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PLANT SPACING AND INTEGRATED NITROGEN MANAGEMENT EFFECTS ON YIELD AND ECONOMICS OF DIRECT SPOT SEEDED RICE IN COASTAL TAMILNADU, INDIA

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Abstract

Field investigations were formulated at Annamalai University Experimental Farm, Annamalainagar during Thaladi (Sep. to Jan.) and Navarai seasons (Jan. to Apr.) to find out the effect of spacing and integrated nitrogen management on the grain yield and economics of direct spot seeded rice in coastal regions. Different treatments consisting of spacing and integrated use of organic and inorganic fertilization significantly influenced the yield and economics of rice. Among the treatments, the crop raised by adopting 30 × 30 cm spacing along with integrated application of 50 per cent N *via., Albizia lebbeck* green leaf manure and remaining with 50 per cent N *via.,* urea recorded the maximum LAI (5.97), productive tillers m^{-2} (375.23), number of filled grains panicle^{-1} (114.67), grain yield (6954 kg ha^{-1}) and B: C ratio (3.47) for medium duration crop. However for short duration crop, rice planted by adopting 25 × 25 cm spacing along with integrated application of 50 per cent N *via., Albizia lebbeck* and remaining 50 per cent N *via.,* inorganic fertilizer gave higher LAI (5.12), productive tillers m^{-2} (352.87), number of filled grains panicle^{-1} (109.63), grain yield (5962 kg ha^{-1}) and B: C ratio (3.10).

Keywords: green leaf manuring, integrated nutrient management, multipurpose tree species, spot seeded rice.

Introduction

Rice (*Oryza sativa* L.) being one of the staple food for more than half of the world's population. Asia accounts 90 per cent of world's rice growing area and production. Among the rice growing countries in the world, India has the largest area under rice (44.16 m ha) and ranks second in rice production (116.48 m t) which contributing to more than 45 per cent of total food grain production in the country. In Tamil Nadu, rice is cultivated in an area of 1.86 m ha with a production of 7.28 m t. The average rice productivity in India and Tamil Nadu are 2.58 and 3.92 t ha^{-1}, respectively as against 7.03 and 4.56 t ha^{-1} in China and the world productivity, respectively (MAFWDA, 2019; USDA, 2020). Thus greater emphasis has to be given to bridging the yield gap between average existing and potential productivity of rice. Further, ever-growing population and declining trends in productivity of food grains, natural and anthropogenic constraints, *etc.* generate a fear among the scientific community that the country may not be in a position to feed India's future projected populations of 1.7 billion by 2050 AD.

Degraded soils especially saline and poorly drained together with climatic adversities and acute shortage of good quality irrigation water and low fertility soils contribute to low rice productivity in the coastal tracts (Rex Immanuel *et al.*, 2018a; Rex Immanuel and Ganapathy, 2019). In coastal Tamilnadu, there is a severe shortage of water for raising rice nursery and it delayed transplanting, leading to excessive reduction in crop yield. To conquer these difficulties wet spot seeding of rice in puddled soils can be a substitute for sustaining the small and marginal farmer's livelihood (Rex Immanuel *et al.*, 2018c). Wet spot seeded rice starts tillering earlier than transplanted rice because its growth proceeds without the set back caused by uprooting injury to the root of seedlings. Sprouted direct seeding under puddled condition favourably influenced the growth attributes of rice. Direct spot seeding mature 10 to 15 days earlier compared with the same variety grown conventionally. Harvesting sooner reduces crop's total water requirement and possible to include one more crop to enhance the resource use efficiency.

In spot seeded rice plant spacing is one of the import component which effectively utilized the available resources effectively (Rex Immanuel *et al.*, 2019b). Improper spacing reduced yield of rice up to 20-30 per cent while optimum spacing ensures better plant growth through efficient utilization of solar radiation and nutrients (Mohaddesi *et al.*, 2011). Wider spacing facilitated better utilization of resources by the plants that converting majority of the tillers into productive tillers (Sarath and Thilak, 2004). On an average, 94 tillers hill^{-1} were observed at 30 x 30 cm spacing compared to 25 x 25 cm spacing on 80 days after sowing (Narayana Reddy, 2002). Length and weight of panicles, number of panicles hill^{-1} and number of grains panicle^{-1} increased with increased spacing (Mohammad *et al.*, 2004). Zheng *et al.* (2004) observed that adoption of 45 x 45 cm spacing produced more tillers m^{-2}, panicles m^{-2} and higher yield over closer dense plantings. Thin tillers, less number of panicles m^{-2}short panicles with less number of grains were responsible for reduction in grain yield at narrow spacing (Thakur *et al.*, 2006).

Gorgy (2007) indicated that 20 x 20 cm spacing gave the highest panicle weight, number of panicles hill^{-1}, number of filled grains panicle^{-1} and grain yield of rice. He also told that, very closer spacing was undesirable for economic yield, and grain yield increased significantly with every increase in the level of plant density up to a desired level. The seed setting percentage, straw yield and harvest index were also significantly higher in 20 x 20 cm spacing for short and medium duration varieties. It is also observed that plant to plant and row to row spacing had a significant effect on yield and yield attributing characters of direct seeded rice (Sultana *et al.*, 2012). Potential of a cultivar varies with effective utilization of solar radiation, soil moisture and nutritional uptake from the soil and all these depends on selection of appropriate plant spacing. At higher plant population these factors may be deficient while at lower plant population these factors are not well utilized. Increasing plant spacing between and within row increases light penetration in to the crop canopy, which enhance weed growth. In general, optimum plant populations enhanced the yield stability along with optimum economic return.

Green leaf manuring (using the leaves of trees for lowland rice) has been used in South Asia for centuries with yield increases of up to 2 t ha^{-1} compared to unfertilized rice fields. The amount of nutrients contributed varies with plant species and geographic region depending on soil type and management practices. Incorporation of green leaf manures increased the number of filled grains and reduced chaffyness in the panicle due to slow release of solubilizing nutrients from the reserve sources (Meelu and Morris, 1984). The physiological efficiency of rice was more with green manuring alone and it was better than fertilizer and integrated N sources (Aruna, 1999). Addition of tree litter with inorganic fertilizers produced significantly higher rice yield than inorganic fertilizers alone (Hossain *et al.*, 2007).

Pongamia pinnata green leaf manuring substantially increased the number of productive tillers m^{-2}, panicle length and filled grains panicle^{-1} (Balaji, 2012). Green leaf manuring with 50 per cent of the recommended fertilizer gave as high yield as that of full recommended dose (Singh and Bhattacharyya, 1989; Selvi *et al.*, 2005). Integration of GLM with chemical fertilizers significantly influenced the yield attributes and yield compared with suboptimal recommended dose of fertilizers and control (Talathi, 2009). With this background field experiments were conducted to evaluate good agronomic management practice for raising direct sown rice in coastal region of Northern Tamil Nadu.

Materials and Methods

Field investigations were conducted at Annamalai University Experimental Farm, Annamalainagar during Thaladi (Sep. to Jan.) and Navarai (Jan. to Apr) seasons. The study area is located at 11°24′ North latitude, 79°44′ East longitude and at an altitude of +5.79 m above the mean sea level and 10 km away from Bay of Bengal. Thaladi season received a well distributed rainfall of 1121.95 mm spread over 43 rainy days and Navarai season received 127.0 mm distributed over 6 rainy days. The study area also experiences, mean maximum temperature of 31.5°C and mean minimum temperature of 23.4°C with an average relative humidity of 89 per cent during Thaladi season while, the mean maximum temperature of 33°C, mean minimum temperature of 25.8°C and average relative humidity of 85 per cent during Navarai season. According to FAO/UNESOC (1974) the soil of the experimental farm is taxonomically classified as Udic Chromustert (clay). The soil is deep, moderately saline (7.2 and 8.3), EC (0.56 and 5.37 dSm^{-1}), low in organic carbon (0.23 and 0.47 %) and available nitrogen (227 and 213 kg ha^{-1}), medium in available phosphorus (17 and 18.5 kg ha^{-1}) and high in available potassium (346 and 298 kg ha^{-1}) during the first and second experimental season, respectively.

The treatments comprised of four spacing in main plots (M_1: 40 × 40, M_2: 35 × 35, M_3: 30 × 30 and M_4: 25 × 25 cm) and four integrated Nitrogen management in sub plots (S_1: control (RDN), S_2 - 50 % N *via*., *Pongamia pinnata* and 50 % N *via*., urea, S_3: 50 % N *via*., *Albizia lebbeck* and 50 % N *via*., urea and S_4: 50 % N *via*., *Azadirachta indica* and 50 % N *via*., urea). The experiments were laid out in a split plot design with three replications. Rice varieties *viz*., CO 43 (medium duration) and ADT 43 (short duration) were used as test variety for Thaladi and Navarai season, respectively.

Green leaf manure yielding multipurpose trees such as *Azadirachta indica*, *Albizia lebbeck and Pongamia pinnata* were used for the study. The green foliage was obtained from the trees grown on the field bunds of the Experimental Farm and incorporated in the individual plots as per the treatment schedule before puddling (15 DBS). As per the Tamil Nadu state government fertilizer recommendation (medium duration crop – 150 : 50 : 50 and short duration – 120 : 38 : 38 N, P_2O_5 and K_2O kg ha^{-1}, respectively) the required quantity of inorganic fertilizers worked out and applied in the form of urea, single super phosphate and muriate of potash. Nitrogen inorganic fertilizer was applied at three splits *viz*., 20 per cent at the appearance of 2nd tiller, 40 per cent at maximum tillering and 40 per cent at panicle initiation stage, while the entire doses of phosphorus and potassium were applied at 15 DAS.

Table 1 : C: N ratio and nutrient content of GLM (%)

Green leaf manure	C: N ratio	N	P_2O_5	K_2O
Azadirachta indica	12.6	0.68	0.15	0.31
Albizia lebbeck	11.8	0.74	0.12	0.46
Pongamia pinnata	13.2	0.59	0.09	0.38

The seed rate used for treatments M_1, M_2, M_3 and M_4 were 12, 9, 6 and 5 kg ha^{-1}, respectively for Thaladi season (CO 43) and 7.5, 5, 4 and 3 kg ha^{-1}, respectively for Navarai season (ADT 43). The seeds were soaked in water for 24 hours and incubated in dark room for 24 hours. Sprouted seeds were carefully spot sown @ 3 seeds per hole in the field with a thin film of standing water as per the treatment schedule. Depending on weather conditions plots were kept under a non-saturated condition during the vegetative phase (alternate wetting and drying method - application of 2 cm depth of water after the formation of hairline crack) was followed. Irrigation was withheld 12 days before harvest. Three series of weeding were done with a mechanical rotary weeder (cono weeder) on 15 DAS followed by 14 days interval. Need based plant protection measures were carried out based on the economic threshold level of insect pests and diseases.

The LAI was worked out as out lined by Palaniswamy and Gomez (1974). The number of productive tillers m^{-2} was counted by plot wise. The grain from the sample panicles were differentiated in to filled grain and chaffs by gently pressing with fingers and counted separately. 1000 well filled grains were counted at 14 per cent moisture content. Grain yield from each net plot was cleaned, sun dried and weighed at 14 per cent moisture content and the grain yield was expressed in kg ha^{-1}. The percentage of harvest index was calculated by using the following formula suggested by

Varma (1973). Benefit-cost ratio was calculated based on gross returns and cost of cultivation. The data on various parameters studied during the investigation was statistically analyzed as per the procedures suggested by Gomez and Gomez (1984) for split plot design. The critical differences were also worked out at 5 per cent probability level for comparison.

Results

The plant spacing's caused considerable variations in LAI at maximum tillering stage (Table 2). The treatment M_2 (30 × 30 cm spacing) recorded the maximum LAI of 5.26 during Thaladi season, while the treatment M_1 (25 × 25 cm spacing) registered the maximum LAI of 4.37 during Navarai season. The difference in LAI values due to the addition of green leaf manuring was significant at maximum tillering stage of the crop. The highest LAI values were observed in 50 per cent N *via., Albizia lebbeck* along with 50 per cent N *via.,* inorganic fertilizer (S_3) which registered 5.25 and 4.35 during Thaladi and Navarai seasons, respectively. The interaction effect between the spacing's adopted and green leaf manuring was found to be significant. The treatment combination, M_2S_3 (30 × 30 cm along with 50% N *via., Albizia lebbeck* and 50 % N *via.,* inorganic fertilizer) registered the maximum LAI of 5.97 during Thaladi season. During Navarai season, the treatment combination M_1S_3 (25 × 25 cm spacing along with application of 50% N *via., Albizia lebbeck* and 50 % N *via.,* inorganic fertilizer) recorded the maximum LAI of 5.12.

Table 2 : Effect of spacing and INM on leaf area index (LAI) at flowering stage

Treatments	Thaladi (CO 43)					Navarai (ADT 43)				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	4.13	4.28	3.63	2.79	3.71	3.34	3.32	3.07	2.74	3.12
S_2	5.20	5.62	4.72	4.68	5.06	4.85	4.36	3.84	3.64	4.17
S_3	5.60	5.97	4.73	4.70	5.25	5.12	4.70	3.86	3.72	4.35
S_4	5.17	5.15	4.70	4.67	4.92	4.16	4.24	3.65	3.56	3.90
Mean	5.03	5.26	4.45	4.21		4.37	4.16	3.61	3.42	

	Thaladi S. Ed	Thaladi CD (0.05)	Navarai S. Ed	Navarai CD (0.05)
M	0.10	0.21	0.09	0.18
S	0.05	0.11	0.07	0.15
MS	0.17	0.34	0.11	0.21

Yield attributes

Among the spacing's adopted, the treatment M_2 (30 × 30 cm spacing) recorded the higher productive tillers of 305.99 m^{-2} during Thaladi and the treatment M_1 (25 × 25 cm spacing) recorded the higher number of productive tillers of 283.76 m^2 during Navarai season. Among the different integrated N management treatments, maximum productive tillers m^{-2} was recorded in 50 per cent N *via., Albizia lebbeck* along with 50 per cent N *via.,* inorganic fertilizer (S_3) treatment which recorded 298.91 and 276.87 tillers m^{-2} during Thaladi and Navarai seasons, respectively. The interaction effect between the spatial arrangements and integrated N management were found to be significant. Among the treatment combinations, 30 × 30 cm along with 50 per cent N *via., Albizia lebbeck* and 50 per cent N *via.,* inorganic fertilizer (M_2S_3) during Thaladi season and 25 × 25 cm spacing along with application of 50 per cent N *via., Albizia lebbeck* and 50 per cent N *via.,* inorganic fertilizer (M_1S_3) during Navarai season recorded more number of productive tillers m^{-2} which recorded a value of 375.23 and 352.87, respectively.

Table 3 : Effect of spacing and INM on number of productive tillers (m^2)

Treatments	Thaladi (CO 43)					Navarai (ADT 43)				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	187.23	191.77	186.28	156.65	180.48	173.60	165.24	148.57	128.15	153.89
S_2	331.62	358.72	238.15	209.43	284.48	331.56	304.60	212.15	198.00	261.58
S_3	349.53	375.23	241.34	229.53	298.91	352.87	326.45	218.64	209.53	276.87
S_4	330.70	298.23	218.97	206.47	263.59	276.99	297.65	201.06	192.54	242.06
Mean	299.77	305.99	221.19	200.52		283.76	273.49	195.11	182.06	

	Thaladi S. Ed	Thaladi CD (0.05)	Navarai S. Ed	Navarai CD (0.05)
M	4.09	8.19	4.55	9.13
S	0.59	11.85	5.80	11.64
MS	3.10	6.21	6.81	13.65

The treatment M_4 (40 × 40 cm spacing) recorded the maximum number of filled grains panicle^{-1} (106.14 and 101.70) during Thaladi and Navarai seasons, respectively. More number of filled grains panicle^{-1} was registered in S_3 treatment (50% N *via., Albizia lebbeck* along with 50 % N *via.,* inorganic fertilizer) which recorded a filled grains values of 107.43 and 100.46 panicle^{-1} during Thaladi and Navarai seasons, respectively. Among the various combinations, treatment M_4S_3 (crop raised by adopting 40 × 40 cm spacing along with 50% N *via., Albizia lebbeck* and 50 % N *via.,* inorganic fertilizer) recorded the higher number of filled grains panicle^{-1} of 114.67 during Thaladi season whereas during Navarai the treatment M_4S_3 (40 × 40 cm spacing along with application of 50% N *via., Albizia* *lebbeck* and 50 % N *via.,* inorganic fertilizer) registered the maximum number of filled grains panicle^{-1} of 109.63. The different spatial arrangements adopted under different integrated N management techniques had no significant influence on the thousand grain weight of rice

Table 4 : Effect of spacing and INM on number of filled grains panicle^{-1}

Treatments	Thaladi (CO 43)					Navarai (ADT 43)				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	89.24	84.88	92.76	95.20	90.52	77.12	82.36	86.45	91.34	84.32
S_2	100.57	103.76	105.36	109.00	104.67	96.12	94.46	98.54	103.15	98.07
S_3	102.55	104.15	108.35	114.67	107.43	95.15	96.53	100.54	109.63	100.46
S_4	99.00	101.20	107.24	105.67	103.28	95.12	92.57	94.86	102.67	96.31
Mean	97.84	98.50	103.43	106.14		90.88	91.48	95.10	101.70	
	S. Ed		CD (0.05)			S. Ed		CD (0.05)		
M	1.27		2.56			1.50		3.01		
S	0.62		1.24			0.68		1.36		
MS	1.55		3.10			0.96		1.95		

Table 5 : Effect of spacing and INM on thousand grain weight (g)

Treatments	Thaladi (CO 43)					Navarai (ADT 43)				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	19.38	19.38	19.40	19.41	19.39	15.05	15.12	15.16	15.19	15.13
S_2	19.50	20.01	20.13	20.31	19.99	15.21	15.18	15.26	15.31	15.24
S_3	19.51	20.05	20.15	20.51	20.06	15.23	15.35	15.36	15.46	15.35
S_4	19.43	19.76	20.10	20.26	19.89	15.25	15.23	15.15	15.25	15.22
Mean	19.46	19.80	19.95	20.12		15.19	15.22	15.23	15.30	
	S. Ed		CD (0.05)			S. Ed		CD (0.05)		
M	0.17		NS			0.15		NS		
S	0.29		NS			0.17		NS		
MS	0.19		NS			0.15		NS		

Yield and Harvest index

The plant spacing's exert marked variation on the grain yield of rice. The treatment M_2 (30 × 30 cm spacing) recorded the highest grain yield of 5328 kg ha^{-1} during Thaladi season. Certainly the treatment M_1 (25 × 25 cm spacing) registered the maximum grain yield of 4490 kg ha^{-1} during Navarai season. The highest grain yield was observed in 50 per cent N *via., Albizia lebbeck* along with 50 per cent N *via.,* inorganic fertilizer (S_3) treatment. It registered the maximum grain yield of 5398 and 4597 kg ha^{-1} during Thaladi and Navarai seasons, respectively. During Thaladi, the treatment 30 × 30 cm spacing along with 50 per cent N *via., Albizia lebbeck* and 50 per cent N *via.,* inorganic fertilizer (M_2S_3) registered the highest grain yield of 6954 kg ha^{-1} whereas, during Navarai, adoption of 25 × 25 cm spacing along with application of 50 per cent N *via., Albizia lebbeck* and 50 per cent N *via.,* inorganic fertilizer (M_1S_3) recorded the maximum grain yield of 5962 kg ha^{-1}.

Table 6 : Effect of spacing and INM on grain yield (kg ha^{-1})

Treatments	Thaladi (CO 43)					Navarai (ADT 43)				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	2846	2906	2306	1786	2461	2395	2268	1804	1358	1956
S_2	5444	6404	4254	3948	5013	5285	4722	3654	3273	4234
S_3	6189	6954	4327	4122	5398	5962	5137	3825	3462	4597
S_4	5321	5048	4018	3850	4559	4317	4665	3348	2930	3815
Mean	4950	5328	3726	3427		4490	4198	3158	2756	
	S. Ed		CD (0.05)			S. Ed		CD (0.05)		
M	156		312			141		282		
S	188		376			117		335		
MS	257		516			214		428		

The treatment M_2 (30 × 30 cm spacing) registered the higher straw yield of 7394 kg ha^{-1} during Thaladi season, while the treatment M_1 (25 × 25 cm spacing) recorded a higher straw yield of 6067 kg ha^{-1} during Navarai season. Among the integrated N management treatments, the treatment S_3 (50% N *via., Albizia lebbeck* along with 50 % N *via.,* inorganic fertilizer) recorded the maximum straw yield of 7516 and 6258 kg ha^{-1} during Thaladi and Navarai seasons, respectively. The treatment combinations M_2S_3 (30 × 30 cm spacing along with application of 50% N *via., Albizia lebbeck* and 50 % N *via.,* inorganic fertilizer) observed a higher straw yield of 8883 kg ha^{-1} during Thaladi season. While the treatment M_1S_3 (25 × 25 cm spacing along with application of 50% N *via., Albizia lebbeck* and 50 % N *via.,* inorganic fertilizer) registered the highest straw yield of 7489 kg ha^{-1} during Navarai season.

Table 7 : Effect of spacing and INM on straw yield (kg ha^{-1})

Treatments	Thaladi (CO 43)					Navarai (ADT 43)				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	5002	5065	4454	3628	4537	3742	3467	2935	2453	3149
S_2	7688	8349	6521	6390	7237	7062	6502	5378	4817	5940
S_3	8224	8883	6531	6426	7516	7489	6921	5529	5095	6258
S_4	7664	7280	6410	6253	6902	5976	6237	4928	4513	5413
Mean	7144	7394	5979	5674		6067	5782	4692	4220	

	S. Ed	CD (0.05)	S. Ed	CD (0.05)
M	118	238	122	245
S	135	270	145	290
MS	258	518	205	412

The highest harvest index value was recorded in 30 × 30 cm spacing treatment (M_2) during Thaladi season (41.11%), while in Navarai season, 25 × 25 cm spacing treatment (M_1) registered the higher harvest index value of 41.77 per cent. With regard to the integrated N management treatments, the significantly higher harvest index values was observed in application of 50 per cent N *via., Albizia lebbeck* along with 50 per cent N *via.,* inorganic fertilizer (S_3) treatment by registering values of 41.44 and 42.07 per cent during Thaladi and Navarai seasons, respectively). The treatment combinations of 30 × 30 cm spacing along with application of 50 per cent N *via., Albizia lebbeck* and 50 per cent N *via.,* inorganic fertilizer (M_2S_3) during Thaladi season and 25 × 25 cm spacing along with application of 50 per cent N *via., Albizia lebbeck* and remaining 50 per cent N *via.,* inorganic fertilizer (M_1S_3) during Navarai season registered the maximum harvest index values of 43.91 and 44.32 per cent, respectively.

Table 8 : Effect of spacing and INM on harvest index of rice

Treatments	Thaladi (CO 43)					Navarai (ADT 43)				
	M_1	M_2	M_3	M_4	Mean	M_1	M_2	M_3	M_4	Mean
S_1	36.27	36.46	34.11	32.99	34.95	38.02	37.55	36.06	35.63	36.82
S_2	41.46	43.12	39.48	38.19	40.56	42.80	42.07	40.46	40.45	41.45
S_3	42.94	43.91	39.85	39.08	41.44	44.32	42.61	40.89	40.45	42.07
S_4	40.98	40.95	38.53	38.11	39.64	41.94	41.19	40.45	39.36	40.74
Mean	40.41	41.11	37.99	37.09		41.77	40.86	39.47	38.97	

	S. Ed	CD (0.05)	S. Ed	CD (0.05)
M	0.24	0.48	0.26	0.53
S	0.27	0.54	0.29	0.59
MS	0.36	0.75	0.28	0.56

The highest B: C ratio was obtained from treatment M_2S_3 (30 × 30 cm spacing along with application of 50% N *via., Albizia lebbeck* and 50 per cent N *via.,* inorganic fertilizer) for Thaladi season (3.47) and M_1S_3 (25 × 25 cm spacing along with incorporation of 50% N *via., Albizia lebbeck* and 50 % N *via.,* inorganic fertilizer) for Navarai season (3.10).

Table 9 : Economics of wet spot seeded rice cultivation

Thaladi (CO 43)				Navarai (ADT 43)			
Treatments	BCR	Treatments	BCR	Treatments	BCR	Treatments	BCR
M_1S_1	1.71	M_3S_1	1.41	M_1S_1	1.51	M_3S_1	1.15
M_1S_2	2.66	M_3S_2	2.10	M_1S_2	2.77	M_3S_2	1.94
M_1S_3	3.10	M_3S_3	2.20	M_1S_3	3.10	M_3S_3	2.02
M_1S_4	2.69	M_3S_4	2.05	M_1S_4	2.27	M_3S_4	1.77
M_2S_1	1.75	M_4S_1	1.10	M_2S_1	1.43	M_4S_1	0.87
M_2S_2	3.10	M_4S_2	1.96	M_2S_2	2.48	M_4S_2	1.73
M_2S_3	3.47	M_4S_3	2.11	M_2S_3	2.69	M_4S_3	1.83
M_2S_4	2.55	M_4S_4	1.97	M_2S_4	2.44	M_4S_4	1.56

Discussion

LAI

Optimum spacing offered the plants to achieve the maximum architecture for the effective utilization of available resources *viz.,* light, water and nutrients without competition. While the application of nitrogen, an essential element for plant growth as an organic (50% N *via., Albizia lebbeck* GLM) and inorganic form (50% N at three splits through urea) could ascribed to the higher urea hydrolysis which might have released more NH_4-N into soil solution and this combination continuously increased the balanced availability of nutrients throughout the crop growth period in the rhizosphere for crop utilization which contributed favorably for enhanced the leaf area index (LAI). The sustained and enhanced availability of space, light and both native and applied nutrients till the maturity that would have enhanced better source-sink relationship which contributed to growth of healthy plant. In rice, increased plant growth parameters and DMP due to optimum spacing, GLM and split application of nitrogen was reported by Selvi and Kalpana (2009), Coumaravel *et al.* (2012), Rex Immanuel *et al.* (2018b) and Rex Immanuel *et al.* (2018c).

Yield

The entire yield attributed components were favorably altered by different spatial arrangement and integrated nutrient management. Among the yield parameters, productive tillers m^{-2} were significantly influenced by spot seeding of rice at 30 x 30 cm (M_2) for Thaladi and 25 x 25 cm (M_1) spacing for Navarai season.

Closer planting configuration (30 x 30 cm and 25 x 25 cm for medium duration and short duration rice, respectively) resulting in increased population stand (16 and 11 hills m^{-2} for medium duration and short duration rice, respectively), which laid down the foundation of higher number of productive tillers m^{-2}. The contribution of closer spacing for higher productive tillers m^{-2} was strongly supported by Islam *et al.* (1994) Salahuddin *et al.* (2009). However, adoption of 40 × 40 cm (M_4) for both the Thaladi and Navarai seasons registered the maximum number of filled grains panicle^{-1}. The plant grown with wider spacing have more area of land around them to draw the nutrition and had more solar radiation to absorb for better photosynthetic process and hence performed higher number of filled grains panicle^{-1}. These findings are in conformity with the observations of Baloch *et al.* (2002).

In general, there is an optimum spacing for any cultivated rice variety and at any environmental condition, and it can be planted at distances ranging from 10x10 cm to 40 x 40 cm without any significant change in yield, provided other cultural practices are ideal (Robert, 1969). Depending upon resource availability (mainly irrigation water) the farmers chose medium or short duration rice variety. Based on the resource availability, CO 43 (medium) and ADT 43 (short duration) varieties were used as test variety in Thaladi and Navarai seasons, respectively. During Thaladi season (Sep. – Jan.) the availability of solar radiation was low due to the North – East monsoon while, Navarai season received considerable amount of light. In Thaladi season optimum spacing *i.e.* 30 x 30 cm was needed to acquire better light to saturate the entire leaves whereas, 25 x 25 cm spacing was enough to attaining the light at saturated level. This optimum level of spacing efficiently utilized both light at canopy level and nutrients at rhizosphere level and translocate photosynthates from source to sink which in turn reflected in higher yield characters and yield.

Contrastingly, the higher grain and straw yield were registered by adoption of 30 × 30 cm, for Thaladi and 25 × 25 cm for Navarai rice. The reason for deviation of this linearity in case of grain and straw yield is that the yield does not entirely depends upon the performance of individual plant grain number but also on the total number of plants per unit area and other yield contributing parameters with in the field. Similar findings were also reported by Baloch *et al.* (2002) who reported that an increase in spacing induced vigorous plant growth as well as increased the number of panicle hill^{-1}, grain yield hill^{-1}, filled grains panicle^{-1} and 1000 grain weight but the spacing 22.5 × 22.5 cm proved more appropriate because it produced better plant stand, gave more panicle density and higher grain yield than other two spacing (20 × 20 cm and 25 × 25 cm). Straw yield and harvest index also exhibited similar trend due to efficient translocation of assimilates to the sink. Similar yield increases due to optimum plant population have also been reported by Krishna *et al.* (2008), Gorgy (2010), Uddin, (2011), Rex Immanuel *et al.* (2019a) and Rex Immanuel *et al.* (2019b).

Economics

The highest B: C ratio was obtained in the treatment combination M_2S_3 (30 × 30 cm spacing along with application of 50 % N *via., Albizzia lebbeck* and 50 % N *via.,* inorganic fertilizer) for Navarai season. In Thaladi season, treatment M_1S_3 (25 × 25 cm spacing along with application of 50% N *via., Albizzia lebbeck* and 50 % N *via.,* inorganic fertilizer) acquired the maximum economic advantages. This is due to the synergistic and cumulative effect of treatments followed. The adoption of proper spacing with N substitution by *Albizia lebbeck* GLM considerably reduced the cost of external inputs, minimizes the labour requirement, effectively utilized the available resources and enhanced the economic produce which ultimately obtained the higher B: C ratio.

Conclusion

For sustainability in crop production integrated use of technologies has been observed to be highly beneficial. Accordingly, wet spot seeding of rice by adopting the spacing of 30 × 30 cm for medium duration rice and 25 × 25 cm spacing for short duration rice and integrated application of 50 per cent N *via., Albizia lebbeck* green leaf manure and remaining 50 per cent N *via.,* urea fertilizer resulted maximum yield and higher B: C ratio.

References

Aruna, L.; Selvakumar, G. and Mohan, R. (1999). Nitrogen release pattern of green manures in sodic soil. Madras Agric. J. 86(7-9): 356-359.

Balaji, K. (2012). Nitrogen mineralization pattern of green leaf manures in flooded rice ecosystem. Unpub. Proj. Rep., Dept. Agro., Annamalai University, Annamalai Nagar, India.

Baloch, A.W.; Soomro, A.M.; Javed, M.A.; Ahmed, M.; Bughio, H.R.; Bughio, M.S. and Mastol, N.N. (2003). Optimum plant density for high yield in Rice (*Oryza sativa* L.). Asian J. Plant Sci., 1(1): 25-27.

Coumaravel, K.; Baskar, A. and Sankar, R. (2012). Effect of different N levels and green leaf manure application on the yield of rice and mineral N content of the soil. Int. Sym. 100 years of Rice Science and Looking Beyond, Jan. 9-12.

Gomez, K.A. and Gomez, A.A. (1984). Statistical procedure for agricultural research (II Ed.) John Wiley and Sons, New York. Pp.680.

Gorgy, R.N. (2007). Performance of hybrid and inbred rice cultivars under different planting geometry and number of seedlings per hill. J. Agric. Sci. Mansoura Univ., 32(1): 117-131.

Gorgy, R.N. (2010). Effect of transplanting spacings and nitrogen levels on growth, yield and nitrogen use efficiency of some promising rice varieties. J. Agric. Res., 36(2): 123-144.

Hossain, K.L.; Wadud, M.A. and Santosa, E. (2007). Effect of tree litter application on lowland rice yield in Bangladesh. Bul. Agron. 35(3): 149–153.

Islam, M.S.; Sarkar, M.A.R.; Rahman, M.S.; Musa, A.I.M. and Dhan, S.C. (1994). Effect of plant population density on transplant aus rice under tidally flooded conditions. Bangaladesh J. Agril. Sci., 21 (2): 349-353.

Krishna, A.; Biradarpatil, N.K.; Manjappa, K. and Channappagoudar, B.B. (2008). Evaluation of system of rice intensification cultivation, seedling age and spacing on seed yield and quality in samba Masuhri (BPT-5204) rice. Karnataka J. Agric. Sci., 21 (1): 20-25.

MAFWDA, (2019). Agricultural Statistics at a Glance 2018. Ministry of Agriculture & Farmers Welfare Department of Agriculture, Cooperation & Farmers Welfare Directorate of Economics and Statistics, Government of India.

Meelu, O.P. and Morris, R.A. (1984). Integrated management of plant nutrient in rice and rice based cropping systems. Fertilizer News, 29: 65-69.

Mohaddesi, A.; Abbasian, A.; Bakhshipour, S. and Aminpanah, H. (2011). Effect of different levels of nitrogen and plant spacing on yield, yield components and physiological indices in high yield rice. Amer-Eur. J Agric Environ. 10(5): 893-900.

Mohammad, A.; Khan, M.A.; Khan, E.A. and Ramzan, M. (2004). Effect of increased plant density and fertilizer dose on the yield of rice variety IR-6. J. Res. Sci., 15(1): 09-16.

Narayana, R.L. (2002).SRI method of paddy cultivation. Leisa India, 11: 28-29.

Palanisamy, K.H. and Gomez, K.A. (1974). Length-width method for estimating leaf area of rice. Agron. J., 66: 430-433.

Rex Immanuel, R. and Ganapathy, M. (2019). Characterization of degraded lands in coastal agro ecosystem of northern Tamilnadu, India. Journal of Emerging Technologies and Innovative Research, 6(2): 200-216.

Rex Immanuel, R.; Ganapathy, M. and Thiruppathi, M. (2018a). Perception analysis of coastal agro ecosystem degradation, its effect on agricultural production and the performance of multipurpose tree species. The Research Journal of Social Sciences, 9(12): 122-135.

Rex Immanuel, R.; Thirupathi, M.; Sriman Narayanan, J. and Sanjai Gandhi, S. (2018b). Plant growth and physiological dynamics of wet spot seeded rice (*Oryza sativa* L.) as influenced by agroforestry based green leaf manures. Journal of Emerging Technologies and Innovative Research, 5(10): 183-188.

Rex Immanuel, R.; Thirupathi, M. and Sanjai Gandhi, S. (2018c). Planting Geometry of Wet Spot Seeded Rice (Oryza sativa L.). International Journal of Research and Analytical Reviews, 5(4): i414 – i419.

Rex Immanuel, R.; Thiruppathi, M.; Saravanaperumal, M.; Murugan, G. and Sudhagar Rao, G.B. (2019a). Impact of crop geometry and integrated nutrient management on NPK uptake and nitrogen use efficiency of rice. Journal of Emerging Technologies and Innovative Research. 6(4): 598-602

Rex Immanuel, R.; Sanjai Gandhi, S.; Thiruppathi, M.; Sriman Narayanan, J.; Saravanaperumal, M.; Sudhagar Rao, G.B. and Murugan, G. (2019b). Post-harvest soil health of wetland rice ecosystem as influenced by spatial arrangements and integrated nutrient management. Journal of Pharmacognosy and Phytochemistry, 8(3): 815-818

Salahuddin, K.M.; Chowhdury, S.H.; Munira, S.; Islam, M.M. and Parvin, S. (2009). Response of nitrogen and plant spacing of transplanted aman rice. Bangaladesh J. Agril. Res., 34(2): 279-285.

Sarath, P.N. and Thilak, B. (2004). Comparison of productivity of System of Rice Intensification and Conventional rice farming system in the Dry-zone Region of Sri Lanka. 4th Int. Crop Sci. Con., http://www.regional. Org. aulau/cs/2004.

Selvi, R.V. and Kalpana, R. (2009). Potentials of green manure in integrated nutrient management for rice – a review. Agric. Rev., 30(1): 40-47.

Selvi, R.V.; Nadanassababadyl, T. and Rajendran, P. (2005). Green manuring in lowland rice –a review. Agric. Rev., 26 (1): 14–26.

Singh, K.N. and Bhattacharyya, H.E. (1989). Direct-seeded rice. Mohan Primlani for Oxford and IBH Pub. Co. Pvt. Ltd. New Delhi. 135-142.

Sultana, M.R.; Rahman, M.M.; Rahman, M.H. (2012). Effect of row and hill spacing on the yield performance of boro rice (cv. BRRI dhan45) under aerobic system of cultivation. J Bangladesh Agril. Univ. 10(1): 39-42.

Talathi, M.S.; Pinjari, S.S.; Ranshur, N.J.; Bhondaveand, T.S. and Suryawanshi, J.S. (2009). Response of hybrid rice (*Oryza sativa* L.) to green leaf manure, FYM and chemical fertilizers. Int. J. Agri. Sci., 5(2): 501-506.

Thakur, A.K.; Chaudhari, S.K.; Singh, R. and Kumar, A. (2006). Performance of rice varieties at different spacing grown by the system of rice intensification in eastern India. Indian J. Agri. Sci., 79(6): 443-447.

Uddin, M.J.; Ahmed, S.; Rashid, M.H.; Hasan, M.M. and Asaduzzaman, M. (2011). Effect of spacings on the yield and yield attributes of transplanted Aman rice cultivars in medium lowland ecosystem of Bangladesh. J. Agric. Res., 49(4): 465– 476.

USDA, (2020). World Agricultural Production. [https://apps.fas.usda.gov/psdonline/circulars/ production.pdf]

Varma, S.C. (1973). Agronomy of new plant types. Tate publications. Varanasi, p.128.

Zheng, J.; Xianjun, L.; Xilnlu, J. and Tang, Y. (2004). The system of rice intensification for super high yields of rice in Sicuan basin. J. South China Agricultural University, 26: 10-12.