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Maximisation of seed production by aditional dose of N and K in hybrid rice

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ABSTRACT

Parental lines (A and R lines) of rice hybrids ADTRH 1and CORH 2 were given four fertilizer dose treatments and the results indicated that the application of recommended dose of fertilizer (RDF) @ 150:60:60 kg NPK ha^{-1}, + 25 kg N and 15 kg K each at PI and 10 days after PI increased the plant height, total tillers, productive tillers and seed weight of both A and R lines. This additional fertilizer dose advanced the days to 50 per cent flowering, improved the panicle exsertion and seed set in A line. Though, there was a progressive increase in most of the growth traits due to progressive increase in fertilizer dose, the stage of application was most critical and specific to certain growth traits. This additional N and K dose exerted an increase of 13.7 and 12.3 per cent hybrid seed yield in ADTRH 1 (2,061 kg ha^{-1}) and CORH 2 (1,663 kg ha^{-1}) respectively. The increase in grain yield was 15.0 and 11.5 per cent in R lines of ADTRH 1 (1,623 kg ha^{-1}) and CORH 2 (1,488 kg ha^{-1}) respectively.

Key words: *Rice, Oryza sativa L., hybrid seed production, fertiliser dose*

Although, several rice hybrids have been released in India for commercial cultivation, the coverage under hybrid rice is far below the projections. Of a host of factors that affect hybrid rice production, low level of exploitable heterosis and non-availability of quality seeds of released hybrids at reasonable price have been identified as the key impediments in adoption of hybrid rice technology (Mahadevappa, 2001). For economic feasibility and commercial viability of the hybrid rice technology, development of an efficient seed production package is a pre-requisite. The inherent yield potential of a crop gets expressed to its maximum extent, if the crop is provided with the required nutrients in abundance. Mother crop nutrition greatly influences the seed yield and quality characteristics (Roberts, 1972). The demand for nutrients may vary with the advancement in growth stages until maturity. Adequate nutrient supply is necessary for maximum growth during the vegetative period. Avoidance of nutrient stress is essential during translocation of nutrients from vegetative to reproductive parts to achieve higher seed yields (Munda *et al.*, 1983). Among the various techniques of N management, split application of N is perhaps one of the simplest agronomic solution for improving the N use efficiency since N demand is not same throughout the plant growth period (Manjappa *et al.*, 1994). Even though, K comes next to N in terms of quantity used, it plays a significant role in increasing the seed yield by activating enzymes involved in the plant growth and development. Split application of N reported to have influenced leaf area, biomass yield (Ramazanova, 1993), number of panicles (Wagh and Thorate 1987), panicle weight and grain yield (Bhattacharya and Singh, 1992). Similarly, application of K in equal splits increased the panicle length (Nannabatcha 1984), number of panicles (Purushothaman 1985), number of filled grains panicle^{-1} (Mahapatra and Patnaik, 1982), plant height

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and yield (Devasenapathy, 1997). With this insight in view, comprehensive field experiments were conducted to elucidate information on the effect of split application of additional dose of N and K yield in hybrid rice seed production.

MATERIALS AND METHODS

Field experiments were conducted in the wetland farm of Tamil Nadu Agricultural University, Coimbatore, India during two consecutive seasons *viz*., July – November 2002 and January – May 2003 with parental lines (A and R lines) of two rice hybrids ADTRH 1 and CORH 2 respectively. The soil type of the experimental fields was moderately drained, deep clay loam, haplustalf with a pH range of 7.6 to 7.8. Normal weather conditions of Coimbatore (mean of 25 years) recorded a mean annual rainfall of 674.2 mm received in 49 rainy days. The mean maximum and minimum temperature were 31.5°C and 21°C respectively. Mean relative humidity ranged from 58 to 63 per cent. Mean bright sunshine hours day^{-1} was 7.3 h with a mean solar radiation of 429.2 cal cm^{-2} day^{-1} (17.68 MJ m^2 day^{-1}). The experiments were laid out in randomized block design with five replications. Individual plots were formed with a buffer spacing of 0.5 m width all around each plot and irrigation channel of 0.75 m was left in between the treatments. Considering the difference in growth duration of parental lines and to extend the pollen supply time, sowing of R lines was delayed and staggered thrice at 12, 15 and 18 days in case of ADTRH 1 and 3, 6, 9 days in case of CORH 2 after A line sowing. The entire first sown R line + 50 per cent of second sown R line seedlings were transplanted along with A line at a row ratio of 2 : 8 (R : A). The remaining 50 per cent of second sown R line seedlings and the entire third sown R lines were transplanted two days after first transplanting. The fertilizer dose treatments were imposed as detailed below.

T_1 – Recommended Dose of Fertilizer (RDF) @ 150:60:60 kg NPK ha^{-1} in four equal splits at basal, active tillering (AT), panicle initiation (PI) and 10 per cent flowering stages.

T_2 – T_1 + 25 kg N and 15 kg K ha^{-1} extra at PI stage

T_3 – T_1 + 25 kg N and 15 kg K ha^{-1} extra at 10 days after PI (10 DAPI) stage

T_4 – T_1 + 25 kg N and 15 kg K ha^{-1} extra at both PI and 10 DAPI stages

Supplementary pollination was done by shaking the male rows with the help of a rope. Rope pulling was done twice a day at half an hour interval during peak anthesis time between 10.00 and 11.30 AM and it was continued for 10 days. GA_3 @ 75 g ha^{-1} was sprayed thrice at 10, 25 and 50 per cent flowering with 25 g ha^{-1} each per spray. Various biometric characters were recorded at different growth stages on randomly selected five plants in each plot from both the parents except for days to 50 per cent flowering, panicle exsertion and seed set percentage which were recorded only on A line. The male and female lines in each plot were harvested and threshed separately. Soil samples were collected before commencement of the experiment and immediately after the harvest of each crop from each plot. The samples were analysed for available N, P and K nutrients. The whole plants samples were collected carefully at the harvest stage. Nutrient uptake was calculated by multiplying the nutrient content of seed / grain and straw.

RESULTS AND DISCUSSION

The additional 25 kg N + 15 kg K ha^{-1} each applied in two stages viz., panicle initiation (PI) and 10 days after PI (10 DAPI) over and above the recommended dose of fertilizer (RDF) @ 150: 60: 60 kg NPK ha^{-1} increased the plant height, number of total tillers and productive tillers in both male (R) and female (A) lines. Due to application of higher N and K at the aforesaid level, the plants grew taller by 4.0-4.2 cm in A line and 4.8 – 6.0 cm in R lines as compared to RDF. The increase in plant height was only upto 50 per cent of the above in A (2.7 cm) and R line (2.3-3.3 cm) when the additional dose was given only at PI stage and was about 25 per cent when applied only at 10 DAPI stage (Table 1 and 2). N apart from being a substrate for protein synthesis, it also stimulates meristematic growth through protoplasmic biosynthesis (Yoshida and Oritani, 1974; Beringer, 1980). Thus, increased availability of N through additional N application resulted in higher values of plant height. Even though, the increase in plant height was corresponding to the additional doses of N and K, the results clearly indicated that the stage of application was critical for the plants to respond significantly and positively.

Additional dose of N and K given at both PI and 10 DAPI promoted 2.0 to 3.0 extra tillers in A line

Table 1. Additional dose of N and K on growth and yield of A line in ADTRH 1 and CORH 2 hybrid rice seed production

Treatment	Plant height (cm)		Number of tillers plant-l		Number of productive tillers plant^{-1}		Days to 50% flowering		Panicle length (cm)		Panicle exsertion (%)		Number of spikelets panicle^{-1}		Seed set (%)		1000 seed weight (g)		Seed yield plant^{-1} (g)		Seed yield (kg ha^{-1})	
	ADRH1	CORH2	ADRH1	CORH2	ADRH1	CORH2	ADRH1	CORH2	ADRH1	CORH2	ADRH1	CORH2	ADRH1	CORH2	ADRH1	CORH2	ADRH1	CORH2	ADRH1	CORH2	ADRH1	CORH2
RDF @ 150:60:60 kg NPK ha^{-1}	75.7	80.1	9.0	8.7	6.8	6.1	92.9	93.7	22.5	23.1	75.9	70.7	131.5	124.6	28.6	26.7	18.7	19.9	4.75	4.17	1779	1459
RDF+ 25 kg N ard 15 kg K ha^{-1} extra at PI	78.4	82.9	10.8	10.2	8.7	7.3	92.4	92.9	23.0	23.2	78.0	74.4	133.2	128.1	29.4	27.2	19.1	20.3	5.24	4.62	1955	1618
RDF+ 25 kg N ard 15 kg K ha^{-1} extra at 10 days after PI (10 DAPI)	77.3	81.5	9.8	9.2	7.7	6.8	89.7	90.4	23.4	23.3	77.0	73.4	132.2	125.8	28.4	26.9	19.1	20.5	4.91	4.45	1832	1558
RDF+ 25 kg N ard 15 kg K ha^{-1} extra at both PI ard 10 DAPI	79.7	84.3	12.0	10.7	9.3	7.9	89.5	89.9	24.0	23.4	79.1	75.8	133.8	129.4	29.8	27.6	9.2	20.5	5.52	4.75	2061	1663
CD (P=0.05)	0.54	1.89	1.34	1.61	0.70	0.15	0.92	0.59	0.15	NS	0.61	0.69	NS	NS	0.36	0.37	0.44	0.11	0.20	0.05	84.2	18.8

Table 2. Additional dose of N and K on growth and yield of R line in ADTRH 1 and CORH 2 hybrid rice seed production

Treatment	Plant height (cm)		Number of tillers plant^{-1}		Number of productive tillers plant^{-1}		Panicle length (cm)		Number of spikelets panicle^{-1}		1000 seed weight (g)		Seed yield plant^{-1} (g)		Seed yield (kg ha^{-1})	
	ADTRH1	CORH2	ADTRH1	CORH2	ADTRH1	CORH2	ADTRH1	CORH2	ADTRH1	CORH2	ADTRH1	CORH2	ADTRH1	CORH2	ADTRH1	CORH2
RDF @ 150:60:60 kg NPK ha^{-1}	81.6	101.4	12.8	10.1	9.6	7.6	21.2	21.0	118.0	107.5	21.7	23.6	15.75	15.65	1379	1317
RDF+ 25 kg N and 15 kg K ha^{-1} extra at PI	84.9	103.7	15.1	10.8	12.2	8.4	21.7	21.0	119.9	115.6	22.8	23.8	17.57	16.51	1537	1444
RDF+ 25 kg N and 15 kg K ha^{-1} extra at 10 days after PI (10 DAPI)	83.7	102.4	14.1	10.5	10.9	8.1	22.1	21.3	119.5	111.4	22.9	24.1	17.5	15.8	1529	1379
RDF+ 25 kg N and 15 kg K ha^{-1} extra at both PI and 10 DAPI	87.6	106.2	15.6	11.5	13.1	9.0	22.1	21.6	121.6	118.1	22.97	24.32	18.55	17.01	1623	1488
CD (P=0.05)	1.72	2.16	0.91	0.65	0.80	0.41	0.29	NS	NS	5.13	0.20	0.31	0.33	1.13	29.0	99.1

and of which 1.8 to 2.5 tillers become productive in both the hybrids. Similarly, in R line also, 3.0 to 4.5 additional tillers were produced due to the above extra doses of N and K and 1.4 to 3.5 of them turned to be productive in both ADTRH 1 and CORH 2. NH_4-N in the soil solution was positively correlated with tillering ability (Jiang *et al* 1993) and K would have contributed to increased production and conversion of tillers more productive (Mengel *et al.*, 1976). The response to additional dose applied at single stage either at PI or 10 DAPI also positive with regard to production of tillers and converting them to be productive, but, the response was comparatively higher when applied at PI stage.

A lines of both the hybrids were early by 3.4 to 3.8 days in attaining 50 per cent flowering at 89.5 to 89.9 days after sowing (DAS) when applied with additional dose of N and K at both PI and 10 DAPI stages as compared to RDF which required 92.9 to 93.7 days. The reduction in number of days required to complete 50 per cent flowering was related to the increase in nitrogen uptake. The early flowering due to higher fertilizer application may be attributed to the early attainment of C/N ratio, accompanied by induction of physiological systems such as enzymes necessary for early initiation of the reproductive phase in rice (Mitsui and Nishigaki, 1940). The additional dose of N and K applied in single stage at 10 DAPI promoted early 50 per cent flowering as that of additional dose applied in two stages viz. PI and 10 DAPI. Therefore, 10 DAPI appeared to be a critical stage for the application of additional dose of N and K in order to advance the 50 per cent flowering.

The response of both the parents to the additional dose of N and K was not consistent in increasing the panicle length, as it was positive in ADTRH 1 and had no effect in CORH 2. Panicle exsertion was higher by 3.2 to 5.1 per cent in A line of both the hybrids due to additional dose of N and K applied at both PI and 10 DAPI as compared to RDF. Application of additional N and K at 10 DAPI also improved the panicle exsertion marginally. The results indicated that top dressing of N and K at around panicle exsertion was a good cultural practice because it enhanced translocation of assimilates from the flag leaf to the panicle during ripening (Yong-Rui Wang and Ying-Jie Zhang, 1995). However, the fertilizer doses had no effect on the number of spikelets panicle^{-1}.

Even though, the seed set per cent in A line increased with the proportionate increase in the supply of fertilizer doses, the later application of fertilizers at 10 DAPI exhibited the effect only as that of RDF. Though, the test weight (1000 seed / grain) of rice is a genetic character, the present study indicated that the fertilizer management could also influence this trait to considerable extent. As compared to RDF, additional dose of N and K applied irrespective of stages increased the test weight of F1 seeds and R line seeds of both the hybrids. It has been reported that sufficient level of fertilizer nutrition lead to higher production of photosynthates and efficient translocation to sink, thus resulting in better filling of the spikelets (Athmanathan, 1996).

The application of additional dose of N and K at both PI and 10 DAPI resulting in greater plant height, productive tillers, panicle exsertion, seed set, efficient filling of spikelets and more seed weight cumulatively resulted in higher single plant yield and thereby, increased hybrid seed yield per unit area. The positive manifestation of these characters in general resulted in increase of 13.7 per cent in ADTRH 1 (2,061 kg ha^{-1}) and 12.3 per cent in CORH 2 (1,663 kg ha^{-1}) hybrid seed yield due to application of additional N and K at both PI and 10 DAPI stages. The additional dose supplied at PI stage alone could also achieve 9.0-9.8 per cent higher seed yield of both the hybrids. A similar trend was observed in R line also with the additional fertilizer dose at both PI and 10 DAPI enhancing the per plant and unit area grain yield to a tune of 15.0 and 11.5 per cent by recording 1,623 and 1,488 kg ha^{-1} in ADTRH 1 and CORH 2 respectively. The additional N and K at PI also maximized the grain yield by 10.3 and 9.8 per cent in R lines of ADTRH 1 and CORH 2 respectively.

The present result indicated a corresponding increase in the N, P and K uptake of both the straw and seeds of A / grains of R lines with the progressive increase in the application of N and K fertilizer dose. The highest uptake of N, P and K was recorded with the application of additional dose of N and K at both PI and 10 DAPI (Table 3 and 4). The lower nutrient uptake in RDF could be attributed to the reduced quantity of fertilizer supply. One way to achieve better use of the applied nutrients is to apply the fertilizer at a time to best meet the demand of the rice plant (De Datta, 1981).

Table 3. Additional dose of N and K on nutrient uptake in A line of ADTRH 1 and CORH 2 hybrid rice seed production

Treatment	N uptake (kg ha^{-1})				P uptake (kg ha^{-1})				K uptake (kg ha^{-1})			
	ADRH 1		CORH 2		ADRH 1		CORH 2		ADRH 1		CORH 2	
	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed
RDF @ 150:60:60 kg NPK ha^{-1}	26.3	17.9	30.0	16.6	5.65	3.58	5.28	3.72	17.3	3.31	8.42	9.83
RDF+ 25 kg N and 15 kg K ha^{-1} extra at PI	30.5	23.8	32.0	19.8	6.53	4.10	5.36	4.44	19.5	1.14	10.7	10.7
RDF+ 25 kg N and 15 kg K ha^{-1} extra at 10 days after PI (10 DAPI)	31.1	22.4	32.4	19.6	6.48	4.28	5.46	4.06	20.9	3.64	9.67	10.0
RDF+ 25 kg N and 15 kg K ha^{-1} extra at both PI and 10 DAPI	33.5	26.1	34.9	21.8	6.86	4.18	5.76	4.87	22.4	4.33	11.0	11.1
CD (P=0.05)	0.24	1.58	0.56	2.09	0.16	NS	NS	0.20	0.68	0.15	0.07	0.30

Table 4. Additional dose of N and K on nutrient uptake in R line of ADTRH 1 and CORH 2 hybrid rice seed production

Treatment	N uptake (kg ha^{-1})				P uptake (kg ha^{-1})				K uptake (kg ha^{-1})			
	ADRH 1		CORH 2		ADRH 1		CORH 2		ADRH 1		CORH 2	
	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed
RDF @ 150:60:60 kg NPK ha^{-1}	9.3	12.3	11.0	11.3	1.59	2.52	1.47	2.57	4.49	2.37	2.99	6.83
RDF+ 25 kg N and 15 kg K ha^{-1} extra at PI	12.0	13.2	12.3	12.1	1.93	2.42	1.60	2.72	5.63	2.44	3.43	7.87
RDF+ 25 kg N and 15 kg K ha^{-1} extra at 10 days after PI (10 DAPI)	11.0	13.2	12.3	12.4	1.97	2.43	1.52	2.56	5.25	2.42	3.24	7.52
RDF+ 25 kg N and 15 kg K ha^{-1} extra at both PI and 10 DAPI	12.8	14.4	13.7	13.5	2.30	2.66	1.70	2.67	6.02	2.49	3.76	8.74
CD (P=0.05)	1.02	NS	1.24	NS	0.10	NS	NS	NS	0.43	0.06	0.15	0.72

Accordingly, the application of additional dose of fertilizers at PI stage and additionally at 10 DAPI attributed to better uptake.

Irrespective of the fertilizer doses, insignificant variations observed in the available soil nutrient contents of the post harvest soil indicated the better uptake and utilization of the applied nutrients by both A and R lines of both the hybrids (Table 5).

The correlation co-efficient of growth and yield parameters and nutrient uptake pattern of A and R lines with hybrid seed yield of ADTRH 1 and CORH 2 revealed that the hybrid seed (F_1) yield was positively and significantly associated with plant height and panicle length of both the parents (Table 6). The direct influence of panicle exsertion per cent, seed set per cent and total N, P and K uptake in seed parent (A line) exhibited positive and significant correlation with hybrid seed yield of both ADTRH 1 and CORH 2. This also indicated that the increase in the plant height and panicle length of R line had indirect influence on hybrid seed yield probably by increasing the out crossing and seed set in seed parent (A line). Correlation coefficient revealed no significant contribution of days to 50 per cent flowering, number of spikelets and 1000 seed weight towards increase of hybrid seed yield. Therefore, the application of additional dose of 25 kg N and 15 kg K ha^{-1} each at PI and 10 DAPI over and above the recommended dose of NPK @ 150: 60: 60 kg ha^{-1} maximized the hybrid seed yield of rice hybrids ADTRH 1 and CORH 2.

Table 5. Additional dose of N and K on available nutrient content in post harvest soils of ADTRH 1 and CORH 2 hybrid rice seed production plots

Treatment	N ($KMnO_4$-N) (kg ha^{-1})		P (Olsen-P) (kg ha^{-1})		K (NH_4OAc-K) (kg ha^{-1})	
	ADTRH1	CORH2	ADTRH1	CORH2	ADTRH1	CORH2
Initial available nutrient content (Before commencement of experiment)	320	308	28.4	23.2	338	627
RDF @ 150:60:60 kg NPK ha^{-1}	333	352	36.6	34.8	355	567
RDF+ 25 kg N and 15 kg K ha^{-1} extra at PI	329	362	36.5	34.3	355	574
RDF+ 25 kg N and 15 kg K ha^{-1} extra at 10 days after PI (10 DAPI)	322	363	40.8	29.8	363	582
RDF+ 25 kg N and 15 kg K ha^{-1} extra at both PI and 10 DAPI	341	348	37.1	30.7	357	568
CD (P=0.05)	NS	NS	0.85	NS	NS	NS

Table 6. Additional N and K on correlation coefficient of growth, yield attributes and nutrient uptake of A and R lines with hybrid seed yield of ADTRH 1 and CORH 2

Parameters	ADTRH 1		CORH 2	
	A line	R line	A line	R line
Plant height	0.816**	0.795**	0.777**	0.870**
Productive tillers	0.559**	0.307	0.261	0.276
Days to 50% flowering	-0.227	-	-0.209	-
Panicle length	0.796**	0.545**	0.637**	0.678**
Panicle exsertion	0.852**	-	0.745**	-
Number of spikelets $panicle^{-1}$	0.101	0.201	0.190	0.465*
Seed set	0.879**	-	0.729**	-
1000 seed weight	0.236	-	0.241	-
Total N uptake	0.727**	0.190	0.698**	0.164
Total P uptake	0.645**	0.224	0.628**	0.265
Total K uptake	0.427*	0.259	0.770**	0.339

** Correlation significant at (P=0.01) level; * Correlation significant at (P=0.05) level

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