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Alternate *Kharif* Rice Crop Establishment Methods and Medium Duration Varieties to Enable Cropping System Intensification in Coastal Saline Region

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Shifting the rice growing season to allow earlier harvesting, may create opportunities for cropping intensification in the coastal zone of the Ganges delta. Field experiments were conducted for consecutive three *kharif* / wet seasons (2016-2018) in the coastal agro-ecosystem of the Indian Sundarbans to evaluate rice establishment methods and to find out suitable rice variety for higher production and earlier harvesting. Four rice establishment methods *viz.* conventional puddled transplanting (PTR), non-puddled transplanting (NPTR), drum seeding of pre-germinated seeds and dry direct seeding (DSR) were evaluated with different varieties of rice. Rice varieties evaluated were Amal-Mana, CR 1009 (Savitree) and Swarna-Sub 1 in 2016, CR 1009 and CR 1017 (Dharitri) in 2017 and CR 1018 (Gayatri) and Pratikshya in 2018. The drum seeded crop failed in 2017 and 2018. Higher plant height was observed in DSR treatment, which helped in better establishment of rice under submergence, whereas drum seeding was an ineffective method for wet season rice establishment. Though in the first year PTR was better in the absence of DSR, in subsequent two years, when DSR was evaluated, it was the best method of establishment followed by NPTR. Out of six rice varieties evaluated over three years, it was found that due to earlier maturity (at least by 15 days) as well as higher yield, the variety Pratikshya appears to be the most suitable one under these conditions.

(***Key words:*** *Coastal region, Flooding, Puddling, Rice varieties, Sundarbans)*

Farming in the Indian Sundarbans (situated in the Ganges delta adjacent to the Bay of Bengal) is based on rice as the main crop during the *kharif* / wet season (June-December). Long duration traditional rice varieties that are grown here, delay the establishment of the second crop. Heavy rainfall and low-lying topography hinder the use of short duration varieties due to the difficulty in harvesting under waterlogging situation. However, selection of modern varieties which are comparatively shorter in duration can lead to earlier harvesting and the possibility of growing a second crop.

In the coastal areas of eastern India, often farmers have no control over the depth, timing and duration of submergence. The low-lying paddy fields during monsoon/rainy season are also difficult to drain because of low gradient and elevation. Therefore, the risk of rice crop submergence and failure is high in this ecosystem. With the long-term adverse effects of climate change, the risk of farmers' exposure to extreme flood events is also high (Dar *et al.*, 2017). The most feasible option in these situations is to adopt suitable management practices and rice varieties that can adapt to submergence. One such option is the crop establishment methods and other, suitable tolerant varieties. Keeping these facts in view, experiments were conducted to find out a suitable rice establishment method which will enable timely establishment of next *rabi* crop, to identify suitable varieties and to study the effect of establishment methods on soil properties.

MATERIALS AND METHODS

Experimental site

Field experiments were conducted in the farmers' fields at Sonagaon village (22° 07′ 24.5′′ N 88° 47′ 39.7′′ E) situated in the Gosaba island of the Indian Sundarbans for three consecutive years (2016-18).

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The top soil (0-20 cm) is silty clay loam (35% clay), acidic (pH 5.7), contains 0.61% organic carbon, 271 kg available N ha^{-1}, 12.5 kg available P ha^{-1} and 260.6 kg available K ha^{-1}. Rainfall during the crop growing period (June-December) was 1659, 1816 and 1372 mm in 2016, 2017 and 2018, respectively (Fig. 1).

This experiment was started in *kharif* 2016 with three crop establishment methods *viz*. puddled transplanting (PTR), non-puddled transplanting (NPTR) and drum seeding in main-plots and three varieties (Amal-Mana, CR 1009 and Swarna-Sub 1) in sub-plots. During the *kharif* season of 2017 experiment was continued for the second year to study the effect of *kharif* crop establishment methods and variety on rice crop. Four crop establishment treatments *viz*. PTR, NPTR, direct seeded rice (DSR) and drum seeding were applied to main-plots and two rice varieties (CR 1009 and CR 1017) in sub-plots. Due to heavy rain, the seedlings under drum seeding could not be established; therefore, this treatment was unsuccessful during the wet season.

In *kharif* 2018, the main plot treatments consisted of PTR, NPTR, drum seeding and DSR, with sub-plots containing two varieties *viz*. CR 1018 and Pratikshya. Again, the drum seeded crop was damaged due to heavy rain coinciding with the initial sowing period. For transplanted rice (PRT and NPTR) nursery was grown and 40 days old seedlings were transplanted. For drum seeded rice, pre-germinated rice seeds were sown by the use of a drum seeder on to the puddled soil (Sarangi *et al*., 2014). For DSR dry seeds were sown before onset of monsoon on to the dry soil.

Rice varieties

Total six rice varieties were evaluated in this experiment. Salient characteristics of these varieties are given in Table 1. Amal-Mana is a variety developed at ICAR-CSSRI, Canning Town; it is relatively salt tolerant (4.0-6.0 dS m^{-1}) as well as tolerant to stagnant flooding, with yield advantage of 0.5 - 1.0 t ha^{-1} than local varieties (Sarangi *et al*., 2016). It was released by Central Variety Release Committee (CVRC) in 2008. Rice variety CR 1009 popularly known as Savitri/ Ponmani is a high yielding mega variety for rainfed shallow lowland of eastern and southern India. It was developed by Central Rice Research Institute (CRRI) and released in 1982 by CVRC and State Variety Release Committee (SVRC) of Odisha, Tamil Nadu and West Bengal. Swarna-Sub 1 was released in 2009 for cultivation in shallow lowland areas of coastal Orissa by the Orissa State Seed Sub-Committee of Agricultural Crops (http://icar-nrri.in/released-varieties/). It is tolerant to complete submergence up to 17 days, and is also suitable for late planting with aged seedlings. Swarna-Sub 1 was approved for notification by the Central Sub-Committee on Crop Standards, Notification and Release of Varieties. CR 1017 known as Dharitri was released by CVRC in 1988. It is tolerant to blast, bacterial leaf blight, stem borer and gall midge. It is recommended for lowlands in eastern and southern states of India. CR 1018 known

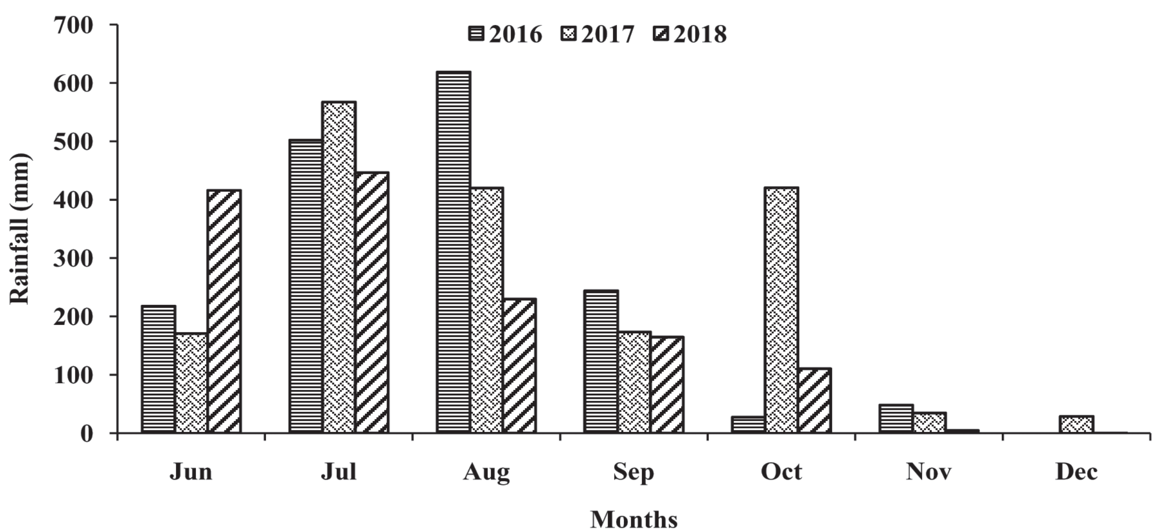

Fig. 1. *Rainfall received at Canning Town, West Bengal India during the wet seasons of 2016, 2017 and 2018. Canning Town is 35 km east of the study area, but the closest weather station*

Table 1. *Salient characteristics of the rice varieties used in the experiment*

Variety	Parentage	Maturity duration (days)	Height (cm)	Grain type*	Grain yield (t ha^{-1})
Amal-Mana	Pankaj × SR 26B	165	160	LS	4.0-6.0
CR 1009	Pankaj × Jagannath	145	130	SB	5.5
Swarna-Sub 1	Swarna × IR49830-7	143	100	MS	5.5
CR 1017	Pankaj × Jagannath	150	110	SB	5.0
CR 1018	Pankaj × Jagannath	160	110	SB	5.0
Pratikshya	Swarna × IR64	135	105	MS	4.9

*LS: Long slender; SB: Short bold; MS: Medium slender.

as Gayatri (CR 210-1018) is a photosensitive popular variety, released and notified (1988) for cultivation in low land of Odisha, West Bengal and Bihar states as well as by CVRC in 1988. It has field tolerance against major diseases (blast, bacterial leaf blight and gall midge) and pests. It has significant extent of grain dormancy, can tolerate up to 50 cm water stagnation and is suitable for delayed transplanting. Pratikshya is released by Orissa University of Agriculture and Technology (OUAT) in 2005 suitable for late sown conditions for rainfed medium land, moderately resistant to brown spot, sheath rot, sheath blight, leaf folder and white backed plant hopper and resistant to gall midge and stem borer (white ear).

Observations

Field water depth was measured weekly in each replication. Plant height was measure from base of the plant to the longest leaf tip for 5 random samples from each plot and mean data is presented. Panicles m^{-2} from each treatment were measured by using 1×1 m quadrats from 3 random points in each plot and averaged. Grains $panicle^{-1}$ were estimated from 10 panicles and 1000 grain weight from these same panicles. Grain yield from 3 quadrats in each treatment was determined and converted to t ha^{-1}. After harvest of rice, soil bulk density (BD) and moisture were determined from 0-15, 15-30, 30-50, 50-80 and 80-120 cm soil layers. Soil BD was measured following core sampler method and moisture by gravimetric method.

Statistical analysis

The replicated data collected from each year of experimentation was analysed separately as there was variations over the years in the rice varieties studied. Analysis of variation (ANOVA) was done by using split-plot design with rice establishment as main-plot and varieties as sub-plot as per the standard procedure (Gomez and Gomez, 1984). The treatment means were compared by using least significant difference (LSD) at P=0.05.

RESULTS AND DISCUSSION

Rice plant height and field water depth

Each year the rice nursery (upto 40 DAS) in transplanted crop was affected by submergence, as was the drum seeded rice in 2016. The transplanted Swarna-Sub 1 and CR 1009 were under water on 45 DAS for all the establishment methods, whereas Amal-Mana escaped this submergence due to its greater plant height (Fig. 3a). The rice plant height was significantly shorter in drum seeding compared to other methods. Drum seeding was reported as a suitable method for rice establishment for coastal saline areas during the dry season (Sarangi *et al*., 2014), when there is control over field water depth. However, this study shows that it is not suitable for wet season due to heavy rainfall, which damaged the pre-germinated seeds in two out of three years (Fig. 2).

The DSR crop was successful and was not affected by heavy rain in July (Fig. 4). The plant height was higher due to DSR, and among the varieties, CR 1017 was comparatively taller than CR 1009 up to 75 DAS while later the difference narrowed (Fig. 3b).

In 2018, both the rice nursery of Pratikshya and CR 1018 were affected due to heavy June rain (416 mm), but the DSR crop was not affected due to its greater plant height. However, after transplanting, there was no effect of submergence for different establishment methods and varieties (Fig. 3c).

Fig. 2. Left. *Sowing of pre-germinated seeds with drum seeder* ***Right***. *Heavy rain submerged the seedlings*

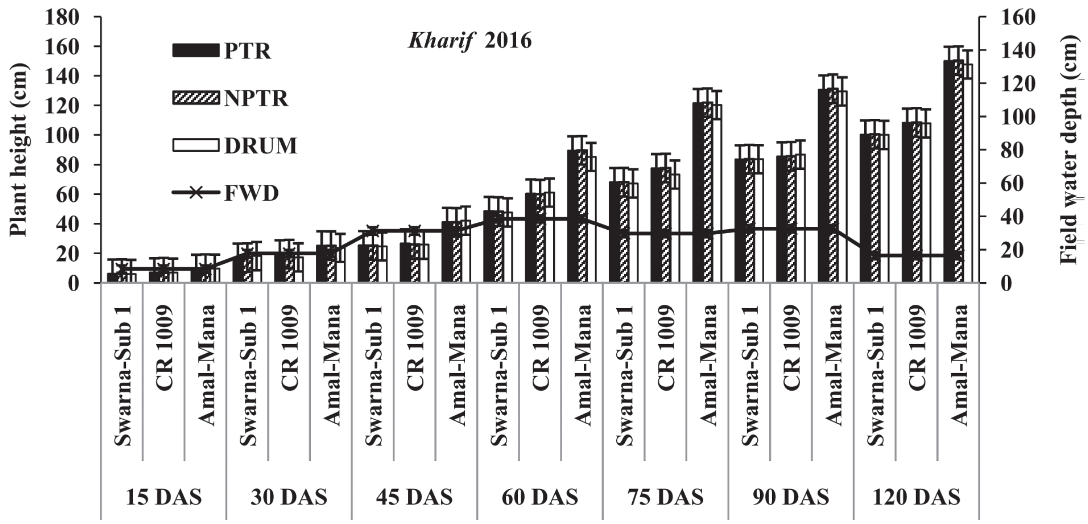

Fig. 3a. *Effect of flooding water height on height of rainfed lowland rice varieties under different establishment methods during kharif 2016 at Sundarbans, India*

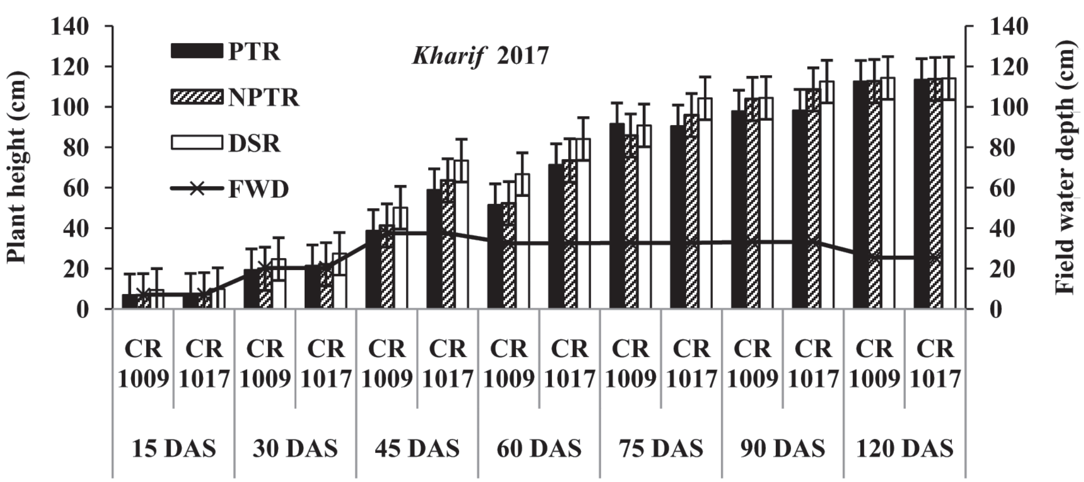

Fig. 3b. *Effect of flooding water height on height of rainfed lowland rice varieties under different establishment methods during kharif 2017 at Sundarbans, India*

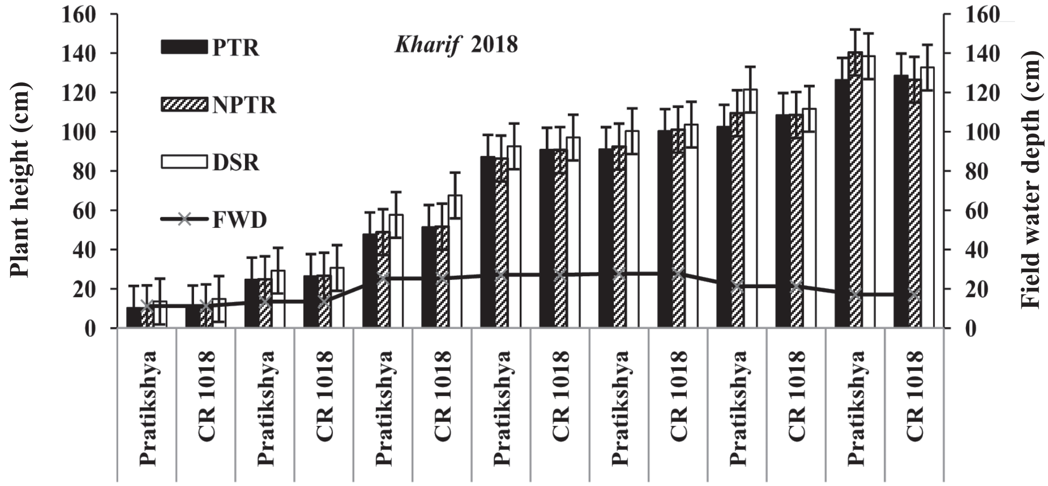

Fig. 3c. Effect of flooding water height on height of rainfed lowland rice varieties under different establishment methods during kharif 2018 at Sundarbans, India

Yield contributing characters

All the yield contributing characters were significantly lower due to drum seeding in 2016 compared to PTR and NPTR (Table 2). CR 1009 had significantly more panicles m^{-2} than Amal-Mana and Swarna-Sub 1. However, the number of grains panicle^{-1} was more in Swarna-Sub 1 than Amal-Mana and CR 1009. Amal-Mana had higher grain weight than other two varieties. In 2017, DSR resulted in significantly more panicles m^{-2} than other treatments except PTR. CR 1017 had more panicles m^{-2} and grains panicle^{-1} than CR 1009. Grains panicle^{-1} was also higher in DSR compared to other methods. Performance of DSR was also confirmed in 2018, with higher panicles m^{-2} and grains per panicle. In 2018, there was no effect of establishment methods on grain weight and the varieties did not differ with panicles m^{-2} and grains panicle^{-1}, however, 1000 grain weight was higher in CR 1018 than Pratikshya.

Yield and maturity duration

During the *kharif* 2016 (Table 3) the highest grain yield of 4.09 t ha^{-1} obtained under PTR, while drum seeding resulted in the lowest grain (3.09 t ha^{-1}). In 2017, DSR resulted in similar grain yield of rice (6.47 t ha^{-1}), compared to PTR (6.52 t ha^{-1}). In 2018, DSR yield was significantly higher than PTR as well as NPTR. The DSR crop was harvested earlier by more than one week, which may facilitate earlier establishment of subsequent rabi crops. Among the 6 rice varieties tested over the years, varieties CR 1009, CR 1017, CR 1018 and Pratikshya performed better with grain yields above 6 t ha^{-1}. However, the rice variety Pratikshya matured earlier by about 15 days, which is very significant in earlier establishment of second crop. Studies in coastal saline soils in Orissa revealed that among the medium duration cultivars (Gayatri, Swarna, Pratikshya), the performance was better in Pratikshya due to its good crop stand with better yield attributing characters and tolerance to disease and pest (Panda *et al*., 2009). Earlier maturity of rice varieties Naveen and Pooja under DSR conditions compared to transplanting conditions have been reported in coastal agro-climatic conditions (Sahu, 2016).

Rice variety Pratikshya matured earlier than other varieties tested, but is not a short duration variety that would not be suitable for these low-lying lands, due to harvesting the crop from the waterlogged fields. Other preferable character for rice in this ecosystem during the wet season is the tall plant height together with lodging tolerance (Padhiary, 2013). Pratikshya is a tall variety and it has tolerance to lodging.

Soil properties

Soil BD was significantly lower in the upper soil layer in DSR and NPTR (Fig. 5). Similarly, less wetness on soil surface was observed in DSR compared to all other methods. The differences of soil BD due to different establishment methods were not observed in lower soil layers, however, the soil moisture was uniformly distributed in the profile due to DSR compared to other methods.

Fig. 4. *DSR crop due to higher plant height tolerated heavy rain during the months of July and August*

Table 2. *Yield contributing characters of kharif rice varieties under different establishment methods at Sundarbans, India (2016-18)*

Treatments	Panicles m^{-2}			Grains panicle^{-1}			1000 Grain wt. (g)		
	2016	2017	2018	2016	2017	2018	2016	2017	2018
Rice establishment methods									
PTR	334	243	221	192	213	224	24.7	22.8	20.6
NPTR	321	181	292	156	204	222	24.5	22.6	20.6
DRUM	290	-	-	132	-	-	24.4	-	-
DSR	-	248	330	-	212	234	-	22.6	20.8
LSD (P=0.05)	6.2	16.5	3.4	3.0	1.2	1.5	0.1	0.1	NS
Varieties									
Amal-Mana	284	-	-	140	-	-	28.5	-	-
CR 1009	352	205	-	165	204	-	24.9	24.0	-
Swarna-Sub 1	309	-	-	175	-	-	20.3	-	-
CR 1017	-	243	-	-	216	-	-	21.3	-
CR 1018	-	-	282	-	-	225	-	-	20.8
Pratikshya	-	-	280	-	-	228	-	-	20.6
LSD (P=0.05)	5.9	24.3	NS	3.6	2.1	NS	0.2	0.2	0.1

PTR: Puddled transplanting; NPTR: Non-puddled transplanting; DRUM: Drum seeding of pre-germinated seeds; DSR: Dry direct seeded rice.

Soil BD, which is an indicator of soil quality, increases with time as particles settle after puddling; this indicator is inversely ralated to many important soil properties, including water-holding capacity, soil particle size, total porosity, infiltration capacity, hydraulic conductivity, gas exchange, and nutrient mobility (Zhou *et al*., 2014). Saturated hydraulic conductivity (Ksat) of 0-20 cm soil in the DSR treatment was 2.6 and 4.3 times higher than their PTR counterparts in the first (Y_1) and second (Y_2) years, respectively (PTR-Y1 = 93 mm day^{-1}, DSR-Y_1 = 241 mm day^{-1}, PTR-Y_2 = 133 mm day^{-1}, DSR-Y_2 = 582 mm day^{-1}), the impact of rice establishment method was also reflected in higher PTR BD in the 5-10 cm (DSR = 1.19 g cm^{-3}, PTR = 1.24 g cm^{-3}) and 10-15 cm (DSR = 1.24 g cm^{-3}, PTR = 1.29 g cm^{-3}) depth increments in the wet season (McDonald *et al*., 2006).

Based on three years of study, it is concluded that alternative rice establishment methods such as dry direct seeded rice or non-puddled transplanted rice may be suitable for the submergence-prone lowlands of the coastal region of the Ganges delta. Pratikshya was a promising rice variety with suitable plant height to avoid submergence in medium to low land situations and it has lodging tolerance therefore this variety is preferred by farmers. Due to it’s early maturity (at least by 15

***Table 3.** Yield and maturity duration of kharif rice varieties under different establishment methods at Sundarbans, India (2016-18)*

Treatments	Grain yield (t ha^{-1})			Maturity duration (days)		
	2016	2017	2018	2016	2017	2018
Rice establishment methods						
PTR	4.09	6.52	4.71	155	152	147
NPTR	3.81	5.43	6.51	155	152	147
DRUM	3.09	-	-	151	-	-
DSR	-	6.47	7.02	-	143	138
LSD (P=0.05)	0.30	0.17	0.33	0.82	0.15	1
Varieties						
Amal-Mana	4.19	-	-	163	-	
CR 1009	3.86	6.18	-	154	151	
Swarna-Sub 1	2.93	-	-	143	-	
CR 1017	-	6.19	-	-	147	
CR 1018	-	-	6.09	-	-	155
Pratikshya	-	-	6.07	-	-	132
LSD (P=0.05)	0.18	NS	NS	1.61	1.25	1

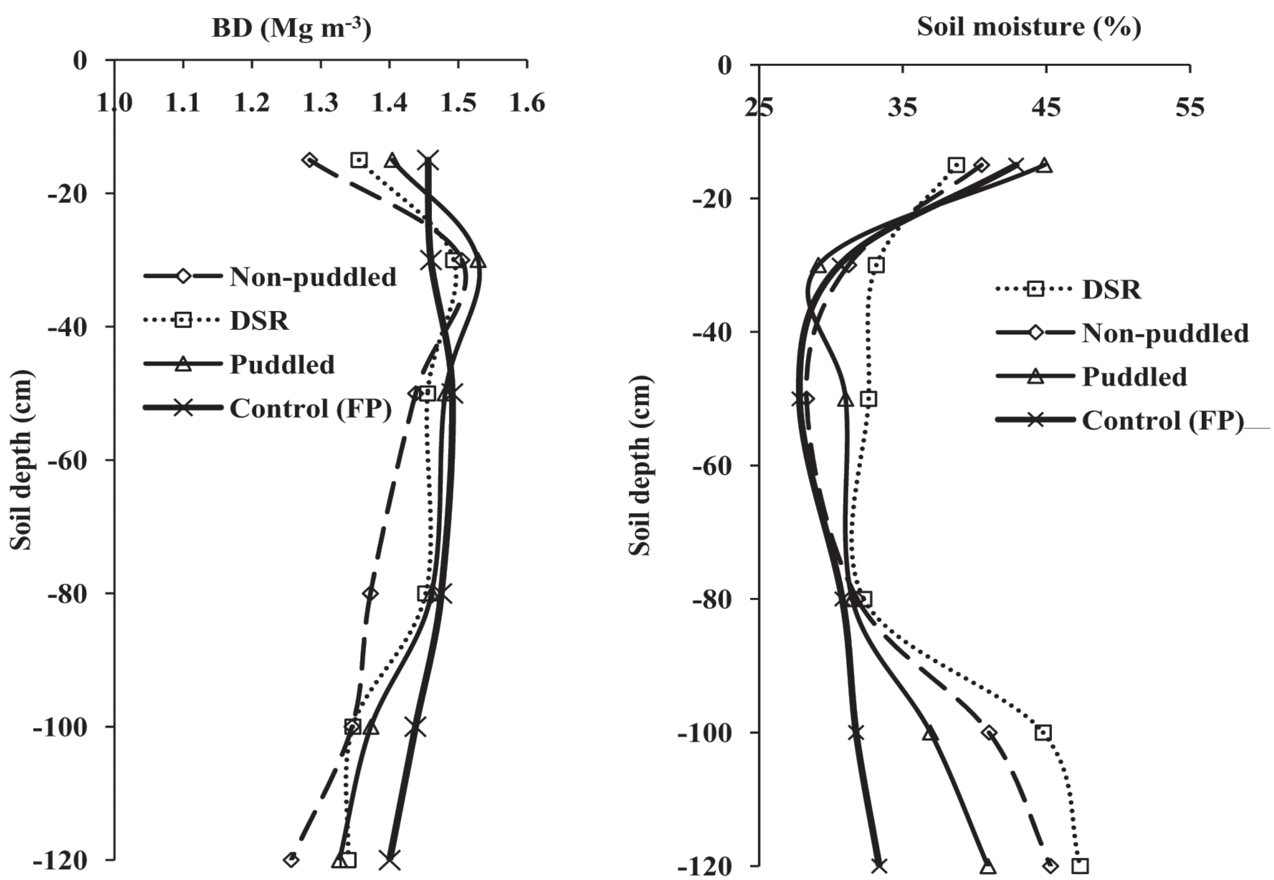

***Fig. 5.** Soil bulk density (BD) and moisture after harvest of kharif rice under different establishment methods in Sundarbans. Values are means of 5 replicates*

days) compared to other prevailing varieties, Pratikshya creates opportunities for cropping system intensification in the coastal zone by earlier establishment of *rabi* season crops.

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REFERENCES

Dar, M. H., Chakravorty, R., Waza, S. A., Sharma, M., Zaidi, N. W., Singh, A. N., Singh, U. S. and Ismail, A. M. (2017). Transforming rice cultivation in flood prone coastal Odisha to ensure food and economic security. *Food Security* **9**: 711-722. soi:10.1007/s12571-017-0696-9.

Gomez, K. A. and Gomez, A. A. (1984). *Statistical Procedures for Agricultural Research*, Second Edition, John Wiley and Sons, New York. 680 p.

McDonald, A. J., Riha, S. J., Duxbury, J. M., Steenhuis, T. S., Lauren, J. G. (2006). Soil physical responses to novel rice cultural practices in the rice-wheat system: comparative evidence from a swelling soil in Nepal. *Soil Tillage Research* **86**: 163-175. doi: 10.1016/j.still.2005.02.005.

Padhiary, A. K. (2013). Screening of lowland rice varieties under waterlogged conditions basing on morpho-physiological characters in coastal belt of Odisha. *Unpublished M.Sc. (Ag.) Thesis*, Orissa University of Agriculture and Technology, Bhubaneswar, Odisha, India. Krishikosh.egranth.ac.in/bitstream/1/5810071215/1/Th-4033.pdf.

Panda, N., Dhal, A. and Sangramsingh, S. P. (2009). Varietal performance of rice [*Oryza sativa* (L.)] cultivars grown under coastal saline soils of Orissa. *International Journal of Agricultural Sciences* **5**(1): 21-23.

Sahu, K. K. (2016). Agrometeorological evaluation of unpuddled transplanting method of kharif rice at Bhubaneswar. *Unpublished M.Sc. (Ag.) Thesis,* Orissa University of Agriculture and Technology, Bhubaneswar, Odisha, India. file:///E:/ACIAR/ACIAR%20Publication/Rev%20of%20Lit/Kamlesh%20Kumar%20Sahu.pdf

Sarangi, S. K., Maji, B., Singh, S., Sharma, D. K., Burman, D., Mandal, S., Ismail, A. M. and Haefele, S. M. (2014). Crop establishment and nutrient management for dry season (*boro*) rice in coastal areas. *Agronomy Journal* **106**(6): 2013-2023. doi: 10.2134/agronj14.0182.

Sarangi, S. K., Maji, B., Singh, S., Sharma, D. K., Burman, D., Mandal, S., Singh, U. S., Ismail, A. M., Haefele, S. M. (2016). Using improved variety and management enhances rice productivity in stagnant flood-affected tropical coastal zones. *Field Crops Research* **190**: 70-81. http://dx.doi.org/10.1016/j.fcr.2015.10.024.

Zhou, W., Lv, T. F., Chen, Y., Westby, A. P., Ren, W. J. (2014). Soil physicochemical and biological properties of paddy-upland rotation: a review. *The Science World Journal* 2014 (85635). http://dx.doi.org/10.1155/2014/856352.