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Yield variability of Sub1 introgressed late-duration rice varieties of Odisha as evidenced by OJIP transient analysis

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ABSTRACT

In current climate changing environment, selection of suitable rice genotype is very important for sustainable rice productivity. Genetic diversity of seven late-duration rice (*Oryza sativa* L.) varieties (Swarna, Swarna Sub1, TDK, TDK Sub1, Bahadur, Bahadur Sub1 and a check variety Mrunalini) of Odisha were analyzed for yield attributing traits and photosystem II activity related to yield.100-grain weight was significantly high in TDK (2.95 g) with low grain number per panicle and TDK Sub1 (2.89 g) with significantly high fertile grain number. Significantly high harvest Index was recorded in TDK Sub1 with second highest plot yield of 49.39 q ha^{-1} which was 1.26-fold more than check variety Mrunalini. However, the highest yield was obtained in TDK (1.33-fold) followed by Swarna (1.14-fold) as compared to Mrunalini. Sub1 gene introgression yielded better in Bahadur *Sub1* which was not found in Swarna Sub1 and TDK Sub1. A significant positive correlation was noticed between 50% days to flowering *vs.* grain yield per plant (r = 0.96) followed by panicle number (r = 0.94). Plot yield was highly correlated with panicle length, panicle number, fertile grain percentage, flag leaf length, flag leaf area and grain yield per plant. Significant alteration of chlorophyll *a* florescent activity was noticed among the studied genotypes. O-J-I-P analysis revealed variable fluorescence intensity at 'J' and 'I' transient point was significantly higher in TDK and TDK Sub1 as compared to check variety Mrunalini which corroborate with highest yield among the studied varieties.The comparatively low productivity of Swarna and Swarna Sub1 might be due to low fluorescent intensity at 'J' and 'I' transient point as compared to check variety. Total performance index on absorption basis was fund significantly high in Swarna and Swarna Sub1 as compared to TDK and TDK Sub1 with higher yield performance. Cluster analysis confirmed close relation of Bahadur and Bahadur Sub1 as well as Swarna and Swarna Sub1. TDK and TDK Sub1 found distantly related as evident by PCA analysis which confirmed a high amount of genetic alteration due to Sub1 introgression in this variety with high grain number and high plot yield. The identified genetically distinct genotype TDK and TDK Sub1 could be selected for breeding partner with high photosynthetic activity, high grain weight with more grain number per panicle following conventional rice breeding program.

1. Introduction

Rice is used as primary food for most of the Indians besides the Asiatic populations of the world (Nahar *et al*., 2018). Most of the mid-early rice varieties are low yielder and cultivated in rainfed environment having less drought tolerant characters (Panda *et al*., 2022). Yield-limiting stress for rainfed rice ecosystems recorded significant yield loss that produce ~ 42 M ha in Asia (Hu *et al*., 2019). Frequent cyclone and flash flood caused havoc due to the growing global climate change specifically in Odisha (Donde *et al*., 2019; Ansari, 2021). So, the estimation of photosynthetic efficiency of rice in the current climatic condition is very important for more quality rice production and to evolve better breeding strategy under the growing population growth of the country. The response of genotypic efficiency against varied climatic conditions stimuli different physiological processes and mainly photosynthetic efficiency of different genotypes and prompts a number of physiological parameters in plants, that help to cope with

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various environmental conditions (Sahoo *et al.*, 2019). A large number of rice landraces compatible with varied agro-ecological conditions have been evolved time to time and a number of submergence introgressed varieties of different duration of maturity of rice have been developed in India which are being used against different climatic conditions as Megha variety (Das, 2018). To check the yield potential of rice varieties of late duration Sub1 introgressed varieties of rice grown in Odisha is very much essential to explore the genetic variability with regard to photosynthetic activity. Several attempts have been made to synthesize heterogeneous populations of rice taking into account different yield attributes to segregate the bulk population of rice (Das, 2018). Thus, a comparative analysis of the efficiency of Photosystem-II has been measured with yield parameters to correlate the genotypic effect on photosynthesis for higher yield and greater physiological activity among the late duration varieties of rice.

Chlorophyll molecules capture light energy during photochemical reactions of photosynthesis and the excess energy is dissipated as heat (Non-Photochemical Quenching) or emitted as chlorophyll *a* fluorescence (Maxwell *et al.*, 2000). Increasing photosynthesis leads to a decrease in extra energy dissipation. Thus, the efficiency of the photochemical reactions and the degree of heat dissipation is estimated by measuring the yield of chlorophyll *a* fluorescence which induces OJIP transient (Stirbet and Govindjee, 2011; Tsai *et al.*, 2019). OJIP transient analysis in submergence tolerance rice was reported earlier in some varieties of Odisha Panda and Sarkar (2012). The Photosystem II (PSII) activity in form of chlorophyll *a* fluorescence could be used as a screening technique to distinguish high yielding genotypes with distinct useful yield attributing traits for parental selection in rice breeding programme. However, the study on chlorophyll *a* fluorescence in different late-duration of rice of Odisha has not been reported earlier. We report a comparative study of PSII activity of different late-duration rice varieties of Odisha by the measuring chlorophyll *a* fluorescence activity to know its contributiontowards the yield potential of different varieties of rice along with their respective Sub1 introgressed genotypes to develop future parental selection strategies in conventional rice breeding plans.

2. Materials and methods

2.1 Plant materials

Six late-duration varieties (Swarna, Swarna Sub1, TDK, TDK Sub1, Bahadur, Bahadur Sub1) rice varieties along with a check variety (Mrunalini) were tested in field in Kharif season for the year 2020-21 in the experimental firm of Orissa University of Agriculture and Technology, Bhubaneswar, Odisha, India. Rice varieties were planted in a randomized block design with a spacing of 15 × 15 cm and 20 cm between plant to plantand in between row respectively. Farm Yard Manure was applied at the rate of 4.0 tones ac^{-1} in the field before 4 to 6 weeks of seed sowing and 10 kg of $ZnSO_4$ ac^{-1} was applied during the last puddling stage. NPK (0.5:0.5:0.5) kg^{-1} 100 sq. m was applied for robust seedling growth and NPK of 100:60:60 was applied during 30 days after transplantation, at active tillering stage, and at panicle initiation stage in the field. Morphological characters of vegetative and reproductive stages of rice plants were collected as per Table 1. Data of all parameters are the mean of two plots (replicas) for all rice varieties.

2.2 Yield attributes

Randomly three plants in each replication were selected for all the morphological characters of each rice variety. Days to 50% flowering and days to maturity were recorded for each variety during one season. The various agronomic characters considered for this study have been presented in Table 1. Detail procedure for measurement of agronomic traits of rice were taken as per our earlier paper (Das *et al.*, 2021).

2.3 Chlorophyll a fluorescence analysis

Parameters related to Chlorophyll *a* fluorescence were measured by a Multifunction Plant Efficiency Analyzer (M – PEA) (Hansatech Instruments Ltd, UK) following the method of Strasser *et al.* (2010) standard method. The leaf samples were illuminated with continuous red light after a dark adaptation of 20 min from the middle part of a leaf blade using leaf clips. The Chl *a* fluorescence transient shows the initial (F_0) to the maximal (Fm) fluorescence value, which has been recorded at O-step (20 µs), J-step (2 ms), I-step (30 ms), and P-step (0.5–1 s) (Šimiæ *et al.*, 2014). The transients in leaves were induced by red light (peak at 650 nm) of 3,000 ìmol (photon) m^{-2} s^{-1} provided by an array of light-emitting diodes with a light pulse exposure time of 1 sec. Photosynthetic data were collected for 118 points in 1 sec for each leaf sample. The fluorescence signal was recorded with a maximum frequency of 105 points s^{-1} (each 10 µs) within 0 to 0.3 ms, after which the frequency of recording gradually decreased collecting a total of 118 points within 1s. PSII behavior was determined on the basis of parameters recorded and derived from the OJIP transients based on Energy Fluxes in chloroplast membranes. The chlorophyll *a* fluorescence parameters and equations of the OJIP-test were given in Table 1 (Tsimilli-Michael and Strasser, 2008).

2.4 Statistical analysis

All the represented mean data are collected from replicas of three samples. Analysis of variance as well as Duncan's Multiple Range Test were made for all mean morphological and biochemical data (Sokal and Rohlf, 1995). UPGMA (Unweighted Pair Group Method with Arithmetic Mean) is a simple agglomerative (bottom-up) hierarchical clustering method. The similarities of presence or absence of the different agronomic characters were calculated in each variety from the mean values of all the agronomic parameters.

3. Results

3.1 Variation in agronomic characters

The agronomical characters of seven studied rice varieties have been given in Table 1. Days to 50% flowering varied from 98 in Bahadur Sub1 to 111 in Bahadur. The range of mean plant height varied from 86.65 cm in Swarna to 111.5 cm in Bahadur. The panicle length was minimum in 21.42 cm in Mrunalini to 26.29 cm in TDK Sub1 whereas panical number ranged from 8 in Bahadur Sub1 to ~12 in Swarna and Swarna Sub1. The fertile grain number was recorded ~89 per panicle in TDK to ~111 per panicle in Mrunalini. Fertility percentage showed a range from ~62% in Swarna to ~89% in TDK Sub1. 100-grain weight significantly varied among the varieties with a prominent difference between Bahadur and Bahadur Sub1 (Table 1). Plot yield found highest in TDK (52.65 qt ha^{-1}) to lowest in Bahadur (32.58 qt ha^{-1}). The Sub1 introgressed varieties showed lower plot yield as compared to its normal varieties (Table 1).

Table-1

Mean performance of seven late-duration genotypes of rice with respect to yield attributing characters*

Variety	DF	PH	PL	PN	FGN	F%	100-GW	HI	FLL	FLA	GYP	PY
Swarna	100.5b	86.65e	22.83b	12.34a	108.5d	61.94d	1.91a	36.0b	22.08d	18.86d	13.6a	44.77c
Swarna Sub1	103b	86.9e	21.75b	12.34a	109.5d	71.22c	1.91a	40.0a	19.08d	15.22e	16.5a	41.44d
TDK	101b	93.65d	23.5b	7.83b	89.5e	82.68b	2.95a	35.0b	26.17c	24.7c	11.61b	52.65a
TDK Sub1	99.5c	99.6c	26.92a	7.66b	134c	88.82a	2.89a	41.0a	29.83b	29.76b	15.15a	49.39b
Bahadur	111a	111.5a	26.67a	8.5b	169a	82.46b	2.01a	34.0b	24.33c	30.78b	14.21a	32.58f
Bahadur Sub1	98c	108.55a	25.08a	8b	149.5b	81.81b	1.97a	35.0b	27.9b	30.22b	13.88a	36.36e
Mrunalini	108a	105.5b	21.42b	9.5a	111.5d	68.86c	2.1a	33.0b	33.08a	35.23a	12.97b	39.3d
Mean	103	98.90	24.02	9.45	124.5	76.82	2.24	36.0	26.06	26.39	12.97	39.3
Stand. dev	4.76	10.14	2.24	2.06	27.59	9.58	0.46	0.03	4.73	7.16	13.98	42.35
Std. error	1.80	3.83	0.84	0.77	10.43	3.62	0.17	0.01	1.78	2.70	1.55	7.10
Coeff. var	4.63	10.25	9.33	21.82	22.16	12.47	20.61	8.37	18.15	27.13	0.58	2.68

DF = Days to 50% flowering, PH = Plant height (cm), PL = Panicle length (cm), FGN = Fertile grain number per panicle, F% = Fertility percentage, 100-GW = 100 grain weight (g), HI = Harvest index, FLL = Flag leaf length (cm), FLA = Flag leaf area (cm^2), GYP = grain yield per panicle, PY = Plot yield (qt ha^{-1}).

*Data pooled from a total of 3 replicas each of two plots. Mean values (within column) followed by different alphabets (superscript) are significantly different ($p < 0.05$; Duncan's Multiple Range Test [DMRT]).

Correlation coefficient analysis among different attributes showed very interesting results. Days of 50% flowering found significant correlation with panicle length, panicle number, fertile grain number, fertility percentage, 100-grain weight, flag leaf length, and grain yield per plant (Table 2). Plant height was found high correlation with harvest index. 100-grain weight, and grain yield per plant. Plot yield and harvest index found very high significant correlation with panicle length (r=0.82 & r=0.70), panicle number (r = 0.86 &r = 0.67), fertility % (r = 0.78 & r = 0.63). Fertility % found significant correlation with harvest index (r = 0.63), grain yield per plant (r = 0.99) and plot yield (r = 0.78). Flag leaf length (r = 0.93), flag leaf area (r = 0.50), and grain per plant (r = 0.56) showed significant correlation with plot yield.

Table-2

Correlation coefficient values among different yield attributing characters of late-duration varieties of rice.

	PH	PL	PN	FGN	F%	100-GW	HI	FLL	FLA	GYP	PY
DF	0.34	0.91	0.94	0.50	0.78	0.50	0.28	0.89	0.45	0.96	0.19
PH		0.22	0.08	0.05	0.25	0.90	0.24	0.14	0.01	0.70	0.14
PL			0.10	0.05	0.03	0.45	0.70	0.72	0.39	0.80	0.82
PN				0.40	0.01	0.13	0.67	0.10	0.05	0.37	0.86
FGN					0.31	0.50	0.82	0.83	0.29	0.48	0.06
F%						0.12	0.63	0.48	0.33	0.99	0.78
100-GW							0.55	0.39	0.68	0.44	0.03
HI								0.47	0.25	0.06	0.33
FLL									0.01	0.32	0.93
FLA										0.40	0.50
GYP											0.56

3.2 Cluster analysis of morphological attributes and PCA analysis

Cluster analysis, based on the morphological attributes, revealed that, Bahadur, Bahadur Sub1 and TDK Sub1 formed a single group forming Cluster-I where Bahadur formed a out group and Swarna, Swarna Sub1, TDK along with check variety Mrunalini formed Cluster-II where Mrunalini remained out group (Fig. 1). However, all the varieties formed a single tree with genetically more distantly related varieties forming Cluster-II than Cluster-I having less genetic variability. The same type of result was also found in Principal Component Analysis (PCA) as evident in Figure 2. TDK Sub1 and TDK although found in Cluster-I and Cluster-II respectively, but they found in different quadrant. Swarna and Swarna Sub1 found genetically more closer as compared to Bahadur Sub1 and Bahadur. The most distant relation was found between TDK and TDK Sub1 where Mrunalini shared a same quadrant with TDK.

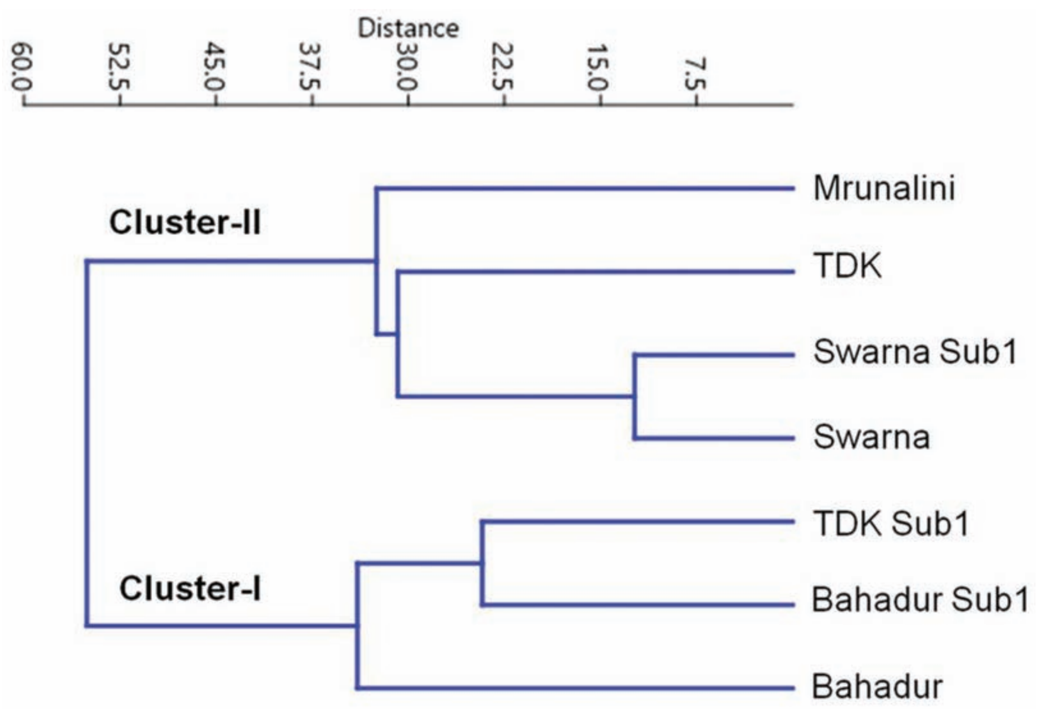

Fig. 1: Cluster analysis showing genetic relationships among different late-duration varieties of rice based on yield attributing characters.

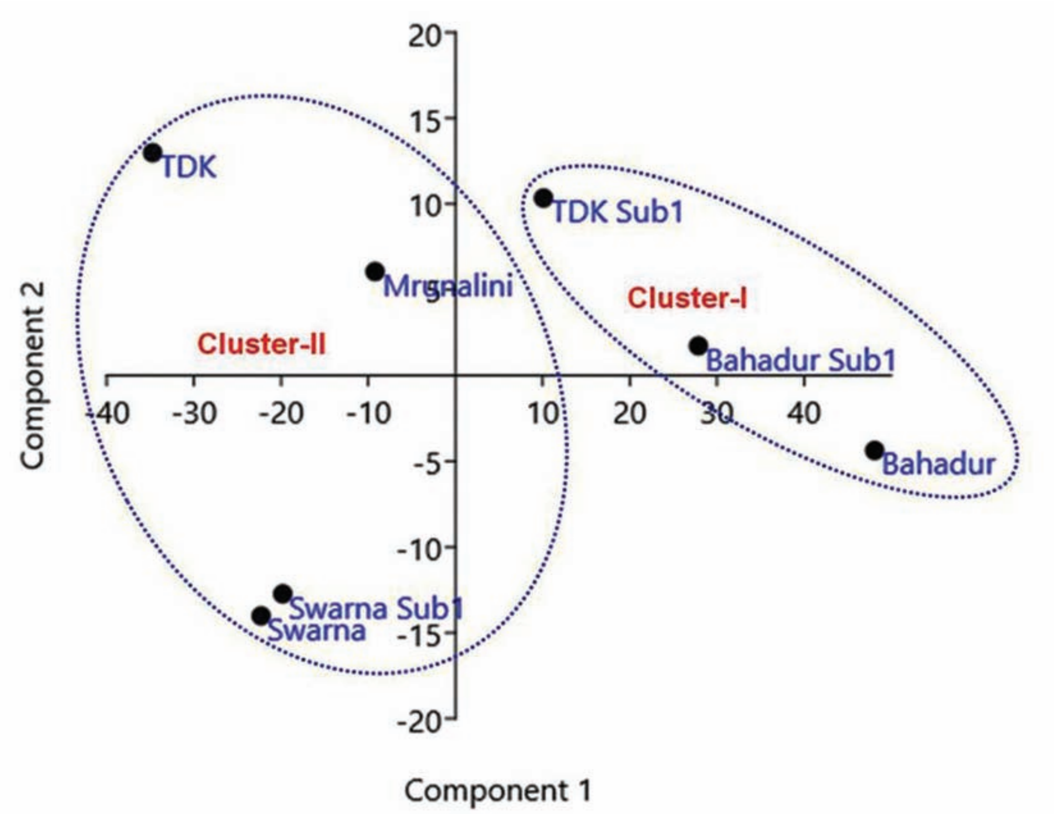

Fig. 2: Principle component analysis showing genetic relationships on the basis of phenotypic variability among the seven varieties of rice.

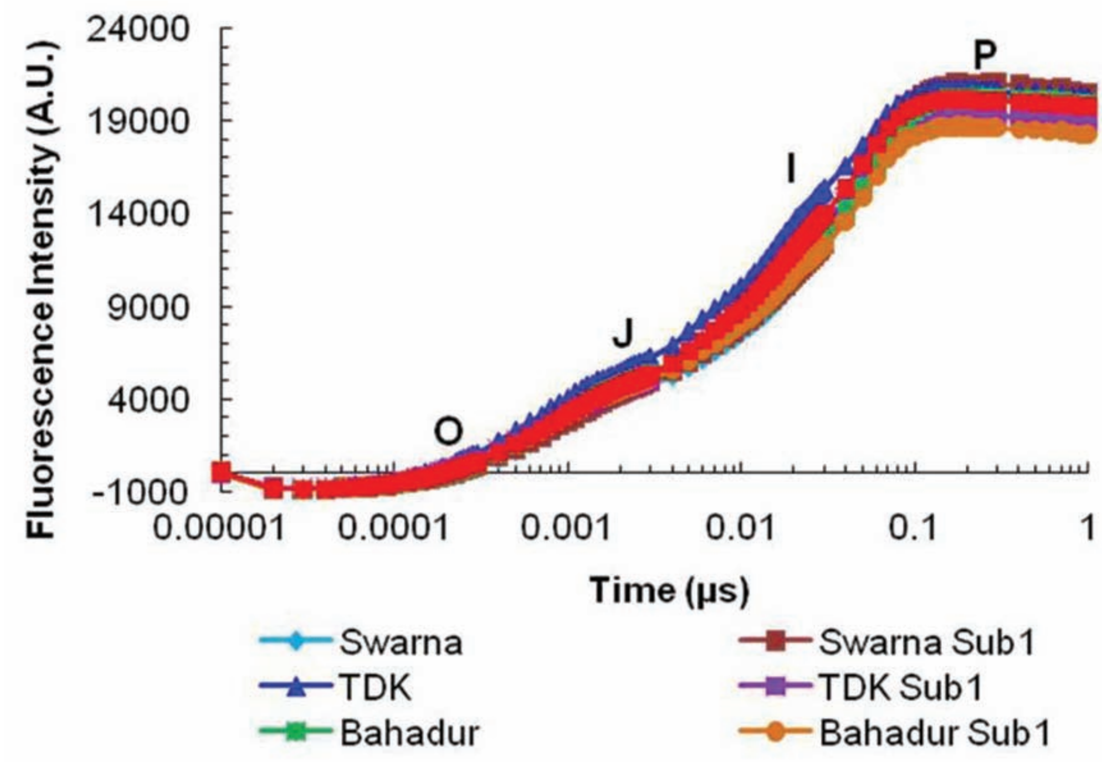

Fig. 3: OJIP graphs of PSII chlorophyll *a* fluorescence of flag leaf of seven late-duration varieties of rice.

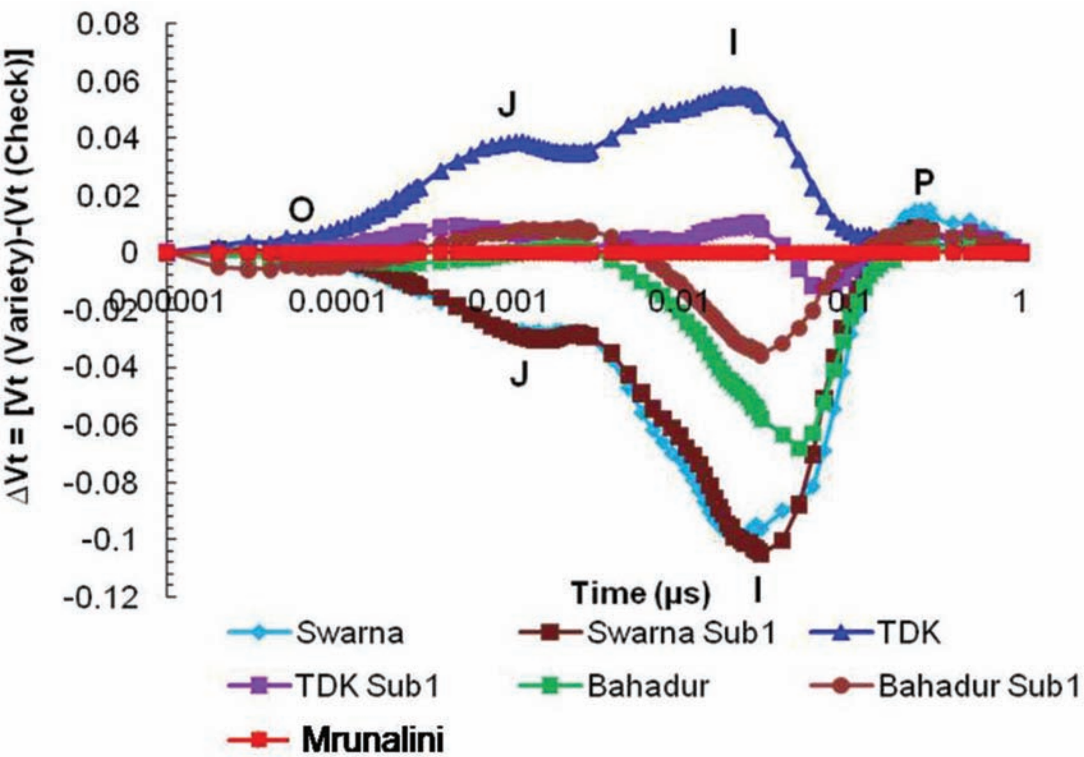

Fig. 4: Changes in prompt fluorescence (PF) curves in seven late-duration varieties of rice. PF curves plotted on a logarithmic time scale from 20 μs to 1 s (JIP time). The steps O (at 20 μs), J (at 2 ms), I (at 30 ms), and P (peak) are marked. Each curve is the average of 3 replicate measurements. Variable fluorescence curves (ÄV = Ä[(Ft—Fo)/(Fm—Fo)]), which were constructed by subtracting the normalized (between the O step and P step) values of the PF recorded in check variety (Mrunalini).

3.3 OJIP analysis

From the OJIP graph, it was observed that there are variable significant differences of different steps of OJIP curves among different varieties (Fig. 3). Chl *a* fluorescence transient shows normal OJIP curves in all the studied seven varieties of rice (Fig. 3). Comparatively high PS-II fluorescence activity was found in Swarna Sub1 followed by Swarna in 'P' transient point. TDK and TDK Sub1 showed significantly lower value at 'I' transient. The higher values of energy flow was noted in 'J' point in Swanra Sub1 and Swarna followed by Bahadur, Bahadur Sub1, TDK Sub1 showed at per with check variety Mrunalini. TDK showed remarkable low energy flow at 'J' transient point as compared to check variety (Fig. 4). Among the studied varieties, plot yield was significantly high in Sub1 introgressed Bahadur (36.36 qt ha^{-1}) as compared to its normal (32.58 qt ha^{-1}) which was significantly lower than check variety (39.30 qt ha^{-1}). In contrary, rest of the varieties showed higher yield in respective varieties without Sub1 introgression.

3.4 Chlorophyll fluorescence studies

Quantum yield (at t=0) of energy dissipation i.e.Fo/Fm could not show much significant variation (Fig. 5). Relative variable fluorescence at J step (Vj) was highest in TDK and lowest in Swarna Sub1 as compared to check. Relative fluorescence in and I step (Vi) also significantly varied among the varieties. The same type of result was also found in ABS/RC (Absorption per Reaction Centre), Dissipation per Active Reaction Centre (DI_0/RC), Trapping per Active Centre (TR_0/RC). Electron Transport per Active Reaction Centre (ET_0/RC) found lowest in Bahadur and highest in TDK. The flux of electrons transferred from QA to final PSI acceptors per active PSII (RE_0/RC) was maximum in Swarna, Swarna Sub1 followed by Bahadur Sub1, Bahadur. No variation was noticed in the φ(Po) whereas probability of trapped excitation which was used in electron transport beyond QA i.e.$^{\Psi}(E_0)$ and the maximum quantum yield for primary photochemistry (at t=0) i.e. Quantum yield of the electron transport beyond QA Õ(E_0) recorded TDK while highest noted in Swarna Sub1. Quantum yield for reduction of end electron acceptors at the PSI acceptor side (φR_0) showed a maximum in Swarna and Swarna Sub1. The electron transfer efficiencies to PSI acceptor (ΔR_0) was found similar trend (Fig. 5). The performance indices, Absorption Basis (PIabs) found lowest in TDK and highest in Swarna and Swarna Sub1.

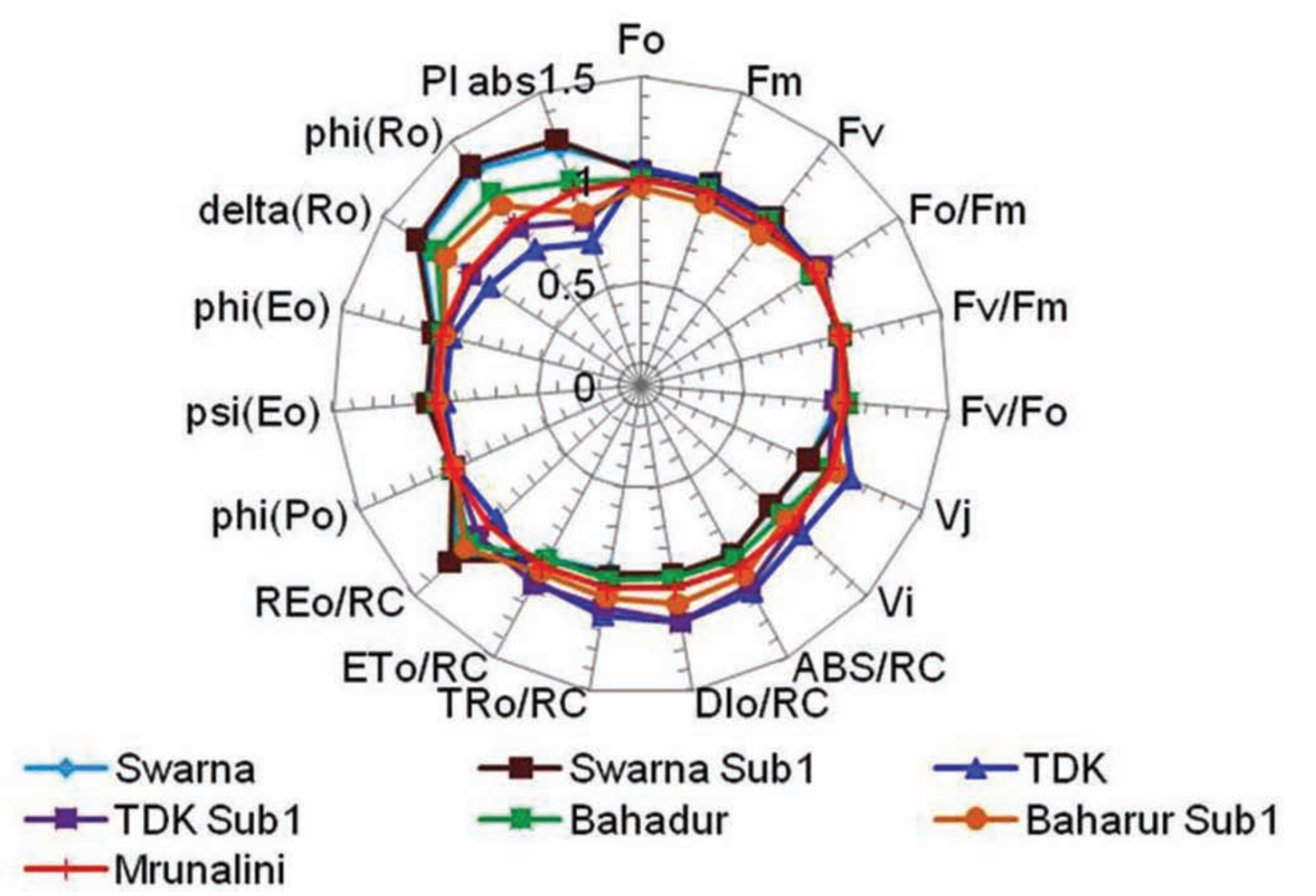

Fig. 5: Comparative analysis of radar graphs of different OJIP transient parameters in seven late-duration seven varieties of rice.

4. Discussion

4.1 Genetic analysis of yield attributing characters

The variations of morphological characters of late duration rice was significant.The grain yield and plot yield properties of rice were influenced directly by some of the characters while some other characters are indirectly responsible for the yield. The coefficient of variation (CV) is an important tool to analyze relative variability of genotype parameters for the biological experiment is <10% (Acquaah 2012). Most of the traits like days to 50% flowering, plant height, panicle length, harvest index showed CV < 10%. Such type variations were observed in different varieties of rice which is according to our result (Yaqoob *et al*., 2012; Ikmal *et al*., 2019). The CV values were ranged from ~4.63% to ~20.6% in other morphological characters. Thus, high CV in different characters among the varieties might be due to background variation of genotypes having Sub1 gene which have been established as normal varieties with distinct morphological characters during long cultural practices.The variability as observed in plant height as recorded from 86.65 cm in Swarna to 111.50 in Bahadur might be due to genetically controlled ethylene-responsive transcription factors beside other physiological factors. SNORKEL1 (SK1) and SNORKEL2 (SK2) gene activation due to low oxygen level during submergence (Colmer and Voesenek, 2009; Bailey-Serres *et al*., 2010) may not be active in the case of Sub1 introgressed varieties in normal environmental conditions. Thus, the varieties with the Sub1 gene showed their efficiency in normal condition which might be the alteration of accessory position effect of genes which affect plant growth and grain yield and stable during selection procedure.

It is interesting to note that flag leaf length and flag leaf area played a big role among the late-duration varieties. The highest yield was found in TDK (52.65 qt ha-^{1}) followed by TDK Sub1 (49.39 qt ha^{-1}) showed more flag leaf length and area. The second highest plot yield recorded in Swarna

(44.77 qt ha^{-1}) and Swarna Sub1 (41.44 qt ha^{-1}) showed less leaf length and leaf area as compared to TDK varieties of Cambodia origin. The lowest plot yield was recorded in Bahadur and Bahadur Sub1 (Table 1) with higher leaf area as compared to Swarna as well as check variety Mrunalini (39.30 qt ha^{-1}). The variation of leaf area is thus, an important characteristic for higher light-harvesting capacity with the generation of more photosynthates towards the yield attributes which can be considered for breeding purpose. Although, ethylene mediated activation of α-amylase and activation of GA and ABA on growth in rice with the activation of genes like CIPK15, MYBS1, and SnRK1 in low oxygen conditions might be cause of genetic control of leaf growth (Nghi *et al*., 2019; Pucciariello, 2020). Thus, the length of rice plant and leaf length is the genetically controlled mechanism and all the Sub1 introgressed varieties which might have not expressed that gene in the normal non-submergence conditions in this experiment.

The morphological variation was found significant among different characters as depicted in Duncan multiple range test. A significant correlation was observed between fertile grain number with days to 50% flowering. Plant height showed a significant positive correlation with flag leaf length, area and plot yield. Fertile grain number showed a significant correlation with grain yield per plan which had a correlation with plot yield. The morphological variation of rice agronomic characters was also reported earlier by us (Dikshit *et al*., 2013, Das *et al*., 2021). The varieties with long grain having good morphological attributes could be used for crop improvement through conventional breeding approach. Although, considerable crop genetic diversity continues to be maintained in farms in traditional varieties (Jarvis *et al*., 2008).

Variation of panicle length was observed in Bahadur (25.08 cm) with highest fertile grain number of 169 per panicle. However, lowest fertile grain number (89.5 per panicle) having maximum plot yield of 52.65 qt ha^{-1} might be due to highest 100-grain weight in TDK which could be a very good agronomic character to choose a breeding partner in rice improvement programme. The introgression of Sub1 gene in TDK although increase fertile grain number significantly without much variation of 100-grain weight also failed to perform equal to TDK in non-submergence condition. The productive tiller producing genotypes could produce higher grain yield which was in accordance to our findings as reported earlier in other varieties of rice (Dutta *et al*., 2002). The positive correlation of number of filled grains panicle with yield could be a critical in yield improvement program of rice (Samonte *et al*., 1998; Mahto *et al*., 2003). Although panicle development and immergenceare important additional factors to have the greater yield in rice (Hori *et al*., 2012).Thus, the improvement of primary branch number could be made by transferring this genetic trait from a stabilized potential donor. The fertile grain number showed significant variation among the studied varieties. All these yield attributing characters are directly related to grain yield and plot yield which need to be carefully observed and an integrated approach of considering all these yield characters needs to be addressed in parent selection of rice during breeding. However, SUS (starch synthesizing enzymes sucrose synthase) and AGPase (ADP Glucose Pyrophosphorylase) activation in endosperm which was found to be blocked with high ethylene synthesis upon activation of Sub1 gene in Swarna Sub1 in submerged condition (Kuanar *et al.*, 2019) causing low starch and carbohydrate accumulation in grains in the developing spikelets. This is similar to the higher accumulation of sugars in inferior spikelets of rice panicles as reported by Naik and Mohapatra, (2000) in addition to the activities of SUS and AGPase in grain-filling of rice (Tang *et al*., 2009; Zhu *et al*., 2011) which are responsible for starch synthesis *vis a vis* sink strength of the grain (Panda *et al*., 2015). In addition, the not used sugar during starch conversion accumulate in caryopsis (Patel and Mohapatra, 1996). These are the limiting factors for production of high quality grains in poorly-developed spikelets in rice.

4.2 Cluster analysis on the basis of morphological attributes

All the varieties formed two clusters *i.e.* Cluster-I and II having Bahadur, Bahadur Sub1, TDK Sub1 in one cluster and rest are in another cluster. The genetic closeness was recorded in Bahabur and Swarna along with their Sub1 introgressed varieties. The check variety Mrunalini formed an out group and a substantial genetic variability was recorded between TDK and TDK Sub1. The use of more genotypes could yield better genetic relations among the studied rice varieties. Principal component analysis (PCA) is used in exploratory data analysis and for making predictive models. PCA data also confirmed Distinct genetic distance between TDK and TDK Sub1 which might have happened due to the ingrogression of Sub1 gene. A similar type of study in morphological and submergence-related traits in different land rice supports our result (Kumar *et al*., 2016). However, cluster formation and grouping of genotypes are also greatly influenced by environmental and soil factors in the landraces of indigenous rice (Wangpan *et al*., 2018). PCA analysis for different attributes interactions found useful for intensive selection procedures could be used for the improvement of submergence tolerance rice.

4.3 Photosynthetic activity and chlorophyll a fluorescence analysis

High PS-II fluorescence activity was found in TDK, TDK Sub1, Swarna and Swarna Sub1 among the late-duration varieties.The lowest was observed at 'P' transient point in Bahadur Sub1. TDK found the highest PSII activity having more plot yield (52.65 qt ha^{-1}). The variations in the 'J' transient point were no significantly noticeable in TDK Sub1, Bahadur, Bahadur, Sub1 as compared to check variety Mrunalini. Significant high 'J' transient and 'I' transient was noticed in TDK with higher productivity. Fv/Fm ratio found no significant variation among the studied varieties which is the maximum quantum yield of primary PSII photochemical reactions, that is mainly used to state the primary health as reported in various plant (Kalaji *et al*., 2017;Stirbet*et al.,* 2018). The presence of stress signature resulting due to either inactivation of PSII or inhibition of quenching might be the causes of low Fv/Fm (Long *et al*., 1994).

Relative variable fluorescence at 'J' step (Vj) and 'I' step (Vi) high in TDK and TDK Sub1. ABS/RC, DI_0/RC, TR_0/RC also showed the same type of result. ET_0/RC was more in TDK which was quite similar with the flux of electrons transferred from QA to final PSI acceptors per active PSII (RE_0/RC). The lowest $^{\Psi}(E_0)$ was recorded in TDK and TDK Sub1 *i.e.* the quantum yield of the electron transport beyond QA. However, quantum yield for reduction of PSI acceptor side (φR_0) showed highest in Swarna and Swarna Sub1 among the studied varieties which were also noted the inefficiency of electron transfer to final PSI acceptors.The performance indices reflected in PIabs for although showedhighest in Swarna and Swarna Sub1, followed by Bahadur, as compared to Mrunalini and lowest in TDK followed by Swarna Sub1, Bahadur Sub1 which might be related to some other factors which are genetically controlled. Radar Plot of different OJIP parameters showed significant variation in RE_0/RC, ΔR0, φR_0 which was reflected in PIabs. Thus, comparatively high plot yielded TDK and TDK Sub1 with distinct genetic background could be used as breeding partner to improve grain yield per panicle and panicle number in other rice variety through conventional breeding methods. However, delayed senescence of flag leaf and sty green character could ensure prolonged photosynthesis without significant yield improvementexcept better grain filling. Furthermore, survival of genotypes with Sub1 gene during flooding by triggering stem elongation and conserving carbohydrates (nonstructural) for fast regeneration (Bailey-Serres *et al*., 2010). Although, semi-dwarf genotypes were reported to perform better growth over Sub1-introgressed varieties (Kuanar *et al*., 2019) with less growth and delayed flowering and maturity as evident in our study.

5. Conclusion

The genotypic variations of late-duration varieties of indica rice were noticeably variety-specific with divergent clusters on the basis of measured agro-morphological traits for selection of a breeding partner in future crop improvement programs in rice. Selection of the traits based on plant height, leaf area, number of spikelets per panicle, leaf area, grain length, breadth, 100-grain weight in the promising TDK and TDK Sub1 could be used as genetic resources for rice breeding programme. Clustering patterns and PCA could also suggest the above varieties for breeders about the suitability of different yield attributes of rice for future accomplishments. Genotype specific OJIP parameters confirms better photosynthetic activity of high yield varieties like TDK, TDK Sub1, Swarna, Swarna Sub1. The yield attributes can be supplemented with a large number of PSII activity-related parameters like photosynthetic efficiencies, electron transfer from PSII to PSI acceptor for selection of better yield attributing rice varieties for rice breeding purpose.

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