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Technologies to enhance the productivity and profitability in mechanised semi dry rice cultivation

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Abstract
Experiments was conducted during dry season at Agricultural Engineering College and Research Institute (TNAU), Kumulur in split plot design with three replication using ADT 49 (Medium duration) rice variety with the objectives to find out alternate method of sowing to overcome the labour scarcity in dry condition, to find out better spacing and crop geometry under mechanised sowing in dry condition and to study the effect of water level and seed rate on productivity under semi dry condition. The main plot treatment consisted of four levels of irrigation *viz.* Irrigation at critical stages up to 45 DAS (PI) and submergence of 2.5 cm(I_1), Supplemental irrigation through Alternate Wetting and Drying (AWD) from 45 DAS (PI) up to harvest(I_2), Continuous submergence of 2.5 cm (Farmers practices under wet condition)(I_3) and Farmers practices (Farmers practices under dry condition).The sub plot treatment consisted of four levels of crop geometry with different levels of seed rate viz., Mechanised sowing @ 30 kg/ha (22.5x10 cm)(S_1), Mechanised sowing 40 kg/ha (25 x15 cm)(S_2), Mechanised sowing 50 kg/ha(25 x 8 cm) (S_3) and Broad casting @ 75 kg/ha (S_4). The experiment results showed that mechanised sowing of seed @ 40kg ha^{-1}(25x 15 cm) by multi crop planter under dry condition along with supplemental irrigation through Alternate wetting and drying (AWD) method of irrigation had recorded highest establishment percentage, optimum number of productive tillers, highest number of grains per panicle, highest grain yield (7.91 t ha^{-1}), net income (71,746 Rs ha^{-1}), BCR (3.56) and highest water use efficiency (0.60 kg ha^{-1} mm^{-1}) and net changes in income of Rs. 60,574 ha^{-1} when compare to farmers practices under semi dry rice cultivation.

Keywords: Mechanization, semi dry rice cultivation, alternate wetting and drying (AWD), partial budgeting

Introduction
Rice is the important food crop of India covering about one-fourth of the total cropped area and providing food to about half of the Indian population. Rice needs plenty of heat, plenty of water, plenty of alluvium and plenty of labour to provide plenty of food for ever increasing population. The demand for human activity in agriculture at a particular moment depends in the first place on the growing season, the type of crop and its development stage. The timing of the crop growing season is in most cases determined by temperature and/or water availability. The method of cultivation of rice in a particular region depends largely on factors such as type of land, type of soils, irrigation facilities, and availability of labourer, intensity and distribution of rainfall. Considerable proportion of the total labour use in all agricultural operations is associated with the rice cultivation. Indeed, rice was considered one of the most labour-intensive crops. But the mechanization process has reduced the labour intensity in rice cultivation. Agriculture mechanization is the application of mechanical technology and increased power to agriculture, largely as a means to enhance the productivity of human labour and often to achieve results well beyond the capacity of human labour. The farm mechanization helps in effective utilization of inputs to increase the productivity of land and labour. Besides it helps in reducing the hard work in farm operations.
The trend over the last 10 years indicates that the rice production is facing many constraints such as untimely release and non availability of water for the dry season, uncertainity in rainfall, increase in labour cost coupled with poor efficiency of labour, increase in cost of inputs and declining of soil fertility, leading to decrease in profitability for the farmers in rice cultivation. Recent changes in rice production technology have improved the desirability towards direct-seeding methods and there has been a rapid shift to the direct-seeding method of rice establishment in Southeast Asia.

Rice can be cultivated by different methods based on the type of region. The principal rice ecosystems followed in southern states of India are Wet system, Dry system and Semi dry system. In Dry Direct Seeded Rice (D-DSR), seeds can be sown before the start of the wet season, permitting the use of early rains for crop establishment or up to 30 days after onset of rains for upland rice. After emergence, rice plants grow in upland (aerobic) conditions until harvest (upland rice) or with accumulated standing water in the field for a significant part of the crop cycle in rainfed low lands. Dry sown rice converted to flooded paddy 30 -40 DAS is called Semi dry rice in Tamil Nadu, India (Balasubramanian and Hill, 2002.) [1]

Rice crop is strongly influenced by water supply, it is a semi - aquatic plant requires near submergence. Water should be kept standing in the field throughout the growth period. Total water requirement of rice is 1200 - 1400 mm, maintenance of water depths in field as recommended for high water use efficiency and yield. Tillering, panicle initiation, boot leaf stage, heading/ panicle emergence and Flowering/anthesis (Reproductive phase) are critical crop growth stages for water stress, during these stages, soil moisture level should be maintained at saturation level. Moisture stress at active tillering phase causes 30% yield reduction and moisture stress at reproductive phase causes 50 - 60% yield reduction. Moisture stress during rooting and tillering stage causes poor root growth leading to poor crop establishment and low yield. Precise water management is also a critical factor for high productivity for both dry- and wet-seeded rice. Therefore, a key concern is how the water requirement of rice culture can be reduced and how farmers can avoid puddling and transplanting operations without yield penalty. Greater understanding is required about the maintenance of the population and their feeding zone, effect of weed pressure and supplementation of soil moisture through irrigation to enhance the production is important to develop management strategies for direct-sown rice in the Tropics. With this background, research was conducted at AEC&RI, Kumulur for a period of three years (2014-2016) by changing crop geometry and seed rate by machine sowing and supplementation of water under mechanised direct sown rice to enhance the production, profitability and water use efficiency of rice under semidry condition. The same research was test verified through on farm trials in major semi dry areas of Tamil Nadu.

Materials and Methods

Experiments was conducted during dry season at AEC&RI, Kumulur in split plot design with three replication using ADT 49 (Medium duration) rice variety with the objectives to find out alternate method of sowing to overcome the labour scarcity in dry condition, to find out better spacing and crop geometry under Mechanised sowing in dry condition and to study the effect of water level and seed rate on productivity and water use efficiency under semi dry condition.

The main plot treatment consisted of four levels of irrigation *viz.,* Irrigation at critical stages up to 45 DAS (PI) and submergence of 2.5 cm(I_1), Supplemental irrigation through Alternate Wetting and Drying (AWD) from 45 DAS (PI) up to harvest(I_2), Continuous submergence of 2.5 cm (Farmers practices under wet condition)(I_3) and Farmers practices (Farmers practices under dry condition).The sub plot treatment consisted of four levels of crop geometry with different levels of seed rate viz., Mechanised sowing @ 30 kg/ha (22.5x10 cm)(S_1), Mechanised sowing 40 kg/ha (25 x15 cm)(S_2), Mechanised sowing 50 kg/ha(25 x 8 cm) (S_3) and Broad casting @ 75 kg/ha (S_4). The main plot treatment was imposed by using Parshal flume and the time taken for each treatment was recorded and the quantity of water irrigated and total water requirement was calculated for each treatment. The sub plot treatment was imposed by using a multi crop planter fitted with an inclined plate seed metering mechanism under dry soil conditions and the quantum of seed and spacing was adjusted by fluted roller metering systems and calibrated for the required quantity of seed. The other agronomic practices of weed management viz., application of Pretilachlor@0.45l/ha on 5 DAS and two (power) weeding on 30 and 45 DAS were adopted along with recommended fertilizer application of 120: 50: 50 NPK kg/ha for delta zone. The experiment was conducted in Split plot design and replicated thrice.

The observation on plant population (numbers/sq.m) at 15 DAS was recorded and establishment percentage was calculated. The weed flora and weed count was recorded on 25 and 40 DAS. The growth and yield parameters of rice viz., plant height at PI and at harvest, tiller production(numbers/hill), productive tillers (numbers/hill), number of grains per panicle (Table-1) were observed and grain and straw yields were calculated (Table-2). The additional cost involved, cost reduction and net income changes was calculated (Table-3) and depicted in fig. 1. The quantity of water used, number of irrigation and water use efficiency was calculated and presented in table-3.The cost of cultivation, gross income, net income and BCR was calculated (Table-4).

Results and Discussion

The outcome of three year studies were pooled and analysed on major parameters viz., grain yield, straw yield, economics, water use efficiency and changes in net income through partial budgeting. All the parameters behaved in the same trend in all the years in the treatment of supplemental irrigation through AWD from PI(45DAS) to harvest had achieved highest grain yield, straw yield, net income, BCR and higher water use efficiency. Increases in seed rate and continuous irrigation method has recorded reduction in weed density and increased plant population with higher establishment percentage. Mahajan *et al*, 2010 [3] suggested that higher seed rates caused significant reductions in weed dry matter, whereas higher than optimum seed rate (15–30 kg/ha) caused reduction in yield. Of all the seeding rates used, 15–30 kg/ha had the lowest grain-yield losses caused by weeds. Therefore, it was concluded that optimum seed rate in direct-seeded rice would minimize the effect of weed competition on rice growth and grain yield and thus would reduce herbicide use, promoting integrated-weed management. Increase in seed rate up to 40 kg/ha is important under moisture stress treatment of I_1- Irrigation at critical stages up to 45 DAS(PI) and submergence of 2.5 cm and I_4- Farmers' practices (Dry conditions up to 45 days, then converted as wet condition). Roderick *et al*., 2011 [4] indicated that the results of the impact analysis using both empirical approaches indicate that AWD, particularly the "Safe AWD" variant, reduces the hours of irrigation use (by about 38%), without a statistically significant reduction in yields and profits. to achieve higher net change in income, the seed rate should not increase beyond 40 kg/ha. The seed rate @ 40 kg/ha has recorded higher grain yield, straw yield, net income, BCR. Gareth *et al.*, 2017 [2] found that at harvest the shoot and grain mass was significantly greater for the plants grown

under AWD (9.0-9.4% and 12.0-15.4%, respectively) with the plants grown under AWD having a greater number of productive tillers.

The treatment combination of supplemental irrigation through Alternate Wetting and Drying (AWD) along with machine sowing @seed rate of 40 kg/ha(25x15cm) had achieved higher grain yield (7.91 t/ha), net income (Rs.71746/ha) and BCR(3.56), changes in net income of (Rs. 60574/ha)with higher water use efficiency (0.60 kg/ kg ha^{-1} mm^{-1}).

Table 1: Influence of seed rate and water regimes on grain yield (($t.ha^{-1}$)) under Mechanised semi dry rice cultivation

Main plot treatments	Sub plot treatments /Grain yield ($t.ha^{-1}$)															
	S_1				S_2				S_3				S4			
	2014	2015	2016	Mean	2014	2015	2016	Mean	2014	2015	2016	Mean	2014	2015	2016	Mean
I_1	4.95	5.46	3.95	4.79	5.42	5.81	4.54	5.26	3.80	3.92	3.93	3.88	3.34	3.42	3.87	3.54
I_2	6.77	7.45	6.03	6.75	7.90	8.42	7.42	7.91	5.40	5.98	6.69	6.02	4.92	5.15	5.7	5.26
I_3	6.34	6.91	4.57	5.94	7.51	7.26	5.9	6.89	5.06	5.26	5.4	5.24	4.08	4.22	5.29	4.53
I_4	4.43	4.62	2.73	3.93	4.24	4.52	2.68	3.81	3.40	3.66	3.09	3.38	3.08	3.25	2.63	2.99
Mean	5.62	6.11	4.32		6.27	6.50	5.14		4.42	4.71	4.78		3.86	4.01	4.37	
		Main plot	Sub plot	Int M x S	Int S x M											
SED		0.072	0.068	0.016	0.014											
CD(p=0.05)		0.16	0.16	0.33	0.32											

Table 2: Influence of seed rate and water regimes on straw yield (($t.ha^{-1}$)) under Mechanised semi dry rice cultivation

Main plot treatments	Sub plot treatments /Straw yield ($t.ha^{-1}$)															
	S_1				S_2				S_3				S4			
	2014	2015	2016	Mean	2014	2015	2016	Mean	2014	2015	2016	Mean	2014	2015	2016	Mean
I_1	4.49	5.34	3.87	4.57	5.05	5.76	4.49	5.10	3.72	3.61	3.62	3.65	3.48	3.76	4.26	3.83
I_2	6.10	7.60	6.15	6.62	7.35	8.93	7.86	8.05	5.18	6.70	7.49	6.46	5.02	5.88	6.48	5.79
I_3	6.71	6.78	4.47	5.99	7.68	7.04	5.72	6.81	5.50	5.37	5.51	5.46	4.53	4.47	5.6	4.87
I_4	4.14	4.53	2.68	3.78	4.02	4.57	2.71	3.77	3.25	3.81	3.22	3.43	2.93	3.45	2.79	3.06
Mean	5.36	6.06	4.29		6.03	6.57	5.20		4.41	4.87	4.96		3.99	4.39	4.78	
		Main plot	Sub plot	Int M x S	Int S x M											
SED		0.052	0.068	0.011	0.016											
CD(p=0.05)		0.13	0.15	0.27	0.30											

Table 3: Influence of water regimes on number of irrigation and water use efficiency of rice under Mechanised semi dry rice cultivation.

Treatment	Number of irrigation				Total quantity of water used (m^3. ha^{-1})				Water use efficiency (kg. ha^{-1} mm^{-1})			
	2014	2015	2016	Mean	2014	2015	2016	Mean	2014	2015	2016	Mean
I_1: Irrigation at critical stages up to 45 DAS (PI) and submergence of 2.5 cm	22	20	24	22	9830	8546	9428	9268	0.32	0.54	0.43	0.43
I_2: Supplemental irrigation through Alternate Wetting and Drying (AWD) from 45 DAS (PI) up to harvest	30	28	30	29	12912	9860	10260	11011	0.48	0.68	0.63	0.60
I_3: Continuous submergence of 2.5 cm	33	30	34	32	13556	11800	12400	12585	0.42	0.42	0.43	0.42
I_4: F Farmers practices (Farmers practices under dry condition)	20	21	28	23	10750	9440	9980	10057	0.35	0.43	0.28	0.35

Table 4: Influence of seed rate and water regimes on economics under Mechanised semi dry rice cultivation

Treatment	Cost of Cultivation (Rs. ha^{-1})				Gross income(Rs. ha^{-1})				Net income (Rs. ha^{-1})				BCR (GI/COC)			
	2014	2015	2016	Mean	2014	2015	2016	Mean	2014	2015	2016	Mean	2014	2015	2016	Mean
I_1S_1	22670	27670	29470	26603	58710	65346	47258	57105	36040	42676	24588	34435	2.59	2.36	1.6	2.18
I_1S_2	22910	27910	29710	26843	64485	69638	54401	62841	41575	46728	31491	39931	2.81	2.5	1.83	2.38
I_1S_3	23150	28150	29950	27083	45480	46570	46677	46242	22330	23420	23527	23092	1.96	1.65	1.56	1.72
I_1S_4	23390	28390	30190	27323	40290	41553	47009	42951	16900	18163	23619	19561	1.72	1.46	1.56	1.58
I_2S_1	23170	28170	28770	26703	80235	89629	72492	80785	57065	66459	49322	57615	3.46	3.18	2.52	3.05
I_2S_2	23410	28410	29010	26943	93975	101798	89696	95156	70565	78388	66286	71746	4.01	3.58	3.09	3.56
I_2S_3	23650	28650	29250	27183	64470	72836	81443	72916	40820	49186	57793	49266	2.73	2.54	2.78	2.68
I_2S_4	23890	28890	29490	27423	59190	62899	69545	63878	35300	39009	45655	39988	2.48	2.18	2.36	2.34
I_3S_1	22970	27970	28170	26370	76635	82718	54644	71332	53665	59748	31674	48362	3.34	2.96	1.94	2.75
I_3S_2	23210	28210	28410	26610	90375	86793	70487	82552	67165	63583	47277	59342	3.89	3.08	2.48	3.15
I_3S_3	23450	28450	28650	26850	61380	63278	64962	63207	37930	39828	41512	39757	2.62	2.22	2.27	2.37
I_3S_4	23690	28690	28890	27090	49635	51020	63920	54858	25945	27330	40230	31168	2.1	1.78	2.21	2.03
I_4S_1	22370	27370	29370	26370	52725	55311	32667	46901	30355	32941	10297	24531	2.36	2.02	1.11	1.83
I_4S_2	22610	27610	29610	26610	50550	54308	32223	45694	27940	31698	9613	23084	2.24	1.97	1.09	1.77
I_4S_3	22850	27850	29850	26850	40575	44140	37289	40668	17725	21290	14439	17818	1.78	1.58	1.25	1.54
I_4S_4	23090	28090	30090	27090	36735	39298	31809	35947	13645	16208	8719	12857	1.59	1.4	1.06	1.35

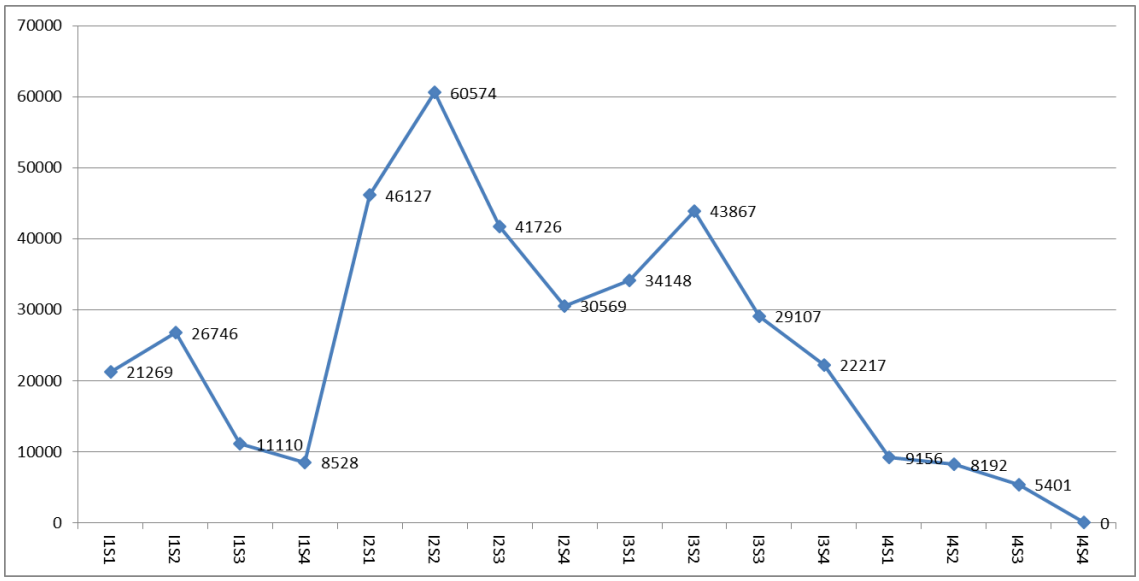

Fig 1: Influence of Mechanised sowing and supplemental irrigation methods on changes in Net income (Rs.ha-1)

Table 5: Influence of seed rate and water regimes on Net Income changes (Partial budgeting) under Mechanised semi dry rice cultivation during (Rs. ha^{-1}).

Treatment combinations	Additional return (A) (Rs. ha^{-1})	Reduced costs (B) (Rs. ha^{-1})	Additional cost (C) (Rs. ha^{-1})	Reduced return (D) (Rs. ha^{-1})	Net change in income (A+B)-(C+D) (Rs. ha^{-1})
I_1S_1	20749	520	0	0	21269
I_1S_2	26466	280	0	0	26746
I_1S_3	11070	70	30	0	11110
I_1S_4	8728	0	200	0	8528
I_2S_1	45507	660	40	0	46127
I_2S_2	60194	540	160	0	60574
I_2S_3	41586	420	280	0	41726
I_2S_4	30669	300	400	0	30569
I_3S_1	33128	1020	0	0	34148
I_3S_2	43087	840	60	0	43867
I_3S_3	28567	720	180	0	29107
I_3S_4	21917	600	300	0	22217
I_4S_1	8436	720	0	0	9156
I_4S_2	7712	480	0	0	8192
I_4S_3	5161	240	0	0	5401
I_4S_4	0	0	0	0	0

Conclusion

Sowing of seed by seed drill @ 40 kg/ha (25x 15 cm)with supplemental irrigation through alternate wetting and drying (AWD) method of irrigation from panicle initiation (PI) to harvest is important to achieve higher yield parameters, grain and straw yield and changes in net income also higher BCR under semi dry rice cultivation.

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