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Productivity and profitability of summer paddy under different establishment method and irrigation management

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Abstract
A field experiment was conducted in the Instructional Farm of College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar during 2017 to study the "Productivity and profitability of summer paddy under different establishment method and irrigation management". The soil of the experimental site was loamy sand with a BD of (1.84 g/cc), FC of (19%), PWP of (8%) and WHC of (31%). The soil was acidic (pH 5.23), low in organic carbon (0.5%), low in available nitrogen (165.7 kg/ha), low in available phosphorus (4.2 kg/ha) and medium in potassium (271.7 kg/ha).The experiment was laid out in Strip Plot Design with sixteen treatment combinations consisting of four establishment methods viz., Direct Seeded Rice (DSR), Pre Germinate Durm Seeded Rice (PGDSR), Puddled Transplanted Rice (PTR) and Non-Puddled Transplanted Rice (NPTR) and four irrigation management practices viz., Conventional Irrigation (CI), irrigation for Field Saturation (FS), irrigation on Disappearance of Ponding Water (DPW) and Alternate Wetting Drying (AWD) in three replication. Rice variety Khandagiri was grown for the study. The observation revealed that PTR method of establishment recorded maximum grain yield (5.23 t/ha), straw yield (5.33 t/ha) and harvest index (0.49) which was similar to NPTR with respective values of 4.97 t/ha, 5.27 t/ha and 0.48. Similarly AWD system of irrigation recorded maximum grain yield (5.07 t/ha), Straw yield (5.15 t/ha) and harvest index (0.49). Among different combinations, PTR with AWD recorded the highest grain yield (5.78 t/ha), straw yield (5.77 t/ha) and harvest index (0.51). However, NPTR with AWD recorded minimum water use (13500 m^3/ha) with water productivity of 0.38 kg/m^3. DSR with AWD recorded the lowest cost of production (35567 Rs/ha) but PTR with AWD recorded the highest gross return (97668 Rs/ha), net return (55005 Rs/ha) and B-C ratio (1.49).

Keywords: Productivity, profitability, summer paddy, establishment method, irrigation management

Introduction
Rice (*Oryza sativa* L.) is one of the most important staple food crops of the world that accounts for more than 20 per cent of the daily calorie intake of about 2.48 billion people. Among the rice growing countries, India has the largest area (44 million hectares) and is the second largest in production (131 million tonnes) next to China. The rice productivity in India is 3.37 t/ha, while the world average is 4.25 t/ha (IRRI, 2011). Rice provides about 700 calories/day/person to about 3000 million people living mostly in the developing countries. The problems and prospects of rice production in different ecosystems vary greatly (Senthil kumar *et al*., 2007). Total rice production in Odisha in 2016-17 was recorded as 7.12 million tonnes with productivity of 1.67 t/ha. The targeted rice production by 2020 has been computed to be of 10.13 million tons with productivity of 2.29 t/ha.

At present, 90 percent of total rice is grown and consumed in Asia (Evans, 2005).Of the three types of rice i.e. Aus (Early monsoon rice), Aman (Monsoon rice) and Boro (Dry season rice), the Boro rice alone grown in the rabi season (November to May) which is grown totally under irrigated condition contributing the highest share to total rice production (BER, 2005). Therefore, increase of Boro rice production would be a significant possible way to overcome food deficiency in the country.

An appropriate crop management strategy to increase the efficient use of inputs is needed to enhance the productivity. The input use efficiency mostly depends on consumptive use of water. Rice consumes around 4000-5000 litres of water to produce one kg grain, which is three times higher than other cereals (Anon., 2014).

The daily evapotranspiration requirement of rice varies from 4–5 mm /day during wet season and 7–8 mm/day during the dry season. But water is becoming increasingly scarce worldwide and more than one-third of the world population would face absolute water scarcity by the year 2025 (Seckler *et al.*, 1999 and Rosegrant *et al.*, 2002). So a method named Alternate Wetting and Drying (AWD) came into practice. The crop productivity in AWD was found to be 5-35% higher than with continuous flooding (Cabangon *et al.*, 2014).

In Asia, rice is commonly grown by transplanting seedlings into puddle soil. Puddling benefits rice by reducing percolation loss of water, controlling weeds, facilitating easy seedling establishment, and creating anaerobic conditions to enhance nutrient availability (Sanchez, 2000). Moreover, puddling and transplanting require huge amount of water and labour, both of which are becoming increasingly scarce and expensive, making rice production less profitable. Resource-conservation technologies such as direct seeding and non-puddled transplanting have been therefore shown to be beneficial in terms of improving soil health, water use, crop productivity and farmers' income (Singh *et al*., 2009).

Flooded rice culture with puddling and transplanting is considered one of the major sources of methane (CH4) emissions. Annually, 4.5 million tonnes of methane is emitted from paddy soils in India alone (Pepsico International, 2011). So considering all these facts, there is a need to find a suitable establishment method with an appropriate irrigation practice that will be economically feasible and environmentally sustainable.

Materials and Methods

The field experiment was conducted in Agronomy Main Research Farm of Orissa University of Agriculture and Technology, Bhubaneswar (20°15′*N* latitute, 85°52′ longitude and 25.9 m above mean sea level) during summer season of 2017 and 2015. The area is characterized by hot and humid climate. Soil of the experimental site was sandy loam in texture, low in organic carbon (0.54%), low available N (184 kg/ha), low in available P (4.2 kg/ha) and medium in available K (297.4 kg/ha). The mean maximum and minimum temperature during crop period was 35.2℃ & 23.7℃ respectively. Rice variety Khandagiri was grown for the study. The experiment was laid out in Strip Plot Design in 3 replication with gross plot size of 20 m^2 and net plot size of 12 m^2 with sixteen treatment combinations consisting of four establishment methods viz., Direct Seeded Rice (DSR), Pre Germinate Durm Seeded Rice (PGDSR), Puddled Transplanted Rice (PTR) and Non-Puddled Transplanted Rice (NPTR) and four irrigation management practices viz., Conventional Irrigation (CI), irrigation for Field Saturation (FS), irrigation on Disappearance of Ponding Water (DPW) and Alternate Wetting rying (AWD).

Results and Discussion

Maximum dry matter production (1235 g/m^2) was recorded in PTR and NPTR (1221 g/m^2). It was also maximum (1246 g/m^2) in AWD followed by DPW (1207g/m^2). However the highest dry matter production (1301 g/m^2) was recorded in PTR with AWD. This was mainly due to the fact that PTR with AWD combination enhanced and sustained plant growth attributes like height of the plant by conserving and improving soil, water and biological resources. Essentially, it maintains a permanent or semi-permanent organic soil cover that protects the soil from sun, rain and wind and allows soil micro-organisms and fauna to take on the task of "tilling" and soil nutrient balancing which boost the vegetative growth and aerated condition enhanced better uptake of nutrient. Similar findings were obtained from the findings of Kumar *et al*., (2011) [4].

Higher number of effective tillers (436/m^2) was observed in PTR as against NPTR (421/m^2). Similarly, maximum numbers of effective tillers (410/m^2) were produced in AWD, which was higher than that in DPW (401/m^2). However, the highest numbers of effective tillers (452/m^2) were produced in PTR with AWD. The higher number of effective tillers per unit area might be due to higher early growth which increased tiller production and reduced tiller mortality due to balanced nutrition at alternate wetting and drying condition compared to saturated condition. Also the vitality of roots is promoted and the space for roots to assimilate nutrient and moisture is extended, which implied that there is an advantage in getting effective tillers. The results are in accordance with the findings of Javaid *et al*. (2012) and Sidhu *et al*. (2014) [6].

The lowest Sterility (6.92%) and higher test weight (22.33g) was recorded with PTR and so also sterility was lower in DPW (5.13 %) but higher test weight (22.15g) was found in AWD. This might be due to good soil condition due to puddling in PTR method produced better growth which resulted in higher accumulation and translocation of these photosynthates to the reproductive part thereby increasing the number of filled grains per panicle. AWD regime as compared to other irrigation management practices might have caused more N losses via. Ammonia volatilization and denitrification under water-saving irrigation, which might have produced less effective grain and contributed to maximum sterility. The higher sterility in AWD might have helped in better grain filling to limited fertile grain with available dry matter. The results are in conformity with the findings of Mahajan *et al*. (2011) and Sekhar *et al*. (2014).

Maximum grain yield (5.23 t/ha) was recorded in PTR, there was no distinct variation in grain yield between PTR and NPTR (4.97 t/ha) along with maximum harvest index (0.49) was found in PTR followed by NPTR (0.48). Among different irrigation practices maximum grain yield (5.07 t/ha) and harvest index (0.49) was observed in AWD, which was higher than that in DWP (4.83 t/ha) and (0.48) respectively. Among all combinations the highest grain yield (5.78 t/ha) and harvest index (0.51) was recorded in PTR with AWD. This might be due to better chlorophyll development that might have improved the vegetative and reproductive growth of the crop which influenced directly or indirectly for higher production under higher fertilizer uptake along with all improved yield attributing characters as more over sustaining higher leaf area due to balanced plant food available in post flowering phase might have encouraged dry matter partitioning leading to better grain filling and higher test weight realizing higher grain yield. Subsequently the harvest index which is an indicative of dry matter partitioning was higher at PTR with AWD.

Minimum volume of irrigation water (15008 m^3/ha) was used in NPTR. So also it was minimum (13992 m^3/ha) in AWD. However the lowest volume of water use (13500 m^3/ha) was recorded in NPTR with AWD. Water productivity was highest (0.34kg/m^3) in PTR and so also in AWD (0.36kg/m^3). However, the highest water productivity (0.42kg/m^3) was recorded in PTR with AWD. This might be due to Puddling which required a large quantity of water accounting for major portion of the water use in the PGDSR as well as PTR method and the water loss in plots was less but maintenance of standing water during cropping season was relatively easy as compared to DSR and NPTR methods due to the presence of impervious soil layer in puddled plots. This corroborated the earlier findings of Bhagat (2003) [1] and Gill *et al*. (2006).The reduction of percolation and seepage resulted from the duration of no water depth and unsaturated condition in paddy field is longer under AWD than that under CI. Although the quantity of water used in PTR method is higher than the PGDSR and DSR but the relative increase in yield in PTR compensated the higher water used and lower irrigation water used along with higher grain yield in AWD resulting highest water productivity. Similar result also given by Castaneda *et al.* (2002) and (Joshi *et al*., 2009).

The minimum production cost was recorded in DSR (Rs 35064/ha) as well as in AWD (Rs 38070/ha) and so also it was lowest (Rs 35567/ha) in DSR with AWD. The highest gross return (Rs 89173/ha), net return (47360 Rs/ha) and B-C ratio (1.25) were realized in the PTR as well as in AWD (85881 Rs/ha, 47656 Rs/ha, 1.25, respectively). Thus, the highest gross return (97668 Rs/ha), net return (55005 Rs/ha) and B-C ratio (1.49) were realized in the PTR with AWD. The increase in cost of cultivation was due to the higher land preparation cost which includes puddling, higher water requirement during land preparation and higher labour requirement for Conventional irrigation. The following benefits are net labour savings with direct seeded rice compared with transplanting and the additional benefit of absence of nursery is needed that reduced the cost of cultivation of DSR methods. The results are in conformity with the findings of Thakur (1993) and Singh and Singh (2003). The increase in gross return, net return and B-C ratio was mostly due to lower water use along with higher yield under this management practices. Similar results were also obtained by Kumhar *et al*. (2014).

Table 1: Effect of establishment method and irrigation management on yield attributes and yield

Establishment Method(E)	Dry matter production (g/m^2)	Effective tillers/m2	Grains/ panicle	Filled grains/ panicle	Sterility (%)	Test Wt (g)	Grain Yield (t/ha)	Straw Yield (t/ha)	HI
E_1-DSR	1142	350	52	47	9.49	21.04	4.19	4.64	0.46
E_2-PGDSR	1168	368	57	52	8.39	21.36	4.3	4.76	0.47
E_3-NPTR	1221	421	58	53	7.85	21.75	4.97	5.27	0.48
E_4-PTR	1235	436	57	54	6.92	22.33	5.23	5.33	0.49
SEm (±)	10.072	2.466	1.019	1.322	0.106	0.122	0.077	0.084	0.006
CD (0.05)	34.85	8.53	3.52	4.57	0.36	0.41	0.26	0.27	0.02
Irrigation management(I)									
I_1-CI	1131.5	367	53	48	10.69	21.08	4.19	4.81	0.46
I_2-FS	1200	389	56	51	8.97	21.39	4.61	4.9	0.47
I_3-DPW	1207	401	58	55	5.13	21.76	4.83	5.11	0.48
I_4-AWD	1246	410	57	53	7.84	22.15	5.07	5.15	0.49
SEm (±)	12.906	2.187	0.888	1.44	0.12	0.244	0.054	0.05	0.005
CD (0.05)	36.5	7.56	3.07	4.98	0.418	NS	0.18	0.18	0.019

Table 2: Interaction effect of establishment method and irrigation management on grain yield (t/ha)

Treatment	I_1-CI	I_2-FS	I_3-DPW	I_4-AWD
E_1-DSR	3.87	3.97	4.34	4.6
E_2-PGDSR	3.89	4.43	4.25	4.64
E_3-NPTR	4.63	4.84	5.16	5.26
E_4-PTR	4.37	5.21	5.58	5.78
	E within I		I within E	
SE m±	0.126		0.114	
CD(0.05)	0.39		0.39	

Table 3: Effect of establishment method and irrigation management on irrigation water use and economics (Rs. /ha)

Establishment method	Quantity(m3/ha)	Water Productivity(kg/m3)	Cost of Cultivation	Gross Return	Net return	B:C
E_1I_1	17467	0.22	38967	67872	28905	0.74
E_1I_2	16767	0.23	37567	69432	31865	0.84
E_1I_3	15667	0.27	36567	75204	38637	1.05
E_1I_4	14267	0.32	35567	76416	40849	1.15
E_2I_1	18093	0.21	39167	68184	30392	0.74
E_2I_2	17400	0.25	38567	76608	39416	0.98
E_2I_3	16000	0.26	37567	73800	37608	0.96
E_2I_4	14700	0.31	36767	79884	44492	1.17
E_3I_1	16200	0.28	43878	79728	37450	0.87
E_3I_2	15367	0.31	42678	83004	41926	0.94
E_3I_3	14966	0.34	41878	87996	47718	1.1
E_3I_4	13500	0.38	40878	89556	50278	1.19
E_4I_1	18500	0.23	40268	75672	34209	0.87
E_4I_2	15833	0.32	39068	88776	46113	1.27
E_4I_3	14500	0.39	39268	94578	54115	1.4
E_4I_4	14200	0.42	39068	97668	55005	1.49
SE m±	316.458	0.013				
CD(0.05)	977.52	.04				

Where E1-DSR, E_2-PGDSR, E_3-NPTR, E_4-PTR, I_1-CI, I_2-FS, I_3-DPW and I_4-AWD

Conclusion

The present study conclude that among the different combination, the puddled transplanted rice (Variety-Khandagiri) with alternate wetting drying produced the highest grain yield of 5.78 t/ha, straw yield of 5.77 t/ha and harvest index of 0.51. It consumed 13500 m^3 of water per hectare with water productivity of 0.38 kg/m^3. And allowed for more gross return was Rs. 97668 and net return was Rs. 55005 per hectare with benefit-cost ratio of 1.49.

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