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Growth, Productivity and Nutrient Uptake of Different Rice Cultivars under Coastal Eco-System of West Bengal

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Field experiment was conducted to evaluate the performance of different rice cultivars in terms of growth, nutrient uptake and productivity at Regional Research Station (Coastal Saline Zone), Bidhan Chandra Krishi Viswavidyalaya, Kakdwip, South 24-Parganas, West Bengal during the rainy seasons of 2015 and 2016. High yielding rice cultivars - Pratikshya, Santoshi, Sabita, Super Shyamali and Swarna Masuri, indigenous non-aromatic cultivars - Black rice, Dudheswar and Kerala Sundari and aromatic rice cultivars - Radhatilak and Gobindabhog were evaluated. The indigenous rice cultivars produced taller plants, while the HYVs produced higher dry matter m^{-2} and number of tillers plant^{-1}. The HYV Santoshi out yielded all other tested cultivars by producing significantly higher grain yield, which was followed by other two HYVs 'Pratikshya' and 'Super Shyamali. The macronutrient concentration (N, P and K) in rice grain was significantly higher in indigenous aromatic and non-aromatic rice cultivars than HYVs. Multiple linear regression analysis of grain and straw yield as a dependent variable showed that grain N concentration and straw P concentration had a positive non-significant relationship with grain and straw yield, respectively.

***(Key words:** Aromatic rice, Coastal eco-system, High yielding variety, Indigenous non-aromatic rice, Nutrient uptake, Yield)*

With growing prosperity and urbanization, the total area under rice cultivation in India as well as in the State of West Bengal is decreasing at rapid rate; however, the demand for rice in the future is bound to increase with the growing population (Banerjee and Pal, 2011). Predominantly medium and low land situation in the eastern part of the country left no other option for farmers but to go for rice cultivation in rainy season. West Bengal, the rice bowl of the country, is the richest reservoir of rice bio-diversity. However, in this state, the expected demand for rice by 2020 AD will be around 17.6 million tonnes, which is nearly 16 percent more than the present production level of 14.9 million tonnes (Mondal *et al*., 2012).

Under the coastal ecosystem, rice is grown in about 10 lakh ha, which accounts for nearly 17% of the total rice area in the state. In these areas, farmers grow mostly low yielding traditional rainfed or long duration rice varieties (145−150 days) during wet season, leaving most of the lands fallow during dry season (mono-cropping) (Banerjee *et al*., 2017). The production of rice is not satisfactory due to aberrant weatherconditions coupled with non-availability of high-yielding varieties (Mondal *et al*., 2012). Moreover, growth and productivity of rice in tropical coastal areas are adversely affected by various abiotic stresses, including water stagnation (medium-deep, 25–50 cm for most of the season), flash floods (complete submergence for 1–2 weeks) and varying levels of soil and water salinity (Islam *et al*., 2016). Based on rice productivity, South 24-Parganas district ranks 12th amongst all rice growing districts of West Bengal (Adhikari *et al*., 2011). Considering the demand-supply gap of rice in this district, still there is huge growth potential in this segment. Adoption of different superior rice varieties could be effective for narrowing down the yield gap and boosting the rice yield under coastal eco-system. Taking cognizance of the above facts, the experiment was undertaken to understand the variation in growth, yield and nutrient (N, P and K) acquisition pattern of rice cultivars in rainy season under coastal belt of West Bengal.

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MATERIALS AND METHODS

Field experiment was conducted during two consecutive rainy seasons of 2015 and 2016 at Regional Research Station (Coastal Saline Zone), Bidhan Chandra Krishi Viswavidyalaya, Kakdwip, South 24-Parganas, West Bengal (22°40′ N latitude, 88°18′E longitude and 7 m above mean sea level). The maximum and minimum air temperatures fluctuated from 24.4 to 31.8°C and from 11.5 to 20.6°C during rainy season of 2015, and from 24.9 to 32.1°C and from 12.3 to 20.4°C during rainy season of 2016, respectively. The maximum and minimum air relative humidity prevailed between 86.7-88.5% and 34.5-59.5% during 2015, and 84.5-85.8% and 48.5-63.0% during 2016. The rainfall during the experimental period (July to November) was 22.4 and 15.8 cm during 2015 and 2016, respectively. The soil was clay in texture with pH 5.84, $EC_{1:2.5}$ 1.55 dS m^{-1}, available N 155.24 kg ha^{-1}, available P 105.76 kg ha^{-1} and available K 365.86 kg ha^{-1} in the 0-30 cm layer.

The experiment was arranged in randomized complete block design with three replications, with individual gross plot area of 5m × 4m. High yielding rice cultivars (Pratikshya, Santoshi, Sabita, Super Shyamali and Swarna Masuri), indigenous non-aromatic cultivars (Black rice, Dudheswar and Kerala Sundari) and aromatic cultivars (Radhatilak and Gobindabhog) were evaluated (Table 1). Seedlings of 25 days old were manually transplanted on August 2 and August 5 during 2015 and 2016, respectively, at a spacing of 20 cm × 20 cm with 3-4 seedlings per hill. A uniform fertilizer dose of 60 kg N (as urea), 30 kg P_2O_5(as single super phosphate) and 30 kg K_2O(as muriate of potash) was applied. Half dose of urea was applied as basal and rest amount in two equal splits at 21 and 42 days after transplanting (DAT). Entire amount of SSP were given as basal *i.e.* at the time of final land preparation. MOP was applied in two splits – 75% as basal and rest 25% as top dressing (42 DAT). Other agronomic management practices were followed based on recommended standards for the region and were applied uniformly across all tested cultivars (Sarangi *et al*., 2016).

The collected data were analyzed statistically by the analysis of variance (ANOVA) technique using the STAR Software version 2.0.1 (International Rice Research Institute, Philippines, 2013). The significant difference between treatments means was tested by the Duncan's multiple range test (DMRT) at p≤0.05. Linear regression - enter method was intervened using SPSS ver. 20 software to establish the relationship between yield and nutrient concentration. To predict the presence of auto-correlation in the residuals of such regression models, Durbin-Watson statistics were used as per Ghasemi *et al*. (2010). Agglomerative Hierarchical Clustering was done using XLSTAT 2017.

RESULTS AND DISCUSSIONS

Growth attributes

Significant variations in different growth parameters were observed amongst different tested cultivars (Table 2). The aromatic rice cultivars were, 21.8 and 5.1% taller than the HYVs and indigenous non-aromatic cultivars, respectively, while the maximum average plant height was observed for Gobindabhog followed by Sabita. The indigenous cultivars are very much prone to lodging because of their height resulting into greater yield loss, which is less common for HYVs. Different mechanical cells in the lodging susceptible varieties were found to be significantly larger than those of the lodging resistant varieties (Joarder and Eunus, 1981). Major part of the culm is occupied by hollow pith in traditional cultivars (Sarwar and Prodhan, 2000). On the other hand, higher number of vascular bundles in the inner circle probably gives lodging resistance to modern HYVs. Moreover, a thick culm may also act as a carbohydrate store for high yield in rice (Hirose *et al*., 2006). Biomass accumulation is a good measure of competitive success, because it reflects resource capture under the interference of neighbours. Unlike plant height, the maximum average dry matter accumulation was greater for indigenous non-aromatic cultivars, accounting 10.6 and 26.8% more than HYVs and aromatic cultivars, respectively. But 'Super Shyamali' produced significantly higher dry matter followed by 'Black rice' and 'Kerala Sundari'. Indigenous non-aromatic rice cultivars produced higher number of tillers $hill^{-1}$, accounting 10.0 and 29.4% more than HYVs and aromatic cultivars, respectively. The HYV 'Santoshi' was capable of producing maximum number of tillers $hill^{-1}$, and it was statistically at par with Pratikshya, Kerala sundari, Super Shyamali and Dudheswar. However,

Table 1. *Generalcharacteristics of the tested rice cultivars grown in coastal agro-ecosystem*

Type of cultivars	Name of the cultivars	Days to maturity (nos.) *	General characteristics
High Yielding Variety	Pratikshya	125	Salinity tolerant; can withstand water stagnation; resistant to sheath blight disease; soft straw
	Santoshi	135	Salinity tolerant; absolutely disease-free
	Sabita	140	Salinity tolerant; can withstand water stagnation; higher incidence of stem borer; incomplete seed setting
	Super Shyamali	140	Salinity tolerant; long grain; good for 'moori' making; moderate incidence of stem borer
	Swarna masuri	130	Salinity tolerant; susceptible to sheath blight disease
Indigenous	Black rice	140	Salinity tolerant; grain colour black; absolutely disease-free
	Dudheswar	125	Salinity tolerant; scented rice; can withstand water stagnation; fine grain; good for 'moori' making; fine straw; moderate incidence of stem borer
	Kerala Sundari	125	Salinity tolerant; can withstand water stagnation; fine grain
Aromatic	Radhatilak	130	Salinity tolerant; scented rice; can withstand water stagnation
	Gobindabhog	130	Salinity tolerant; scented rice; fine straw and palatable for livestock; moderate incidence of stem borer

* based on the present experimental findings

Table 2. *Growth attributes of tested rice cultivars at harvest during rainy season (Pooled data of 2015 and 2016)*

Type of cultivars	Name of the cultivars	Plant height (cm)	Dry matter (g $plant^{-1}$)	No. of tillers $hill^{-1}$	No. of panicles $plant^{-1}$
High Yielding Variety	Pratikshya	111f	102d	26ab	25a
	Santoshi	117e	91e	28a	24ab
	Sabita	158b	87e	10e	8f
	Super Shyamali	115ef	142a	24abc	22abc
	Swarna Masuri	94g	48h	11e	11ef
	Mean	119	94	19.8	18
Indigenous	Black rice	153c	123b	19bcd	17cde
	Dudheswar	132d	81f	22abcd	18bcd
	Kerala Sundari	130d	109c	25ab	16cde
	Mean	138	104	22	17
Aromatic	Radhatilak	119e	106cd	16de	12def
	Gobindabhog	171a	57g	17cde	11ef
	Mean	145	81.5	16.5	11.5

The superscript letters indicate DMRT rank for significant differences at $p< 0.05$ (otherwise statistically at par)

HYVs produced a greater number of panicles plant^{-1}, accounting 5.9 and 41.7% more than indigenous non-aromatic and aromatic cultivars, respectively. The HYV Pratikshya produced significantly higher number of panicles plant^{-1}, which was statistically at par with that ofthe cultivars Santoshi and Super Shyamali.

Yield attributes and yield

The HYVs performed better than indigenous non-aromatic and aromatic rice cultivars with respect to yield attributes and yields (Table 3). Amongst all the tested cultivars, Santoshi recorded the significantly higher panicle length, panicle weight, number of filled grains per panicle and test weight. The average grain yield was higher for HYVs, accounting 47.0 and 141.4% more than indigenous non-aromatic and aromatic cultivars, respectively. Consequently, the maximum grain yield was obtained with Santoshi followed by another two HYVs Pratikshya and Super Shyamali. However, the higher average straw yield was recorded for indigenous non-aromatic cultivars, accounting 17.6 and 60.0% more than HYVs and aromatic cultivars, respectively. The Black rice produced maximum amount of straw followed by that of Sabita and Dudheswar. The trend for harvest index was similar to that of grain yield. Mondal *et al*., (2012) also recorded significantly better performance of high yielding rice (cv. Narendra dhan) than the traditionally grown cultivars with respect to yield attributes and yield. Comparatively poor yield of indigenous non-aromatic and aromatic rice cultivars might have been associated with undesirable traits like susceptibility to pests and diseases, and strong shedding (Bemer and Hoff, 1986).

Nutrient uptake

Irrespective of rice cultivars tested, N accumulation in grain was higher than P and K accumulation whereas K accumulation in straw was higher. The N and P concentrations in rice grain were significantly higher in indigenous non-aromatic rice cultivars, accounting 5.6 and 15.9% more than that of aromatic and HYVs for N, and 4.2 and 13.6% for P, respectively. But indigenous aromatic rice cultivars accumulated higher K, amounting 5.9 and 20.0% more than that of indigenous non-aromatic and HYV respectively (Fig. 1a). Amongst the tested rice cultivars, the highest N concentration in grain was recorded in Gobindabhog, while both Black rice and Radhatilak exhibited the highest P accumulation in grain. However, the maximum K content in rice grain was found in Dudheswar. On the other hand, significantly higher straw N concentration was found in HYVs, accounting 15.4 and 25.0% more than indigenous aromatic and non-aromatic rice cultivars, respectively. The indigenous non-aromatic rice cultivars accumulated higher amount of P and K in straw accounting 12.5 and 28.6% more than that of aromatic and HYVs for P, and 4.1 and 23.1% more that HYVs and aromatic cultivars for K, respectively (Fig. 1b). This result indicated that grain yield of HYVs is moderately dependent on NPK concentration in grain and straw, and increase in total NPK concentration might have enhanced grain yield. However, total (grain + straw) NPK concentration was not a good indicator of the yield response of indigenous aromatic or non-aromatic rice cultivars. To date, little information is available concerning the yield and high

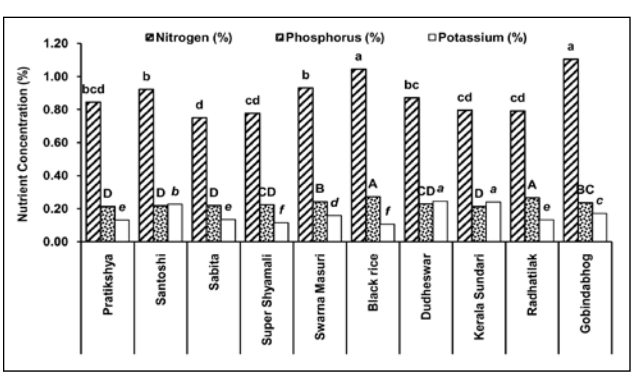

Fig. 1a. *Nutrient concentration (%) in rice grain of tested rice cultivars*

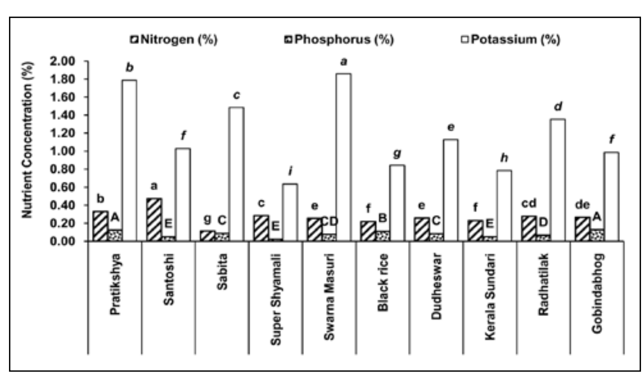

Fig. 1b. *Nutrient concentration (%) in rice straw of tested rice cultivars*

Table 3. *Yield attributes and yields of tested rice cultivars at harvest during rainy season (Pooled data of 2015 and 2016)*

Type of cultivars	Name of the cultivars	Panicle length (cm)	Panicle weight (g)	No. of filled grains $panicle^{-1}$	Test weight (g)	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Harvest index (%)
High Yielding Variety	Pratikshya	25.3cde	6.12a	131f	20.25e	5.40b	5.25c	47.0c
	Santoshi	29.2a	6.23a	221a	30.65a	6.00a	5.25c	53.3a
	Sabita	26.3bc	4.07c	142e	22.00d	4.05d	6.00b	40.3d
	Super Shyamali	27.3b	6.21a	102h	26.10b	5.40b	5.25c	50.7b
	Swarna Masuri	23.8ef	3.48d	160d	19.60e	4.50c	3.75d	54.5a
	Mean	26.38	5.22	151.20	23.72	5.07	5.10	49.16
Indigenous	Black rice	23.0f	3.33d	102h	23.75c	4.35c	6.75a	39.2de
	Dudheswar	23.2f	3.00e	205b	16.00g	2.85f	6.00b	32.2f
	Kerala sundari	26.0bcd	4.65b	179c	14.00h	3.15e	5.25c	37.5e
	Mean	24.07	3.66	162.00	17.92	3.45	6.00	36.30
Aromatic	Radhatilak	25.3cde	2.99e	116g	18.10f	2.25g	3.75d	37.5e
	Gobindabhog	24.2def	2.35f	91i	13.25h	1.95h	3.75d	34.2f
	Mean	24.75	2.67	103.50	15.68	2.10	3.75	35.85

The superscriptletters indicate DMRT rank for significant differences at $p< 0.05$ (otherwise statistically at par) nutrient use efficiency (NUE), and their relationship with NPK accumulation and utilization characteristics for indigenous aromatic or non-aromatic rice. Only few earlier studies revealed that higher K accumulation in its straw increases lodging resistance (Yang *et al*., 2004). Among HYVs, significantly higheramount of N, P and K concentration in rice straw was found in Santoshi, Pratikshya and Swarna masuri, respectively. Multiple linear regression analysis of grain and straw yield as a dependent variable showed that grain N concentration and straw P concentration had positive non-significant relationship with grain and straw yield, respectively (Table 4). Therefore, contribution of these factors could only bring little improvement in grain and straw yield, but not in a significant way.

Hierarchical clustering

Agglomerative Hierarchical Clustering (AHC) was performed for clustering the different homogeneous groups of rice cultivars on the basis of grain yield (Ward, 1963). Based on AHC a nalysis, a dendrogram is illustrated in Fig. 2 which reveals that 10 different types of rice cultivars (HYV, indigenous non-aromatic and aromatic) were grouped into three clusters based on cut off value of the average dissimilarity at 1.70. Cluster I included three superior HYVs (Pratikshya, Santoshi and Super Shyamali), Cluster II was comprised of two HYVs (Sabita and Swarna Masuri) and one indigenous rice cultivar (Black rice)

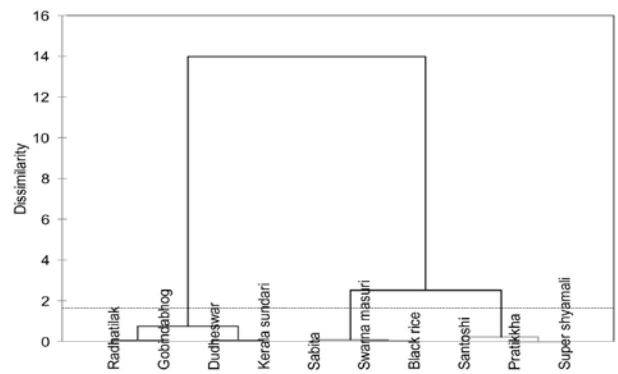

Fig. 2. Clustering of tested rice cultivars based on their yield by Agglomerative Hierarchical Clustering using Euclidean dissimilarity distance

and Cluster III included rest other indigenous non-aromatic and aromatic rice cultivars (Dudheswar, Kerala sundari, Radhatilak and Gobindabhog). The class statistics of different rice cultivar obtained from AHC analysis has been presented in Table 5.

Based on the results of Agglomerative Hierarchical Clustering (AHC) of tested rice cultivars, it can be concluded that three HYVs namely Pratikshya, Santoshi and Super Shyamali belong to same cluster which showed superiority over other cultivars with respect to grain yield. Moreover, the higher grain yield could be obtained with Santoshi followed by Pratikshya

Table 4. *Relationship between yield and nutrient content of tested rice cultivars (Based on pooled data of 2015 and 2016)*

Relationship	R^2	Adj. R^2	SEest	Durbin-Watson
Grain yield = 1.15 Grain Nitrogen - 40.38 Grain Phosphorus - 13.24 Grain Potassium + 14.73	0.312	-0.032	1.42	1.46
Straw yield = -2.43 Straw Nitrogen + 4.09 Straw Phosphorus - 0.98 Straw Potassium + 6.60	0.17	-0.28	1.17	0.82

Table 5. *Class statistics of Agglomerative Hierarchical Clustering*

Class	I	II	III
Rice Cultivars	Pratikshya, Santoshi, Super Shyamali	Sabita, Swarna Masuri, Black rice	Dudheswar, Kerala Sundari, Radhatilak, Gobindabhog
Within-class variance	0.120	0.053	0.291
Minimum distance to centroid	0.200	0.050	0.263
Average distance to centroid	0.267	0.167	0.438
Maximum distance to centroid	0.400	0.250	0.613

and Super Shyamali. The highest N concentration in grain was recorded in Gobindabhog, while both Black rice and 'Radhatilak' exhibited the highest P accumulation in grain. However, the maximum K content in rice grain was found in Dudheswar. Hence, it can be inferred that the productivity of rice under coastal ecosystem of West Bengal, particularly during *Kharif* season, could be increased through selection of suitable cultivars and their cultivation with site-specific approach.

REFERENCES

Adhikari, B., Bag, M. K., Bhowmick, M. K. and Kundu, C. (2011). Status paper on rice in West Bengal. In: Rice Knowledge Management Portal (RKMP), Directorate of Rice Research, Rajendranagar, Hyderabad.

Banerjee, H. and Pal, S. (2011). Effect of planting geometry and different levels of nitrogen on hybrid rice. *Oryza* **48**(3): 274-275.

Banerjee, H., Chatterjee, S., Sarkar, S., Gantait, S. and Samanta, S. (2017). Evaluation of rapeseed-mustard cultivars under late sown condition in coastal ecosystem of West Bengal. *Journal of Applied and Natural Science* **9**(2): 940-949.

Bemer, D. K. and Hoff, B. J. (1986). Inheritance of scent in American long grain rice. *Food Science & Technology* **26**: 876-878.

Ghasemi, H., Keyhani, A. Mohammadi, A. Rafiee, Sh. and Akram. A. (2010). Sensitivity analysis of energy inputs for barley production in Hamedan Province of Iran. *Agriculture Ecosystems & Environment* **137**: 367–372.

Hirose, T., Ohdan, T., Nakamura, Y. and Terao, T. (2006). Expression profiling of genes related to starch synthesis in rice leaf sheaths during the heading period. *Physiologia Plantarum* **128**(3): 425-435.

Islam, M. R., Sarker, M. R. A., Sharma, N., Rahman, M. A., Collard, B. C. Y., Gregorio, G. B. and Ismail, A. M. (2016). Assessment of adaptability of recently released salt tolerant rice varieties in coastal regions of South Bangladesh. *Field Crops Research* **190**: 34-43.

Joarder, N. and Eunus, A. M. (1981). An analysis of some mechanical tissues in lodging and non-lodging rice varieties. *Oryza* **18**: 85-89.

Mondal, P., Pal, S., Alipatra, A., Mandal, J. and Banerjee, H. (2012). Comparative study on growth and yield of promising rice cultivars during wet and dry season. *Plant Archives* **12**(2): 659-662

Sarangi, S. K., Maji, B., Singh, S., Sharma, D. K., Burman, D., Mandal, S. and 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.

Sarwar, A. K. M. G. and Prodhan, A. K. M. A. (2000). Variation in stem anatomy of rice cultivars. *Pakistan Journal of Botany* **32**(2): 259-264.

Ward J. H. (1963). Hierarchical grouping to optimize an objective function. *Journal of the American Statistical Association* **58**: 238-244.

Yang, C., Yang, L., Yan, T. and Ou-Yang, Z. (2004). Effects of nutrient and water regimes on lodging resistance of rice. *Chinese Journal of Applied Ecology* **15**: 646-650.