.50	23.50
M_3	440	21.72	124.60	105.70	17.90	14.36	23.69
M_4	351	22.41	131.10	113.20	17.80	13.57	23.91
CD (0.05)	17.0	NS	6.36	5.31	NS	0.76	NS
N management							
N_1	261	19.54	103.60	89.20	14.40	13.89	23.41
N_2	439	21.91	126.30	106.50	19.70	15.59	23.80
N_3	501	23.61	137.20	116.60	20.50	14.94	24.60
N_4	448	22.29	129.60	110.80	18.70	14.43	23.50
N_5	434	21.73	123.50	108.70	14.60	11.82	23.60
N_6	372	20.88	116.40	101.80	14.50	12.45	23.60
N_7	509	23.80	141.10	117.90	23.10	16.37	24.10
CD (0.05)	18.55	1.40	7.18	5.94	1.06	0.80	NS

Interaction not significant

used. But perhaps, this lower seed rate coupled with the fairly wide 20 cm inter-row space accomplished by the use of drum seeder holes manipulation reduced the interplant competition and consequently with no adverse effect on plant height. But at the early stages of crop, plant height in different wet seeding treatments is higher than transplanting whereas in the later stages there is no significant difference in plant height between the establishment methods. The higher plant growth in early stages in wet seeding might be due to early establishment of direct seeded crop in the absence of transplantation shock as reported by Sharma *et al.* (1989). Santhi (1997) observed that there is no marked difference in plant height between direct seeding and transplanting. Similar trend of adoption of different seed rates without significant difference in plant height was reported by Joseph (2001).

Greater availability of nutrient and higher uptake were the causes for the beneficial effect on the growth due to different N management practices. Nitrogen is well recognized as a promoter of vegetative growth and apart from being a substrate for protein synthesis; it also stimulates meristematic growth through protoplasmic synthesis (Yoshida and Oritani, 1974; Beringer, 1980). Thus increased availability of N through different N management practices resulted in higher values of plant height during both the years. Application of higher dose of N based on STCR to a tune of 189 to 191 kg ha^{-1} results in higher availability of N which in turn results in stimulation of merisematic growth leading to increase in plant height. Similar results of increased plant height in ADTRH1 due to N application at 200 kg ha^{-1} was reported by Suganthi *et al.* (2003). Similar result of enhancement in height of rice plant with increased level of applied N has been documented by several researchers (Muralidharan, 1996). The mineralization during the decomposition of green manure due to integrated use of inorganic fertilizers have enhanced the N availability in the rhizosphere resulting in increased N uptake by rice hybrids which in turn promoted the increase in plant height and consequent favourable effect of growth characters at higher levels of fertilizer N at early stages. This trend is in conformity with that of Siddeswaran (1992). In general addition of green manure in rice soil has a positive correlation with plant height (Hiremath and Patel, 1998).

Leaf Area Index (LAI) in the two seasons was significantly influenced by the crop establishment methods and N management at all crop growth stages. Seeding through all the holes (M_1) recorded the highest LAI of 3.69 and 3.51 at 40 DAS, 5.82 and 5.48 at 60 DAS and 6.37 and 5.90 at 80 DAS which was on par with transplanting (M_1) and seeding through one out of two holes (M_3). Seeding through one out of three holes registered the lower LAI at all the stages of the crop growth. Nitrogen management practices had significant positive influence in enhancing LAI at all the stages irrespective of the seasons. The maximum LAI of 4.20 and 4.02 at 40 DAS, 6.5 and 6.28 at 60 DAS, 7.10 and 6.63 at 80 DAS was registered with N application based on STCR (N_7) and it was on par with 120 kg N ha^{-1} plus green manure (N_3) but significantly higher than the rest of the treatments. There is no significant interaction between crop establishment methods and N management throughout the crop growth during both the years. Higher tiller production in seeding through all the holes due to higher seed rate enabled the production of more leaves per unit area and consequently higher leaf area index. Balasubramanian and Palaniappan (1991) also reported that LAI increased with higher population due to more leaves produced per unit area. Joseph (2001) also reported that adoption of seed rate of 24 kg ha^{-1} produced higher leaf area index. Similar finding of LAI not being significantly influenced between drum seeding and transplanted crop was reported by Santhi (1997). The total leaf area per unit ground area is an important indicator of

Table 9: Influence of Crop establishment methods and N management on yield attributes of ADTRH1 during 2003

Treatments	Productive tillers (m^{-2})	Panicle length (cm)	Total No. of grains panicle^{-1}	No. of filled grains panicle^{-1}	No. of ill-filled grains panicle^{-1}	Sterility (%)	1000 grain weight (g)
Establishment methods							
M_1	427	21.80	122.10	105.60	16.47	13.49	23.61
M_2	437	21.00	118.20	100.80	17.40	14.72	23.29
M_3	421	21.30	120.40	103.50	16.90	14.04	23.43
M_4	436	21.90	126.60	110.60	15.95	12.60	23.61
CD (0.05)	18.0	NS	5.95	5.16	0.84	0.76	NS
N management							
N_1	251	19.20	100.20	85.60	14.56	14.53	23.50
N_2	420	22.20	125.00	107.00	18.00	14.49	23.61
N_3	476	23.00	132.00	115.00	17.00	12.88	24.40
N_4	428	21.50	123.30	107.60	15.70	12.82	23.22
N_5	414	21.30	120.60	106.10	14.50	12.10	23.42
N_6	362	20.10	116.20	99.90	15.40	14.11	23.22
N_7	485	23.20	135.60	114.70	20.86	15.46	23.80
CD (0.05)	19.64	1.20	6.59	5.80	0.93	0.85	NS

Interaction not significant

total source available to the plant for the production of photosynthates, which accumulate in the developing sink (grain). All the N management treatments recorded substantially higher LAI compared to control in both seasons of investigation. Such increase in LAI is quite obvious due to higher availability of N. At all the stages of growth the LAI was highest in STCR based N applied plots and was on par with the N application in four splits plus green manure applied treatment. The highest plant height coupled with more number of leaves, number of tillers might have led to significant positive influence on the leaf area index of the STCR based N applied plots. Similar results of increased N supply resulting in taller plants and higher LAI was reported by Muralidharan (1996). The increase in LAI of rice in the plot applied with fertilizer application plus green manure is attributed to adequate availability of N during the initial stages of the crop by the split application. The contribution of N from the mineralization of the green manure incorporation might have benefited the expansion of leaf area. The lower response in LCC cv. 4 based N application as expressed in LAI is the result of poor N nutrition due to inadequate supply of N to meet the physiological need of the hybrid.

Yield components: The production of panicles both per plant and per unit area is one of the important yield contributing characters. During both the years, the hybrid exhibited significant variation in productive tiller formation due to different crop establishment methods and N management practices. Significantly higher number of productive tillers (454 and 437 m^{-2}) was registered in seeding through all the holes (M_2) and it was on par with transplanting (M_1) and seeding through one out of every two holes (M_3) (Table 9). The number of panicles m^{-1} was significantly enhanced by N management practices over control in all the seasons of cropping. Application of N based on STCR (N_7) registered significantly higher number of productive tillers (563 and 545 m^{-2}) and it was on par with application of 150 kg N ha^{-1} (N_3). Interaction effect between crop establishment methods and N management practices was significant. Seeding through all the holes and application of N based on STCR (M_2N_7) resulted in maximum number of productive tillers. The values of yield attributes of most of grain crops including rice would generally be in accordance with that of vegetative growth parameters, since the size of source most often determines the size of sink. In terms of yield attributes, a positive linear relationship with seed rate due to different seeding method was observed only in productive tillers per unit area. Possibly an increase in total tiller production might have led to the promotion of more panicle bearing tillers per unit area under the seeding through all the holes with higher seed rate. This is in agreement with the findings of Thakur (1993). Similarly the increased effective tillers per unit area under higher seed rate in wheat as compared to lower seed rate was reported by Upadhyay *et al.* (1993). Tillering ability exerted a significant influence on future production of panicle in a study by Miller *et al.* (1991). Joseph (2001) confirmed that more panicle bearing tillers per unit area with seed rate of 24 kg ha^{-1} in wet seeded hybrid rice than at 20, 16 and 12 kg ha^{-1} seed rate levels. The seeding method *viz.*, drum seeding and transplanting did not have significant influence on the number of panicles was reported by Santhi (1997). Enhancement of vegetative growth favourably influenced the yield attributes and higher N application levels i.e., more than 200 kg ha^{-1} increases the productive tiller density was also reported by Aruna Geetha (1998). High N responsive genotypes were found to produce more productive tillers (Tanaka *et al.*, 1964). Hybrid rice responds to higher N application as they have unique physiological pattern of N requirement (Yan, 1988). The obvious reason for the higher effective tiller production might be due to high

N responsiveness of the hybrid to higher N levels i.e., 189 and 192 kg ha^{-1}. Higher number of panicles with STCR based N application (256.70 kg ha^{-1}) was also reported by Balasubramanian (2002). Similar results of higher productive tillers was recorded by CoRH2 with application of 175 and 200 kg N ha^{-1} were observed by Somasundaram *et al.* (2000) and Suganthi *et al.* (2002). The application of N fertilizer in four splits along with green manure recorded more number of productive tillers and it was comparable with STCR based N application. Higher N both through organic source as well as fertilizer N resulted in higher nutrient uptake which might have delayed senescence and increased photosynthetic efficiency which ultimately led to increased number of productive tillers (Yoshida, 1981).

Among the yield attributes, panicle length and thousand grain weight were not influenced by the methods of crop establishment. But the number of filled and ill filled grains $panicle^{-1}$ was significantly influenced by the seeding methods due to variation in seed rate adopted. Seeding through one out of three holes (M_4) recorded significantly higher number of total grains $panicle^{-1}$(131.10 and 126.60) and was on par with transplanting but differed significantly to that of M_3 and M_2. Significantly more number of filled grains (113.20 and 110.60) during 2002 and 2003 and less number of ill filled grains per panicle (18.20) were recorded with seeding through one out of three holes (M_4) with lower seed rate as compared to transplanting and other treatments. Similar finding was reported by Joseph (2001) in which 12 kg seed ha^{-1} produced least ill-filled grains, more grains per panicle than 24, 20 and 16 kg ha^{-1} seed rate but with lesser productive tillers. Panicle m^{-2} was more or less the same in both the wet seeded and transplanted crops was reported by Thakur (1993).

Panicle length and total number of grains per panicle were significantly improved with N application based on STCR (N_7) and it was on par with four splits of fertilizer N plus green manure application (N_3). Higher availability of N at various stages of growth in STCR based N application treatment favourably influenced the yield attributes. Similar observation was also made by Balasubramanian (2002). Number of filled grains was significantly higher with N application in four splits along with green manure application. This might be due to better availability of N from organic and inorganic sources at different critical physiological stages which favoured better growth of rice as evidenced by increased tiller number, LAI, leaf N content and consequently higher DMP. Virmani (1996) also reported increased number of spikelets with higher accumulation of dry matter in hybrid rice. Availability of adequate N promotes the supply of assimilates to sink thus increasing the number of spikelets and filled grains. About 15-20% of total N uptake by hybrid rice is reported to take place after heading and therefore hybrid rice responds well to N application at flowering (Yang *et al.*, 1987). Nutrients available from decomposing green manure to the rice crop during the reproductive stage were utilized for grain formation and grain filling leading to more number of filled grains per panicle. Generally there is an inverse relationship between sterility percentage and N levels. To fall in line with the above fact, the sterility percentage recorded in the study was least in LCC cv. 4 based N application and highest in STCR based N application treatment. This is due to higher N regime in the STCR based N application which results in more tiller production and increased the possibility of unfilled panicles in the later produced tillers. However LCC based N management reduces the sterility percentage compared to the conventional N application. Similar results were also reported by Bindhu (2002). Thousand grain weights remain unaltered by nitrogen management practices because it is mostly governed by the genetic make up of the plant.

Grain and straw yield: The grain yield of ADTRH1 under different establishment methods varied widely from 2380 to 7374 kg ha^{-1}. The main cause for this variation in the different establishment method was due to variation in the seed rate caused by different seeding methods which is reflected in the tillers and productive tillers production and consequently in the yield. Seeding through all the holes (M_2) produced significantly higher grain yield of 7374 kg ha^{-1} which was on par with transplanting (M_1) and seeding through one out of two holes (M_3) (Table 10). In case of seeding through one out of three holes (M_4) with seed rate of 17.43 and 16.78 kg ha^{-1} during both the years, there is a drastic yield reduction compared to other method of establishment. Higher grain yield with increasing seed rates in the wet seeded rice has earlier been reported in conventional inbred varieties (Singh *et al.*, 1997). Wet seeding of rice has produced grain yield as that of transplanted rice as reported by Singh and Garg (1993). Higher grain yield with adoption of higher seed rate of 24 kg ha^{-1} in wet seeded CoRH2 rice hybrid was reported by Joseph (2001). Productive tiller per unit area are strongly correlated with grain yield in any rice variety (Counce and Wells, 1990). Production of more panicles per unit area at higher plant density associated with higher seed rate led to significant increase in grain yield with seeding through all the holes (M_2) and seeding through one out of two holes (M_3) compared to seeding through one out of three holes (M_4). This was due to increase in economic sink strength. The higher plant

Table 10: Grain and straw yield (kg ha^{-1}) of hybrid rice ADTRH1 as influenced by Crop establishment methods and N management practices

	Kharif 2002		Kharif 2003	
Treatments	Grain yield	Straw yield	Grain yield	Straw yield
Establishment methods				
M_1	6037	7323	5765	7065
M_2	6140	7512	5904	7222
M_3	5953	7220	5688	6942
M_4	4672	5841	4487	5601
CD(0.05)	208	353	215	311
N management				
N_1	3508	4673	3301	4396
N_2	5934	7169	5684	6964
N_3	6695	7871	6383	7509
N_4	6050	7428	5794	7236
N_5	5873	7101	5565	6842
N_6	5026	6393	4914	6144
N_7	6820	8181	6586	7862
CD (0.05)	233	359	139	347
M at N CD(0.05)	489	754	503	730
N at M CD (0.05)	465	718	476	695

population resulted in more utilization of natural resources particularly soil nutrients, moisture, carbon-di-oxide and radiant energy. The ability to accept and to transform the solar energy by a crop stand has increased the yield (Upadhyay *et al*., 1993). Though the grains panicle^{-1} was higher and sterility percentage was lower with the seeding through one out of three holes (M_4) with lower seed rate of 16-18 kg ha^{-1}, it could not compensate the reduction in panicles per unit area at lower plant density. Similar results were reported by Ramakrishnan and Soundarapandian (1990). A distinct enhancement in straw yield with increase in seed rate was evident in both the years. Straw yield is directly proportional to tiller formation and dry matter accumulation in rice. Hence, seeding at higher seed rate by seeding through all the holes (68-70 kg ha^{-1}), seeding through one out of two holes (26-28 kg ha^{-1}) and transplanted rice produced more tillers m^{-2} and recorded higher DMP resulting in higher straw yield (Singh *et al*., 1997). Higher straw yield production through the adoption of higher seed rate of 24 kg ha^{-1} in wet seeded CoRH2 hybrid seed was reported by Joseph (2001).

Ensuring adequate availability of N during the crop growth period is a prerequisite for higher grain yield. Generally the increase in grain yield due to N fertilization was attributed directly by significant improvement in yield attributes like number of panicles m^{-2} and number of grains panicle^{-1}. Consequent to the improvement in yield attributes, grain yield was markedly increased in N application based on STCR in both the seasons and it was on par with four split application of N along with green manure application. Aruna Geetha (1998) reported higher grain yield of ASD 20 which was 90% of targeted yield through STCR based N application at the highest N application rate of 234 kg ha^{-1}. Similarly the application of N based on STCR (256.7 kg ha^{-1}) for CoRH1 in four splits resulted in higher grain yield was reported by Balasubramanian (2002). Because of the higher N responsiveness of hybrids, STCR based N application recorded higher grain yield as the total N applied through this regime was higher as compared to other N management practices. Addition of N at the highest level resulted in maximum grain yield in hybrid rice was confirmed by Singh (1999). Highest grain yield of hybrid rice due to enhanced N rate application of 200 kg N ha^{-1} was noticed due to increased N availability in soil, plant growth parameters and yield attributes was reported by Ajay Prakash (2002). Wopereis *et al*. (1994) and Thiyagarajan *et al*. (1994) reported a positive correlation between dry matter production and grain yield. Similar result of higher grain yield of CoRH2 and ADTRH 1 with 200 kg N ha^{-1} application was reported by Rajarathinam and Balasubramanian (1999). Significantly higher yield obtained in STCR based N application was 7374 and 7208 kg ha^{-1} during 2002 and 2003 as against the targeted yield of 7 t ha^{-1} with a deviation of +5% and +2.97%, respectively. Similar results of deviation of +10% to the targeted yield was reported in wheat crop by Sharma and Singh (2000). The strategy of applying the fertilizer N in four splits plus green manure appears to match the crop demand at different physiological stages and reduces the losses through denitrification and volatilization as reflected in recording higher grain yield comparable to STCR based N application. Thus the increased availability of nutrients at critical physiological phases would have supported for better assimilation of photosynthates towards grain. Increase in grain yield can also be attributed to favourable effect in accelerating the growth and yield parameters. Similar findings have also been reported by Stalin *et al.* (1999). The marked increase in grain yield by the application of fertilizer N in four splits plus green manure might be due to the role played by green manures in dissolving the native and added nutrients and charging the soil solution with adequate essential elements by the production of various organic acids during the decomposition (Mishra and Bangar, 1986). The enrichment of soil fertility through green manure addition into the soil (Gopalaswamy and Vidhyasekaran, 1987) and improved soil physical condition might have promoted the yield attributes contributing to the increased grain yield (Thiyagarajan, 1991). The slow and steady release of nutrients from green manures have helped the rice plant to meet the nutrient requirement at all the stages and thereby favourably influenced the various yield parameters and ultimately resulted in higher yield (Budhar *et al.*, 1994).

The response of hybrid to N application based on STCR was in the higher magnitude as evident from significant variation in straw yield from the various treatments but was on par with the application of fertilizer N in four split plus green manure at the rate of 6.25 t ha^{-1}. Application of higher dose of N in STCR based N application promoted higher biomass and this resulted in significant enhancement in straw yield. It might be due to higher number of tillers and enhanced N uptake at all growth stages of crop. This trend of results was confirmed by Siddeswaran (1992). Maheswari (1997) reported increased straw production with increased N levels. Balasubramanian (2003) observed that highest straw yield in CoRH1 was recorded with N application based on STCR methods. The demonstrated effect of green manure as well as N on grain yield has been repeated once again with straw production. It is a known fact that the grain yield is a function of straw yield as adequate straw production is obligatory for effective photosynthesis and steady transport of nutrients and metabolites required for grain production.

Interaction between crop establishment and N management: In the preceding discussion, the effects of two production variables on the growth of hybrid rice have been discussed individually. Each one of them viz., establishment method and N management practices exerted a significant influence on the growth and yield of both the seasons. The interaction effect of these production factors was also significant in respect of most of growth parameters, important yield attributes and yield of grain and straw from the hybrids. The interaction effect was found to be additive. Thus the combination of the best level of each of the two variables invariably resulted in better growth and higher yield. The benefits of the larger plant density with seeding through all the holes with higher seed rate were complemented by increased nutrient contribution from N application based on STCR and the application of N in four splits along with green manure. The highest grain yield of 7374 and 7208 kg ha^{-1} was recorded when the seeding through all the holes using the drum seeder combined with N application based on STCR (M_2N_7) which was comparable with M_2N_3, M_1N_7, M_1N_3 and M_2N_3. The nutrient requirement for this stand establishment was adequately met by the N application based on STCR approaches and the green manure incorporation plus N application in four split.

The present study concludes that wet seeding of hybrid rice could be accomplished as an economically viable technology by the use of eight row drum seeder with some modifications in the seed holes of the seeder. Seeding through one out of two holes using eight row seeder with a optimum seed rate of 28 kg ha^{-1}in combination with N application based on Soil Test Crop Response (STCR) approach resulted in highest grain yield of 7378 kg ha^{-1} with a maximum of +5% deviation of targeted yield under Tamil Nadu condition.

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