

Research Article

Influence of nitrogen application on direct seeded rice in old and new Cauvery Delta zone of Tamil Nadu, India

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Abstract

Direct seeded rice is a boon to farmers where the water release from the reservoir is delayed. Nitrogen fertiliser management is one of the strategies to rectify the nutrient-related issue in Direct seeded rice. The present study aimed to optimize the nitrogen dose for direct-seeded rice in the new and old Cauvery delta zone of Tamil Nadu. Field experiments were conducted during kuruvai and samba seasons at Tamil Nadu Rice Research Institute, Aduthurai and Agricultural research station Thanjavur representing old and new Cauvery delta regions during 2019-20 and 2020-21. Totally from eight experiments, the results of four field experiments in each location revealed the highest grain yield in the treatment T6 -application of 150 kg N/ha⁻¹ (5596kg/ha) which was statistically on par with treatment T5 -125kg N/ha (5326 kg/ha) in old delta and new delta. The higher grain yield was recorded in the T6 (5140 kg/ha), statistically on par with T5 (4550 kg/ha). The higher available nitrogen content of 312 kg/ha, 292 kg/ha was recorded for N application @ 150kg/ha, which was statistically on par with 309 kg/ha and 289 kg/ha, respectively, both the kuruvai and samba seasons for N application of 125 kg/ha. In the new CDZ, the same trend was followed as that of the old delta. Based on economics, N applied @125 kg/ha recorded a higher BC ratio for direct-seeded rice. For the benefit of farmers of both deltaic regions, the nitrogen application of 125 kg ha⁻¹ for direct-seeded rice is recommended.

Keywords: Cauvery delta, Direct seeded rice, Nitrogen management, Yield, Nutrient uptake

INTRODUCTION

Tamil Nadu has an area of 1.8 million ha of rice cultivation with the production of 7.9 million tonnes and the average yield level is 3.9 t/ha. More than 85.00 per cent of Tamil Nadu districts have a yield level of >2.5 t/ha. However, the Yield gap is around 2.1 t/ha (Vasanthakumar, 2017). Among various means of improving rice productivity, direct-seeded rice is a technology where the water release is delayed. India has a large deltaic area for crop cultivation (Gopal *et al.*, 2019). In Tamil Nadu, the Cauvery delta is the biggest

rice area and occupy a major area. Direct seeded rice occupied around thirty per cent of the Cauvery delta area. In the direct-seeded rice (DSR), the maturity is somewhat quicker than normal transplanting. In this situation, nutrient management study plays an important role in the DSR. Nitrogen (N) is an essential macronutrient for the growth of rice (*Oryza sativa*L.) and the major factor with respect to the development of high-yielding rice cultivars. Nitrogen fertilizers have been applied with increasing amounts in rice production, which has led to a drastic increase in N loss or removal resulting from N leaching, runoff, denitrification

and ammonia volatilization (De Datta, 1995; Zhu *et al.*, 2000; Choudhury and Kennedy, 2005; Yoon *et al.*, 2006; Thuy *et al.*, 2008; Alam *et al.*, 2021). From 2004 to 2014, the average N recovery efficiency (NRE) and Agronomic efficiency (NAE) of applied N for rice production were only 39% and 13 kg/kg, respectively (Yu *et al.*, 2015), both of which were significantly lower than the global average Nitrogen recovery efficiency (46%) and NAE (22 kg/kg) for rice (Ladha *et al.*, 2005). Fertilization based on plants' nutrient requirements and uptake ability can greatly enhance N use efficiency (NUE) and reduce atmospheric and aquatic pollution. Additional studies on nutrient uptake at different rice growth stages found that N uptake is low at the seedling stage but peaks at the tillering and booting stages, with approximately 34%, 38% of the total N absorption occurring from jointing to heading (YU *et al.*, 2013). Qi *et al.* (2012) found that delaying the first urea application increases plant growth, grain yield significantly, aboveground N uptake and NRE of dry direct-seeded rice. From the perspective of reducing labour costs and increasing NRE, N fertilizer was applied to direct-seeded rice as three split applications, such as basal, tillering, and panicle. Usually, basal fertilizer is broadcast and incorporated into puddled soils shortly before direct seeding, tillering fertilizer is broadcast (top dressed) at the initial tillering stage, and panicle fertilizer is top-dressed at the panicle initiation or heading stage. In direct-seeded rice, Xu *et al.* (2018) found that applying N fertilizer with four splits during rice growth (basal : seedling: tillering: panicle = 5: 2 : 2: 1) results in significantly higher grain yield compared to application with three times (basal: tillering : panicle = 5 : 4: 1). Indirect-seeded rice, N application rates typically range from 150- 300 kg/ha. The application rate of N also may vary with soil types (Machado Pereira *et al.*, 2021). Hence research work was initiated at heavy textured Old Cauvery delta soil and light textured New Cauvery delta soil to study the nitrogen application rates on growth, yield and soil properties of rice.

MATERIALS AND METHODS

Field experiments were completed during 2019-20 and 2020-21 at both the locations, i.e. Tamil Nadu Rice Research Institute of old Cauvery delta zone of heavy textured soil and Agriculture Research Station, Thanjavur of light-textured New Cauvery Delta soil. Totally four field experiments in each location and altogether, eight experiments were completed. Field experiments were conducted during kuruvai (June to September) and samba seasons (August to December) for the first year 2019-20. In the second year also, field experiments were conducted (2020-21) during kuruvai and samba

seasons at both locations. The details of field experiments are presented below:

Location/ season	Tamil Nadu Research Aduthurai	Rice Institute, Samba	Agricultural Research Station, Thanjavur	
Varieties	Kuruvai	Samba	Kuruvai	Samba
2019-20	ADT 37	ADT51	ADT53	ADT51
2020-21	ADT53	ADT 51	ADT43	CO52
Soil type	Old Cauvery delta, Heavy type Montmorillonitic, isohyperthermic, Udorthentic Chromusterts heavy clay texture, Kalathur soil series	delta, New Cauvery delta, Light type KaoliniticTypic Haplustalf light Madukkur series	delta, Light type KaoliniticTypic Haplustalf light Madukkur series	texture, soil

The treatments tried in all the locations and seasons were T1: No nitrogen (Control), T2: 50 kg N ha⁻¹, T3: 75 kg N ha⁻¹, T4: 100 kg N ha⁻¹, T5: 125 kg N ha⁻¹ and T6: 150 kg N ha⁻¹. N was applied in four splits at 30 (20%), 60 (35 %), 90 (35 %) and 120 (10 %) DAS. Fertilizers of 100 % P₂O₅, 25 % K₂O and 100% ZnSO₄ were applied as basally. Ist, IInd and IIIrd top dressing of N & K fertilizers were applied as per the treatment schedule on 30, 60 and 90 DAS for kuruvai and for samba season, N was applied as 20% (20-25DAS), 35% (40-45DAS), 35% (60-65DAS) and 10 % (90DAS). The soil samples were collected from the field experiment at 0-15 cm depth during kuruvai and summer seasons. All the samples were brought to the laboratory and air-dried and passed through a 2mm sieve was used for determining other soil analysis. The methods employed for analysing soil parameters based on standard procedures viz. Organic carbon by chromic acid wet digestion (Walkley and Black (1934)), available Nitrogen by alkaline permanganate method (Asija (1956)), available phosphorus by 0.5 M NaHCO₃ (Olsen, 1954), available potassium by Neutral Normal ammonium acetate method (Stanford and Eng-lish, 1949).

RESULTS AND DISCUSSION

Effect of nitrogen application on growth and yield attributes of rice

In the old Cauvery delta zone (CDZ), field experiments were conducted to study the effect of graded doses of nitrogen during 2019-20 in kuruvai season and results showed that the higher number of productive tillers (329 /m²) was recorded in the T6 which was on par with T5 (318nos/m²) (Table1). The plant height also recorded a higher value in the T6 (105.8 cm) which was at par with T5(104.6 cm). The highest grain yield was obtained in the treatment T6 -application of 150 kg Nha⁻¹

(5596kg/ha) which was statistically on par with treatment T5 -125kg N/ha(5326 kg/ha). So increasing the dose of nitrogen application did not influence yield significantly. The results pertaining to the field experiment conducted in the old CDZ samba season 2020 are given in Table 2. The higher grain yield (5636 kg/ha) was recorded in T6, which was statistically on par with T5 (5494 kg/ha). The number of productive tillers/m² of 411 was recorded T6, which was statistically on par with T5 (399 numbers/m²). The results of the second year trial conducted during 2020-21 also confirmed the first year experimental results and are depicted in Fig.1. The season results clearly indicated that the direct-seeded rice in the old Cauvery delta zone responded statistically up to 125 kg N/ha. So increasing the dose of nitrogen application did not influence yield significantly.

In the New Cauvery delta zone, field experiments were conducted during kuruvai and samba seasons of 2019-20 and 2020-21 and results of kuruvai 2019-20 indicated that higher grain yield was recorded in the T6 (5140 kg/ha), which was statistically on par with T5 (4550 kg/

ha). Numbers of productive tillers and grain yield were significantly higher in T6 (345/m²) followed by T5(291/m²) & T4(235/m²). During samba 2020(Table 7), the results revealed that T6 recorded a higher grain yield of 4450 kg/ha, which was on par with T5 (4270 kg/ha). The analysed data revealed that significantly higher plant height (1106.1 cm) and No. of productive tillers (402 / m²) were recorded in T6, which was on par with T5. In the confirmation trial (fig2), The statistical analysis of the data revealed that significantly higher plant height (109.8 cm and 107.3 cm), No. of productive tillers (338 & 304/m²) and grain yield (5017 & 4760 kg ha⁻¹) were recorded in T6 and T5 respectively but on par with each other followed by T4, T3 & T2. Significantly least yield and yield parameters were recorded in T1. From all four experiments, the application of N significantly promoted the yield attributes of rice as compared to control. The yield attributing characters such as productive tillers/m² and the number of filled grains were maximum at 150kgN/ha and on par with 125 kg/ha. Direct seeded rice produced more tillers under favourable growing conditions. The reason might be

Table 1. Effect of nitrogen application on growth and yield attributes of rice in old Cauvery delta zone (2019-20)

Treatments	Kuruvai			Samba		
	Plant height (cm)	No. of productive tillers / m ²	Grain Yield (kg/ha)	Plant height (cm)	No. of productive tillers / m ²	Grain Yield (kg/ha)
T1 : Control	87.5	185	3438	85.6	175	4026
T2 : 50 kg N ha ⁻¹	93.3	242	4325	92.4	229	4485
T3 : 75 kg N ha ⁻¹	95.8	247	4582	101.5	282	4853
T4 : 100 kg N ha ⁻¹	98.2	252	4896	108.2	336	5175
T5 : 125 kg N ha ⁻¹	104.6	318	5326	112.7	399	5494
T6 : 150 kg N ha ⁻¹	105.8	329	5596	115.8	411	5636
SEd	3.4	15	142	1.6	18.7	148
CD(p=0.05)	6.7	32	353	3.6	35.3	316

Table 2. Effect of nitrogen application on growth and yield attributes (kg/ha) of rice in new Cauvery delta zone (2019-20)

Treatments	Kuruvai			Samba		
	Plant height (cm)	No. of productive tillers / m ²	Grain Yield (kg/ha)	Plant height (cm)	No. of productive tillers / m ²	Grain Yield (kg/ha)
T1 : Control	84.4	170	2920	75.3	165	2960
T2 : 50 kg N ha ⁻¹	87.5	227	3710	87.4	220	3270
T3 : 75 kg N ha ⁻¹	90.5	231	3750	92.1	271	3610
T4 : 100 kg N ha ⁻¹	95.6	235	4430	98.5	327	3930
T5 : 125 kg N ha ⁻¹	99.3	291	4550	103.4	389	4270
T6 : 150 kg N ha ⁻¹	97.8	345	5140	106.1	402	4450
SEd	1.3	24	294	1.1	23	141
CD(p=0.05)	3.5	54	578	2.4	49	290

due to higher plant density and absence of transplanting shock (Schnier *et al.*, 1990). Ali *et al.* (2006) reported that panicles per square meter were higher under DSR in clay soil. Sathya (2007) reported that the rice grain yield was maximum at 175 kg/ha and was at par with 150kg/ha. Singh *et al.* (2015) obtained responses up to 120 kg/ha where applied N fertilizer increased grain yield of direct-seeded rice by 62 %. Beyond 120 kg/ha, no increase in grain yield was observed, but its application resulted in more production of rice straw. Ramesh *et al.* (2009) recorded a significantly higher number of tillers /m² with the nitrogen application of 150 kg/ha, which was on par with the results of 125 kg /ha of Pathak *et al.* (2011) reported higher grain yield of dry direct-seeded rice at NPK dose of 120-150 kg N. 60kg P₂ O₅ and 40 kg K₂O /ha along with 25 kg ZnSO₄/ha. The increase in the N level resulted in a reduction in the use efficiency of nitrogen. This might be due to the greater loss of nitrogen at higher doses. This is in line with Thind *et al.* (2018) that was in a rice crop with 130 kg N /h. Seema *et al.* (2014) reported that 125 kg/ha of N caused a significant increase in dry matter production due to higher N availability. Liu *et al.* (2015) reported that DSR recorded comparable grain yield and nutrient use efficiency. The results obtained in the present ex-

periment of increasing yield with increasing N application is in line with reports of direct-seeded rice, which was reported by Nayak *et al.* (2015); Reddy *et al.* (2017); Munda *et al.* (2017) and Ramya *et al.* (2019) in rice crop.

Effect of graded levels of N fertiliser on Soil available nutrients

In the old Cauvery delta soil, regarding post-harvest soil characteristics of 2019-20 experiments of kuruvai and samba showed that increasing dose of nitrogen levels increased the nitrogen content in soil significantly. The higher available nitrogen content of 312 kg/ha, 292 kg/ha was recorded for N application @ 150kg/ha in the kuruvai and samba seasons (Table 3). The result was statistically on par with N application of 125 .kg/ha of 309 kg/ha and 289 kg/ha, respectively, in the kuruvai and samba seasons. But the effect of nitrogen treatments on available P and Zn was not significant. Further, the availability of K decreases with increasing doses of nitrogen might be due to increased uptake of these nutrients. The same trend of results was obtained during the second year also. The soil available nutrient status in the confirmation trial also followed the same trend (Fig. 3)

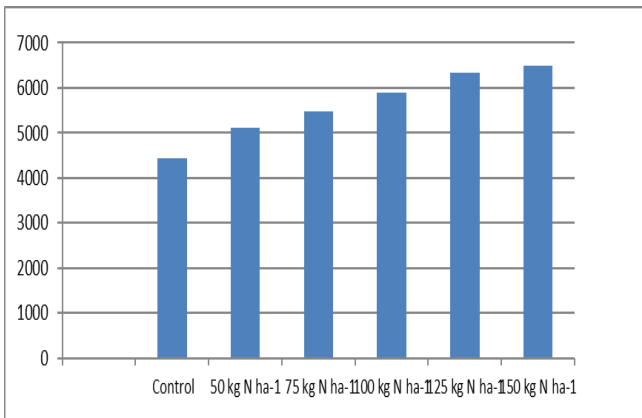


Fig. 1. Effect of nitrogen application on grain yield of rice in old Cauvery delta zone –confirmation trial 2020-21

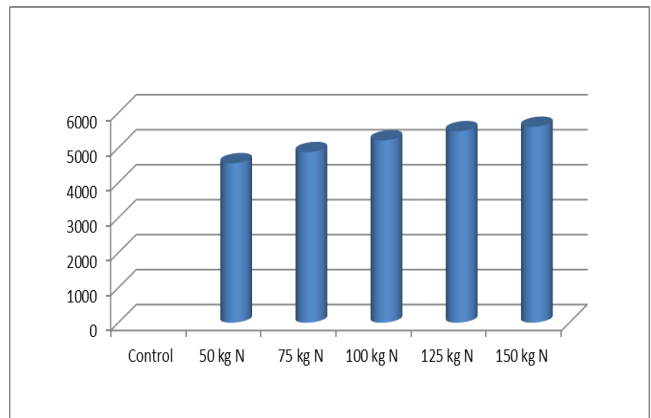


Fig. 2. Effect of nitrogen application on grain yield of rice in new Cauvery delta zone –confirmation trial 2020-21

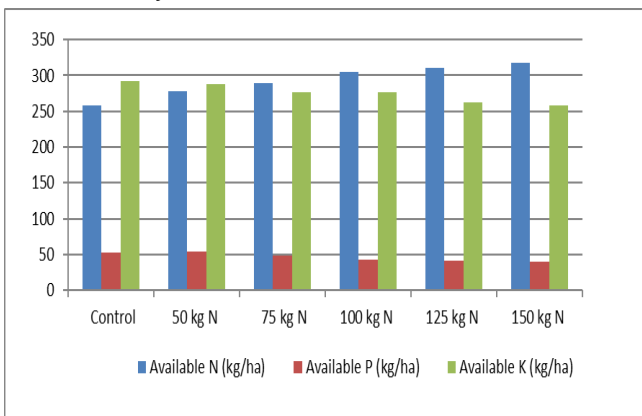


Fig. 3. Effect of nitrogen application on soil properties of rice in old Cauvery delta zone –confirmation trial 2020-21

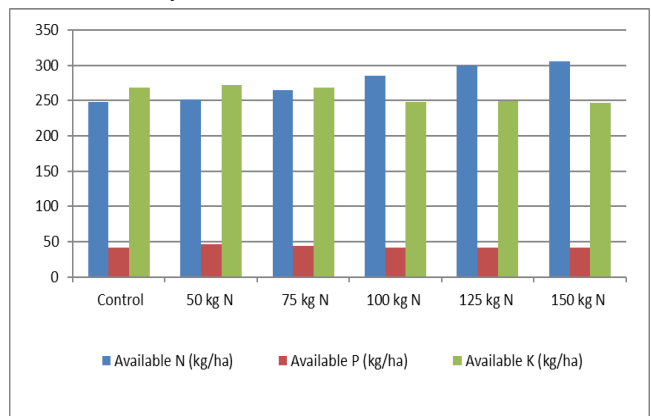


Fig. 4. Effect of nitrogen application on soil properties of rice in new Cauvery delta zone –confirmation trial 2020-21

In the new CDZ, during kuruvai the results revealed the higher available N (267 kg/ha), available P (19 kg/ha) and available K (241 kg/ha) in T6 followed by T5. During samba also the T6 was recorded a higher value of 259 kg/ha, which is on par with T5 (237 kg/ha). With respect to available K, a higher value was recorded in the T6 (215 kg/ha), which was on par with T5 (213 kg/ha). In the confirmation trial also the nitrogen application followed the same trend (Fig. 4). Johnkutty *et al.* (2000) reported that higher nitrogen application would increase the P availability in rice. Linwattana (2001) reported that yield and agronomic parameters of direct-seeded rice gave a better response to N application. Sudhakar *et al.* (2003) reported an increase in soil available NPK from 0 to 120 kg N/ha in Coimbatore.

Effect of graded levels of N fertiliser on pooled mean nutrient uptake of grain

The effect of N application on nutrient uptake of rice grain for pooled data of all the seasons for both the locations showed that the uptake was increased with increasing levels. N application @ 150 kg/ha recorded higher nitrogen nutrient uptake in grain (81.2kg/ha)

(table5) which was on par with T5 (75.9 kg/ha) and T4 (73.1kg/ha). Regarding P uptake, except for control, all Nitrogen application treatments recorded comparable values ranging from 9.23 kg/ha to 11.39 kg/ha. The higher potassium uptake was recorded in the T6 (51.3 kg/ha), which was on par with T5 (46.1 kg/ha), T4 (45.9 kg/ha). The uptake of nutrients by straw also followed the same trend of result: N application @ 150 kg/ha recorded a higher value, which was on par with N @125 kg/ha. Raj *et al.* (2017) reported that higher N levels improved the vegetative foraging capacity of the roots, which in turn increased the NPK uptake in rice crops. Increasing N application stimulated more vegetative growth and increased the foraging capacity of roots, which increased the uptake of phosphorus. Ram-mohanet *et al.* (1999) observed the highest P and K uptake with the application of 150 kg/ha. Increasing dose of N increasing the N uptake was reported by Marlar *et al.* (2007). Sathya *et al.* (2007) reported that agronomic and physiological efficiency was maximum at 150kg N/ha. Singh *et al.* (2015) reported that increasing N application stimulated more vegetative growth and increased the foraging capacity of roots, which

Table 3. Effect of nitrogen application on soil available nutrients of rice in old Cauvery delta zone (2019-20)

Treatments	Kuruvai				Samba			
	N (kg/ha)	P (kg/ha)	K (kg/ha)	Zn (ppm)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Zn (ppm)
T1 : Control	252	62.5	282	0.98	232	58.2	282	0.88
T2 : 50 kg N ha ⁻¹	272	64.2	278	0.95	244	56.5	278	0.86
T3 : 75 kg N ha ⁻¹	283	57.6	267	0.92	253	54.6	274	0.84
T4 : 100 kg N ha ⁻¹	293	52.7	257	0.87	273	52.4	262	0.80
T5 : 125 kg N ha ⁻¹	309	50.6	252	0.82	289	50.5	252	0.80
T6 : 150 kg N ha ⁻¹	312	50.4	248	0.75	292	50.1	245	0.80
SEd	11	08	11	0.12	13	07	12	0.12
CD(p=0.05)	22	NS	19	NS	24	NS	21	NS

Table 4. Effect of nitrogen application on soil available nutrients of rice in new Cauvery delta zone (2019-20)

Treatments	Kuruvai				Samba			
	N (kg/ha)	P (kg/ha)	K (kg/ha)	Zn (ppm)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Zn (ppm)
T1 : Control	190	13	196	0.33	189	18	192	0.43
T2 : 50 kg N ha ⁻¹	226	15	198	0.37	225	19	199	0.45
T3 : 75 kg N ha ⁻¹	248	14	205	0.43	246	18	201	0.45
T4 : 100 kg N ha ⁻¹	236	15	209	0.45	235	19	205	0.49
T5 : 125 kg N ha ⁻¹	247	17	221	0.47	237	20	213	0.48
T6 : 150 kg N ha ⁻¹	258	19	235	0.45	259	20	215	0.49
SEd	09	07	12	0.12	12	1.1	8	NS
CD(p=0.05)	18	NS	19	NS	27	NS	14	NS

Table 5. Effect of nitrogen application on nutrient uptake (kg/ha) of rice in old Cauvery delta zone (2019-20)

Treatments	Grain			Straw		
	Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium
T1 : Control	50.5	6.66	34.6	30.2	7.10	55.0
T2 : 50 kg N ha ⁻¹	60.4	9.23	38.4	33.3	8.20	65.6
T3 : 75 kg N ha ⁻¹	66.3	9.32	41.6	36.2	9.32	69.1
T4 : 100 kg N ha ⁻¹	73.1	9.43	45.9	40.1	10.61	75.5
T5 : 125 kg N ha ⁻¹	75.9	10.39	46.1	39.9	12.02	81.0
T6 : 150 kg N ha ⁻¹	81.2	11.39	51.3	51.3	9.09	81.2
Sed	9.8	1.5	5.8	4.5	2.1	8.2
CD (p=0.05)	18.2	3.2	11.5	9.6	4.1	16.5

Table 6. Application of N for direct seeded rice for old and new Cauvery delta zone :125 kg N/ha

Treatments	Kuruvai 2019	Kuruvai 2020	Pooled mean	NUE	BCR	Samba 2019-20	Samba 2020-21	Pooled mean	NUE	BCR
Old delta-TRRI,Aduthurai,Clay,Kalathur soil series										
125 kg N ha ⁻¹	5326	6326	5826	15.10	1.62	5494	5477	5485	11.36	1.47
150 kg N ha ⁻¹	5596	6496	6046	14.05	1.56	5636	5601	5618	10.35	1.38
SED	142	258	168			148	150	152		
CD(p=0.05)	353	421	325			316	311	315		
New delta -ARS, Thanjavur, Sandy loam, madukkur soil series										
125 kg N ha ⁻¹	4550	4760	4655	13.10	1.22	4270	4862	4566	13.06	1.17
150 kg N ha ⁻¹	5140	5047	5094	13.80	1.21	4450	4782	4616	13.81	1.01
SED	294	318	215			141	153	115		
CD(p=0.05)	578	626	465			290	307	245		

increased the uptake of potassium by rice. Thind *et al.* (2017) reported that nitrogen uptake in grain increased with increasing N rate from 120 to 150 kg/ha.

Effect of graded levels of N fertiliser on the economics of rice

The field experiment conducted on nitrogen application on direct-seeded rice revealed that the BC ratio was higher under N applied @125 kg/ha of 1.62 and 1.47 respectively for old and new Cauvery delta zone. Ye *et al.* (2007) reported that the nitrogen use efficiency under conventional transplanted rice (30-40%) was lesser as compared to direct-seeded rice. Ali *et al.* (2006) reported that the highest benefit-cost ratio of 2.36 was obtained from the dry seeding method followed by the drum seeding. Direct seeded rice required less cost to cultivate as compared to transplanted rice. Higher net return per hectare and B: C ratio was observed under dry direct-seeded rice (2.00) compared with puddled transplanted rice (1.63). The reason might be due to less labour and low irrigation requirement, which contributed to the low cost of cultivation. Moreover, higher farm gate prices of paddy as earlier harvest are the major reasons for this profitability. Singh *et al.* (2015) reported that the maximum BC ratio of 1.59 was ob-

tained from the application of 150 kgN/ha (1.59) followed by 120 kgN/ha (1.54). Younas *et al.* (2021) reported that the total cost of production, net economic benefits per hectare and BCR for direct-seeded rice were Rs. 112047 Rs15014 and 1.11. Kaur and Singh. (2017) reported that, B: C ratio of direct-seeded rice varied from 2.29 to 3.12. Ramya and Pandove (2021) reported that the grass return, net return and BC ratio were higher in the N application of 150 kg/ha followed by 125 kg/ha.

Conclusion

For direct-seeded rice, based on the grain yield and soil available nutrients status, for both in Old and new Cauvery delta zone of Tamil Nadu, Nitrogen application @ 150 kg ha⁻¹ and @125 kg ha⁻¹ during kuruvai and samba seasons showed comparable grain yield. Based on economics, N applied @125 kg/ha recorded a higher BC ratio for direct-seeded rice in the old and new Cauvery delta zone. For the benefit of farmers of both deltaic regions, the nitrogen application of 125 kg ha⁻¹ for direct-seeded rice is recommended in place of the already recommended dose of 150 kg/ha in the crop production guide of Tamil Nadu. The results could save

money by reducing the nitrogen dose without affecting economics and preventing the environment from reducing nitrogen use.

Conflict of interest

The authors declare that they have no conflict of interest.

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