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Relationship between biometric and biophysical parameters with yield in traditional rice varieties in coastal saline belts of Tamil Nadu

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Rice is the major food crop of Asian and African countries. The nutritional qualities of rice grains vary based on their nutrient and amino acids content. Indigenous varieties are conserved for a variety of reasons. Farmers have great awareness about the rice varieties they were using and their importance. Some of them are pest and disease resistance (Sigappu Kuruvikar); some of them are suitable for saline soil (Kalarpalai); flood and drought resistance (Samba Mosanam and Vadan Samba) and provide energy and stamina (Mappillai Samba). In order to study the response of these traditional varieties to salinity, a replicated trial was conducted in a completely randomised block design (RBD) with 50 varieties (47 traditional rice varieties and 3 local varieties as check) in the coastal saline areas of Tamil Nadu. In this study, data on biometric, biophysical, growth analysis and yield parameters were recorded and statistical analysis of clustering of genotypes, correlation analysis, multidimensional scale and principal component analysis (PCA) were also done using the statistical tools for agricultural research software with the varieties. The results revealed that the varieties Raja mannar, Pal kudaivazhai, Kuzhiadichan and Raja mudi performed well by recording better observations in biometric, biophysical, growth analysis and yield parameters.

Keywords: Biometric, Biophysical, Growth analysis, Traditional rice, Yield parameters

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Rice, botanically known as *Oryza sativa,* is unique among the cultivated field crops. Rice is known to be a staple food for one third of the world's population and also the first fully sequenced crop[1-2]. Rice due to its diploid genetics (2n=24) and relatively small genome size, considered as a 'model crop'[3-4], with considerable level of the polymorphism[5].

The cultivation and selection of rice by farmers in different environmental conditions resulted in the availability of abundant cultivars. It has been reported that ~120,000 rice varieties were cultivated in more than hundred countries[6]. Thereby, rice cultivars offer vast opportunities to researchers to study the varietal divergence among them.

Among all the Asian countries, India is blessed with a large diversity of rice germplasm in its vast productive land area accounting for 20% of global rice production[7]. The germplasm was improved via selections, based on advantageous characters (grain yield, aroma, cooking quality) and climate resilient nature to environmental stresses[8].

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Aromatic rice crops represent a special group of Indian rice cultivars and are rated as the best in quality and aroma[9]. With the growing demand for aromatic rice in the local and international market, high importance has to be laid on development and improvement of such new varieties. In spite of high quality traditional basmati varieties in India, the research is continued for the improvement of many new basmati and hybrid rice varieties with better quality to meet the increasing demand both domestically and internationally.

For utilizing useful donor traits and for protecting unique rice varieties, systematic study and characterizing rice germplasm is important. Characterization is required to find genetic relationships among the genotypes, for selection of diverse parents in rice breeding program and for the improvement of quality traits in rice[10].

The quality of rice grain is important as most of them are cooked and consumed as a whole kernel, while a small percentage alone is converted into flour or flakes[11]. From quality point of view rice cultivars can be assessed into 03 main categories, i.e., physical, nutritional and processing qualities[12]. Nutritional qualities of diverse rice grains depend upon starch, protein, carbohydrates, vitamins, minerals, ash, amino acids and fat. Therefore, the characterization of morphological, physico-chemical, cooking, eating and textural properties of rice grains determine the overall assessment of divergence among rice cultivars based on quality traits[13].

Indigenous varieties are conserved for a variety of reasons. Some of which are pest and disease resistant (Sigappu Kuruvikar); some are suitable for fodder and roofing material (Kullakar); saline soil (Kalarpalai); energy and stamina (Mappillai Samba); flood and drought resistant (Samba Mosanam and Vadan Samba); medicinal properties (Pitchavari for curing diarrhea); useful for pregnant and lactating mothers (Navara and Neelan Samba).

Besides all this, it is very important to conserve rice genetic pool to help in times of disasters like tsunami. Only certain traditional varieties came to rescue of farmers when their lands were affected by disasters like Tsunami. These varieties have to be planted and conserved in various regions in order to prevent them from extinction. Indigenous varieties are in limited availability with farmers and these varieties cannot be assessed from universities and research institutes. Only by providing adequate support to the farmers growing these varieties, they can be made available to other farmers and public.

Occurrence of salinity and its severity are expected to increase around 25% by 2050 particularly in deltaic coastal regions and other vulnerable regions[14]. Saline water used and high soil salinity may also exhibit an adverse effect of salt stress in crop plants[15]. Adaptation of plants to salinity during early seedling stages is crucial for the establishment of the crop. Soil salinity reduces the germination of seeds by NaCl toxicity or by preventing water uptake by seed[16]. Even though rice cultivation is common in moderately saline soils, cultivation of traditional rice varieties in saline soils and their biometric, biophysical relationship with yield under such conditions has not been studied so far. Hence, an attempt has been made for such a study with 47 traditional rice varieties in the coastal saline areas of Tamil Nadu. In this study, observations like biometric, biophysical and yield parameters were recorded in traditional rice varieties cultivated under coastal deltaic areas of Tamil Nadu. Statistical analysis of clustering of genotypes, correlation analysis, multidimensional scale and PCA were also done using the statistical tools for agricultural research software with the varieties.

Material and methods

The study was conducted under natural saline condition (pH: 7.7, EC: 3.6) at the Plant Breeding Farm, Annamalai University (11.24 N Latitude and 79.41 E Longitude with +5.79 m above mean sea level) with 47 traditional rice genotypes in 2017 and 2018 (Table 1). Completely Randomised Block Design (RBD) with three replications was followed and mean values of two year data were taken for statistical analysis.

Biometric parameters

All the biometric parameters were recorded for all the genotypes. Plant's height were measured and expressed in cm $plant^{-1}$. The biomass production was recorded from 10 plants selected at random which were uprooted with the intact root system and were washed to remove the soil particles, dried under shade for 24 h, then kept in the hot air oven at 100°C for 24 h. The dried plants were kept in desiccators for 30 min and the mean weights were recorded in grams.

Growth analysis parameters

Four growth analysis parameters viz., leaf weight ratio, relative water content, relative growth rate and absolute growth rate were studied for all the varieties. For RWC, the samples were taken at 60 DAS whereas, for other parameters, observations were taken at an interval of 15 days (60–75 DAS). Relative water content was calculated as per the formula[17]. The water saturation deficit (WSD) was also calculated by using the following formula

WSD=100–RWC (%)

Leaf weight ratio was worked out by dividing the dry weight of leaves to whole plant dry weight. Absolute growth rate calculated by the following formula and expressed as cm day^{-1}.

$AGR=h_2-h_1/t_2-t_1$

Where, h_1 and h_2 are plant heights at times t_1 and t_2.

Relative growth rate was worked out as per the formula [18] by taking plant dry weight regularly during growth period and represented as day^{-1}.

$RGR=\log_e W_2-\text{Log}_e W_1/t_2-t_1$

Where, W_1 and W_2 are the plant dry weight at timesof t_1 and t_2.

Biophysical parameters

Gas exchange parameters viz., leaf photosynthetic rate (Pn), transpiration rate (Tr) and stomatal

Table 1 — List of Genotypes

Sl. No	Code	GENOTYPES	Sl. No	Code	GENOTYPES
1	G1	SIVAPU KAVUNI	26	G26	MARATHONDI
2	G2	SELAM SAMBA	27	G27	SORNAMUGI
3	G3	VALAN	28	G28	KALUNDAI
4	G4	ARUPATHAM KURUVAI	29	G29	BOOMMI
5	G5	KARUDAN SAMBA	30	G30	KARUVACHI
6	G6	NAVARA	31	G31	POONKAR
7	G7	KARUNKURUVAI	32	G32	KATTU YANAM
8	G8	KALAN NAMAK	33	G33	KARUPU KAVUNI
9	G9	SEERAGA SAMBA	34	G34	KUZHI ADICHAN
10	G10	MILAGU SAMBA	35	G35	MAPILLAI SAMBA
11	G11	KAIVARAI SAMBA	36	G36	ATHUR KICHADI
12	G12	KUDAIVAZHAI	37	G37	MANJAL POONI
13	G13	RAJAMUDI	38	G38	ILLAPAI POO SAMBA
14	G14	PAL KUDAIVAZHAI	39	G39	SORNA MASURI
15	G15	CHINNAR	40	G40	KICHADI SAMBA
16	G16	OTTADAM	41	G41	MYSORE MALLI
17	G17	VADAN SAMBA	42	G42	KULLAKAR
18	G18	SINKINI KAR	43	G43	PERUNKAR
19	G19	THULASI VASAM	44	G44	THOOYAMALLI
20	G20	KANDA SALI	45	G45	BASUMATHI
21	G21	RAJA MANNAR	46	G46	SOOR KURUVAI
22	G22	THANGA SAMBA	47	G47	KATTUPOONI
23	G23	NEELANJ SAMBA	48	G48	CSR10
24	G24	KOTHAMALI SAMBA	49	G49	TRY1
25	G25	KOONDUKAR	50	G50	IR64

conductance (Cs) were measured from two uppermost fully expanded leaves from all the genotypes using LICOR-6400 XT Portable Photosynthetic system (Lincoln, USA) and expressed as mg CO_2 $m^{-2}s^{-1}$, mmol H_2O $m^{-2}s^{-1}$and mol H_2O $m^{-2}s^{-1}$ respectively. All these estimations and measurements were made between 10.00 am – 11.00 am from each treatment.

Yield parameters

Total number of tillers per plant was counted (by average of all tillers of a plant considered as panicle/plant). Panicle length was taken from ten selected plants randomly from each variety and expressed in cm. 1000 seeds collected from the matured panicle were weighed and expressed in grams. Seeds from the 10 selected plants were collected manually, cleaned, dried to constant moisture content, weighed and expressed as 1000 grain weight. The grain and straw yield were recorded and expressed as $kgacre^{-1}$.

Statistical analysis

The mean values were computed for each genotype over 03 replications. The variances and the standard errors of mean were computed from the deviation of the individual values[19]. Correlation (SPSS 16.0) and PCA (STAR – Statistical Tool for Agricultural Research By IRRI) were conducted and calculated using the standard formula[20,21]. Clusters of varieties were identified by sequential multivariate statistical analysis[22].

Results and Discussion

Biometric parameters

In general, vide variability was observed among the varieties for all the biometric parameters studied under saline condition. In the present study, plant height ranged from 80-153 cm. The varieties Kudaivazhai (153 cm) followed by Pal Kudaivazhai (150 cm) and Chinnar and Sinkini Kar (143 cm) recorded highest plant height, whereas, the varieties Pal kudaivazhai (80 cm), CSR10 (90 cm) and Seeraga samba (92.5 cm) recorded lowest plant height under saline condition (Fig. 1).

Among the varieties Raja Mannar, Milagu Samba and Koondukar recorded higher dry weight of leaves (2.47, 2.37 and 2.32 g respectively) and the genotypes Kullakar, Athur Kichadi and Arupatham Kuruvai

Fig. 1 — Graphical representation showing various parameters (a). Dry matter production, TDWL – Total Dry weight of Leaf, TDWS - Total Dry weight of Stem and TDWP - Total Dry weight of Plant (gplant^{-1}) and (b), (c). Growth analysis parameters (RWC - %, LWR- ratio , AGR- cmday^{-1} , RGR- day^{-1}).

recorded lower dry weight of leaves (0.66, 0.81 and 0.81 grespectively) under saline condition. In the case of dry weight of stem, the varieties namely Marathondi, Karupu Kavuni and Koondukar recorded the maximum stem weight (8.41, 7.76 and 7.01 g respectively) whereas the minimum stem weight was recorded by Athur Kichadi, Sorna Masuri and Chinnar with 1.73, 1.92 and 2.14 g respectively. A similar trend was followed in total dry weight of the plant wherein the maximum was recorded in Marathondi, Karupu Kavuni and Koondukar (10.7, 10.0 and 9.3 g respectively) and the minimum was recorded in Athur Kichadi, Chinnar and Sorna Masuri (2.54, 2.96 and 3.17 g) respectively.

Biomass and yield reduction at 3 dSm^{-1} with 13% decrease was already reported[23,24]. Rice growth, relative biomass and leaf area were decreased with increasing salinity (from 4 dSm^{-1} to 12 dSm^{-1}) and at different rates of decline for different genotypes. However, decreases in biomass, and leaf area were significant but not the relative decrease in plant height[25]. Such decreases in plant biomass were also reported in IR29 and IR64 under salinity stress of 6 dSm^{-1} [26-27].

Growth analysis parameters

Growth analysis parameters viz., relative water content, absolute growth rate, leaf weight ratio and relative growth rate were studied for all the varieties under natural saline conditions. The varieties Rajamudi, Navara and Seeraga Samba recorded high relative water content with 94.34%, 93.11% and 93.02% respectively, whereas for water saturation deficit, the varieties Kattupooni (59.6%), Kullakar (45.7%) and Kullakar (40.67%) recorded higher values. Wide variation was observed among the varieties which ranged from 59.64% in Kattupooni to 6.89% in Kullakar (Fig. 1).

Among the varieties studied, two varieties Soor Kuruvai and Rajamudi recorded significantly higher leaf weight ratio of 0.39 and 0.34 respectively. Whereas, it was significantly low in the case of IR 64, Navara and Poonkar with 0.17, 0.18 and 0.17 respectively. The varieties such as Sornamugi, TRY1 and Kanda Sali recorded high absolute growth rate of 4.06, 3.68 and 3.55 cmday^{-1} respectively, whereas the varieties Kullakar, Athur Kichadi and Valan recorded absolute growth rate of 0.15, 0.10 and 0.07 cmday^{-1}respectively. Significantly higher relative growth rate of 5.39, 1.41 and 1.34 day^{-1}were recorded by Arupatham Kuruvai, Karupu Kavuni and Raja Mannar respectively and the lowest was recorded by Athur Kichadi (0.120 day^{-1}).

Increase in leaf RWC in paddy under salinity was recorded and opined that it could be due to prevention of cell injury from salt stress by the osmo-protectants[28]. The importance in understanding the salt tolerance index (STI) in evaluating the landraces has been reported[29,30] who studied the response to salinity stress in four Japonica rice cultivars and found N18 as the most tolerant genotype based on the minimum reduction rate in total dry weight and relative growth rate which was related to Net assimilation rate (NAR).

Biophysical parameters

Even though the responses of rice varieties to gas exchange parameters under saline conditions were already reported by many researchers, they were very meager in the case of traditional rice varieties. Among the gas exchange parameters studied *viz.,* photosynthetic rate (Pn), transpiration rate (Tr) and stomatal conductance (Cs), more photosynthetic rates (26.4, 26.0 and 25.6 mg CO_2 m^2s^{-1}) were recorded by CSR10, Seerega samba and Thoyamalli and less photosynthetic rates (19.9, 20.1 and 20.3 mg CO_2 m^2s^{-1}) were recorded in varieties, Rajamudi, Kondukar and Karudan Samba, Pal kudaivazhai and Kandasali (Table 2). Similarly, higher transpiration rates (13.00, 12.90 and 12.86 mmol H_2O m^2s^{-1}) were recorded in Seraga Samba, CSR10, Sinkinikar and TRY1 and lower transpiration rates (10.01, 10.03 and 10.07 mmol H_2O m^2s^{-1}) were observed in Rajamudi, Karudan samba and Navara under saline condition. The varieties Sivapukavuni (0.31 mol H_2O $m^{-2}s^{-1}$), Valan (0.30 mol H_2O $m^{-2}s^{-1}$) and Selam samba, Kullakar and CSR10 (0.28 mol H_2O $m^{-2}s^{-1}$) recorded high stomatal conductance and the variety Kothamali samba (0.18 mol H_2O $m^{-2}s^{-1}$) recorded the lowest stomatal conductance under saline condition.

Stomatal conductance acts as a vital factor in photosynthesis in rice plants because both CO_2 and H_2O should enter mesophyll cells and chloroplast stroma through the stomata[31]. High concentration of solute in root zone could be a reason for decreasing stomatal conductance under salinity. Reduction in stomatal conductance caused reduction in photosynthesis in salt sensitive genotypes[32,33].

The tolerant plants maintain high photosynthetic rate due to their high ion toxicity which involves in compartmentation within the tissue or cells as already reported[34-35]. The decline in photosynthetic rate under salinity is due to reduction in CO_2 assimilation as already reported[32].

Significant differences between salinity treatments and genotypes were found for transpiration rate, leaf net photosynthesis rate and leaf conductance[25]. They also noted that variability among genotypes was significant for transpiration rate and net photosynthesis rate representing 20% and 50% of the total variation for net photosynthesis rate and transpiration rate respectively.

Reduced photosynthetic activity and stomatal conductance were the physiological responses when plants were subjected in salinity[36]. Differences in salinity tolerance in rice and it's responses to salinity at the reproductive stage were already reported[37-38] which may be due to the mechanisms involved in saline tolerance at the vegetative stage.

Yield parameters

Among the 50 varieties, the varieties Kudaivazhai and Pal kudaivazhai produced more number of tillers per panicle (31) and the variety Kattuyanam recorded lower number of tillers per panicle (19) (Table 3). The variety Sivapukavuni produced the lengthier panicle of 29 cm whereas the variety Kuzhiadichan produced panicles with minimum length of 17 cm under saline condition. Maximum number of grains per panicle was recorded by Kudaivazhai, Palkudaivazhai and Kandasali with 240, 230 and 225 grains respectively and the minimum number of grains per panicle was recorded by Kaivarai samba followed by Kattuyanam with 80 and 95 grains respectively. The 1000 grain weight ranged from 33.75 g, in Kudaivazhai to 10.1 g the lowest in Kandasali under saline condition. The number of tillers was reduced with varying levels in different genotypes under saline condition. The maximum seed yield was recorded in CSR10 (1875 $gplant^{-1}$) followed by Karudan samba (1650 $gplant^{-1}$) and the minimum seed yield was recorded in Kalan namak (825 $gplant^{-1}$) under saline condition.

Correlation coefficient

The phenotypic correlations among yield, growth analysis parameters, dry matter production and bio physical parameters of rice were shown in Table 4. The phenotypic correlation coefficients indicate a strong association between the characters studied and suppressive effect of the environment modified

Table 2 — Yield parameters for traditional rice genotypes

Genotypes	Plant height (cm)	Length of the panicle (cm)	No of tillers per Plant	No of grains per panicle	1000grain weight (g)	Grain yield (kgacre^{-1})	Straw yield (kgacre^{-1})
G1	135	29	25	180	27.10	1275	1425
G2	110	22	22	150	16.36	1125	1450
G3	110	21	23	115	17.23	1200	1275
G4	130	26	26	175	25.36	1125	1250
G5	140	28	30	200	19.00	1650	1450
G6	130	27	23	135	21.02	1500	1325
G7	100	21	21	100	30.01	825	825
G8	130	25	22	120	17.65	975	1150
G9	93	24	26	180	17.02	1575	900
G10	93	23	25	175	24.21	1500	875
G11	103	21	20	80	24.62	900	1075
G12	153	28	31	240	33.71	1350	1250
G13	125	27	23	115	24.02	1200	1150
G14	150	27	31	230	33.25	1425	1175
G15	143	26	25	163	26.03	1125	1225
G16	127	26	23	135	27.02	1125	1325
G17	103	20	24	160	26.35	1200	1000
G18	143	27	26	165	27.41	1125	1200
G19	115	23	24	150	17.21	1200	900
G20	124	28	27	225	10.10	1125	1400
G21	130	24	21	140	15.02	1275	850
G22	137	25	28	186	18.16	1500	1450
G23	140	27	30	187	24.72	1425	1425
G24	110	25	25	153	21.03	1425	1450
G25	135	25	20	100	21.03	1350	1050
G26	100	26	21	103	30.25	1050	1125
G27	135	25	24	125	31.25	1125	1200
G28	125	27	23	121	32.31	1050	1050
G29	110	25	20	110	23.02	1200	1125
G30	134	25	21	102	30.21	1125	1450
G31	125	23	23	120	21.32	1275	1200
G32	130	23	19	95	31.25	1125	1050
G33	133	25	20	101	32.12	975	1425
G34	80	17	23	117	17.00	900	675
G35	120	19	21	110	19.24	1275	1200
G36	117	22	25	130	17.10	1125	825
G37	135	25	21	115	16.40	1200	1350
G38	117	27	23	145	23.58	1575	1500
G39	127	25	24	127	33.00	975	1175
G40	116	22	26	129	16.90	1125	825
G41	110	23	21	105	17.02	1275	1200
G42	97	21	20	103	27.00	1425	1225
G43	130	23	24	120	23.01	1350	1450
G44	123	25	26	125	19.01	1125	825
G45	115	23	24	110	20.03	1275	1225
G46	118	22	25	124	22.23	975	1300
G47	134	25	23	145	25.36	1125	1450
G48	90	27	25	115	21.03	1875	1350
G49	140	26	26	120	24.01	1575	1300
G50	120	27	21	117	23.12	1500	1325

Table 3 — Bio physical traits for traditional rice genotypes

Genotypes	Photosynthetic rate (P_n) (mg CO_2 $m^{-2}s^{-1}$)	Transpiration rate (Tr) (mmol H_2O $m^{-2}s^{-1}$)	Stomatal conductance (Cs) (mol H_2O $m^{-2}s^{-1}$)
G1	23.5	12.20	0.31
G2	21.6	11.03	0.28
G3	23.1	12.01	0.30
G4	24.5	12.80	0.27
G5	20.3	10.03	0.24
G6	21.1	10.07	0.23
G7	23.4	12.50	0.25
G8	24.1	12.65	0.23
G9	26.0	13.00	0.26
G10	23.1	12.30	0.22
G11	22.0	12.03	0.20
G12	23.1	11.90	0.24
G13	19.9	10.01	0.19
G14	20.3	10.90	0.20
G15	21.4	11.21	0.22
G16	23.5	12.30	0.24
G17	24.0	12.75	0.22
G18	25.1	12.90	0.24
G19	23.1	11.30	0.25
G20	20.3	11.20	0.19
G21	24.1	12.01	0.23
G22	20.9	10.97	0.19
G23	21.8	11.02	0.21
G24	23.7	11.30	0.18
G25	20.1	11.08	0.26
G26	23.4	11.50	0.24
G27	20.4	10.90	0.19
G28	21.8	11.05	0.24
G29	22.3	11.32	0.23
G30	23.4	11.65	0.24
G31	20.4	11.21	0.18
G32	25.0	12.50	0.24
G33	24.8	12.42	0.23
G34	24.3	12.35	0.26
G35	25.1	12.61	0.27
G36	23.8	12.23	0.24
G37	22.9	11.35	0.23
G38	23.4	12.01	0.24
G39	21.6	11.31	0.22
G40	22.4	11.20	0.23
G41	23.4	12.01	0.25
G42	25.1	12.54	0.28
G43	23.7	11.92	0.23
G44	25.6	12.85	0.27
G45	23.4	11.67	0.25
G46	21.5	11.20	0.23
G47	25.1	12.67	0.27
G48	26.4	13.00	0.28
G49	25.0	12.86	0.26
G50	24.6	12.75	0.25

the phenotypic expression by reducing phenotypic correlation values of these characters. Biophysical parameters and dry matter production recorded positive correlation whereas the growth analysis and yield parameters have shown both the positive and negative correlation under natural saline condition.

Higher genotypic correlations than phenotypic values were observed in medium duration rice varieties[39]. Significant positive correlation of paddy yield with effective panicle length, tillers plant^{-1}, grains panicle^{-1} and 1000 grain weight were observed[40-42].

Table 4 — Correlation of genotypes under study using euclidian distance matrix at different parameters

Bio Physical Traits

Traits	Pn	Tr	Cs
Pn	1.000	0.895	0.573
Tr	0.895	1.000	0.508
Cs	0.573	0.508	1.000

Dry Matter Production

Traits	Dry weight of leaves	Dry weight of stem	Total dry weight
Dry weight of leaves	1.000	0.720	0.827
Dry weight of stem	0.720	1.000	0.981
Total dry weight	0.827	0.985	1.000

Growth Analysis Parameters

Traits	RWC	WSD	LWR	AGR	RGR
RWC	1.0000	-0.8569	0.1683	0.0495	-0.0276
WSD	-0.8569	1.0000	-0.0501	-0.0987	-0.0016
LWR	0.1683	-0.0501	1.0000	-0.0406	-0.1892
AGR	0.0495	-0.0987	-0.0406	1.0000	-0.1030
RGR	-0.0276	-0.0016	-0.1892	-0.1030	1.0000

Yield Parameters

Traits	PH	LOP	NTPP	NGPP	GW	Yield	Straw
PH	1.0000	0.5940	0.3724	0.3781	0.2865	0.0421	0.4360
LOP	0.5943	1.0000	0.3989	0.4541	0.2502	0.3590	0.5030
NTPP	0.3724	0.3990	1.0000	0.8435	-0.0046	0.3718	0.1390
NGPP	0.3781	0.4540	0.8435	1.0000	-0.0254	0.3358	0.1950
GW	0.2865	0.2500	-0.0046	-0.0254	1.0000	-0.1805	0.1150
Yield	0.0421	0.3590	0.3718	0.3358	-0.1805	1.0000	0.3370
Straw	0.4364	0.5030	0.1388	0.1954	0.1146	0.3367	1.0000

P_n– Photosynthetic rate, T_r– Transpiration rate, Cs- Stomatal conductance

RWC- Relative water content, WSD- water saturation deficit, LWR- Leaf weight ratio, AGR- Absolute growth rate and RGR- Relative Growth Rate

PH- Plant height, LOP- Length of the panicle, NTPP- Number of tillers per plant, NGPP- Number of grains per panicle, GW- Grain weight.

Cluster analysis

A UPGMA dendrogram was constructed using the Euclidean distance values of standardised morphological data for 50 traditional rice varieties. Among the 50 rice varieties, five major groups were observed based on multivariate analysis at a 0.713- 0.874 dissimilarity coefficient value (Fig. 2 and Table 5). The highest value of 0.874 was observed in case of growth analysis and cluster I was observed to contain the maximum number of genotypes (42), the second highest was cluster II, with 4 genotypes. Clusters III, IV, and V consists of 01, 01 and 02 genotypes respectively. The lowest value of 0.713 was observed in case of Pn. Cluster IV contained the maximum number of genotypes (22) followed by cluster III having 16 genotypes, cluster II, which consisted of 04 genotypes and clusters I, II, and V consisted of 02, 04 and 06 genotypes respectively.

For improving various characters, superiority of clusters can be considered which were computed from cluster wise mean values from nine different traits[43]. Differences in clustering pattern and swapping of genotypes among different clusters in different methods of diversity analysis have been reported[44-47].

Principal component analysis (PCA)

PCA is useful to understand the basis for grouping of genotypes of similar categories. The findings of cluster analysis were partly confirmed by PCA and the genotypes are clustered into five groups (Fig. 3), with few differences between the parameters. In Biplot method, the parameter dry matter production showed the highest diversity of genotypes and growth analysis parameters showed the lowest diversity, establishing that experimental data were accurate and reliable.

Five groups were obtained from 50 traditional varieties based on the dendrograms of cluster analysis and PCA. A similar dendogram topology was exhibited from hierarchical cluster analysis and PCA analysis also confirmed accuracy of the constructed dendogram[48]. The clusters were mostly created based on the geographical area of the genotypes which was

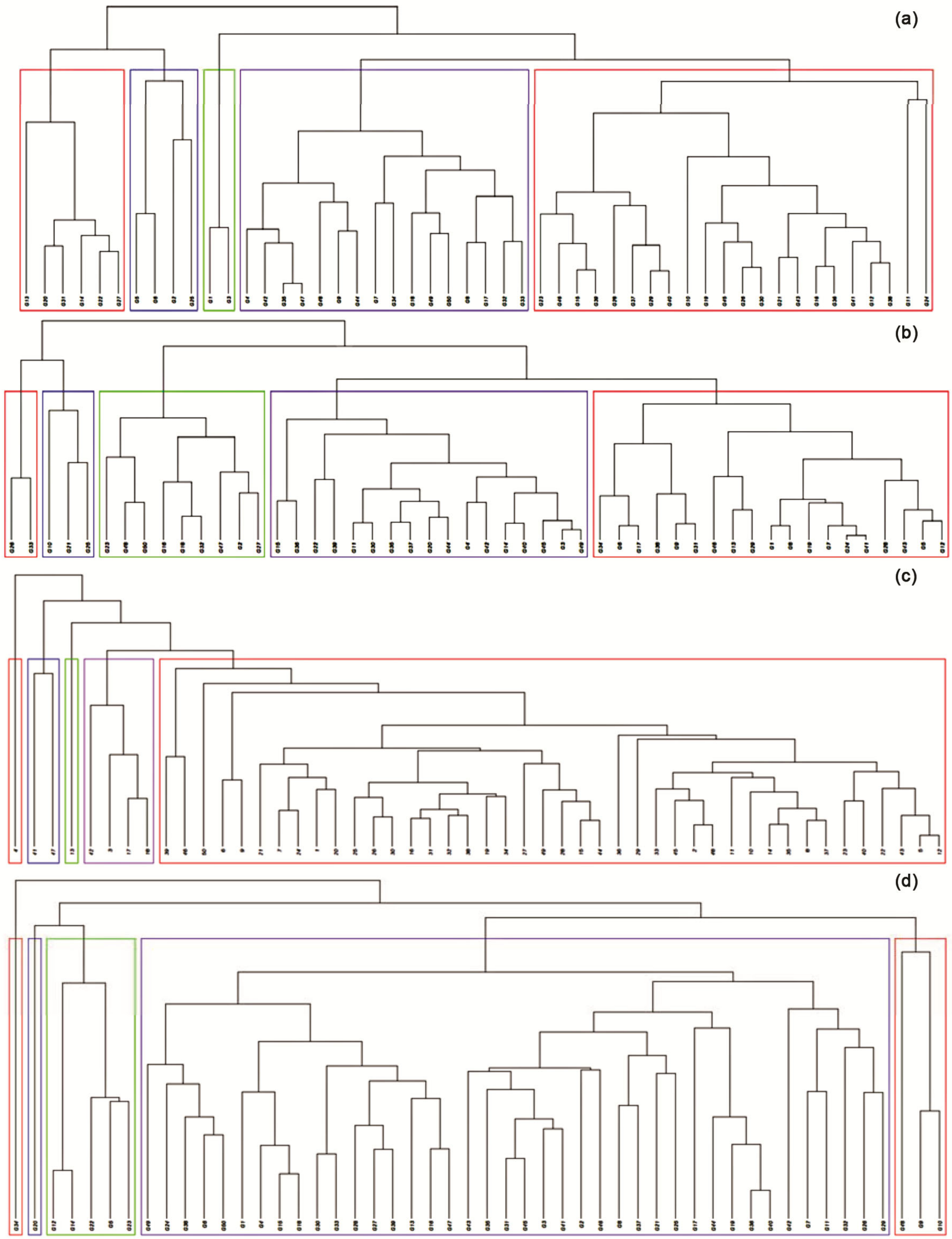

Fig. 2 — Clusters of genotypes under study using Euclidian distance matrix at different parameters (a)Bio Physical Traits, (b)Dry Matter Production, (c) Growth Analysis and (d)Yield Parameters

Table 5 — Clusters of genotypes under study using Euclidian distance matrix at different parameters

Cluster (Photo)	No of Genotypes	Genotypes
I	2	G1 G3
II	4	G2 G5 G6 G25
III	16	G4 G7 G8 G9 G17 G18 G32 G33 G34 G35 G42 G44 G47 G48 G49 G50
IV	22	G10 G11 G12 G15 G16 G19 G21 G23 G24 G26 G28 G29 G30 G36 G37 G38 G39 G40 G41 G43 G45 G46
V	6	G13 G14 G20 G22 G27 G31
Cophenetic Correlation Coefficient =0.713		
Cluster(Dry)	No of Genotypes	Genotypes
I	19	G1 G5 G6 G7 G8 G9 G12 G13 G17 G19 G24 G28 G29 G31 G34 G38 G41 G43 G46
II	9	G2 G16 G18 G23 G27 G32 G47 G48 G50
III	17	G3 G4 G11 G14 G15 G20 G22 G30 G35 G36 G37 G39 G40 G42 G44 G45 G49
IV	3	G10 G21 G25
V	2	G26 G33
Cophenetic Correlation Coefficient =0.831		
Cluster(Growth Analysis)	No of Genotypes	Genotypes
I	42	G1 G2 G5 G6 G7 G8 G9 G10 G11 G12 G14 G15 G16 G19 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 G32 G33 G34 G35 G36 G37 G38 G39 G40 G43 G44 G45 G46 G48 G49 G50
II	4	G3 G17 G18 G42
III	1	G4
IV	1	G13
V	2	G41 G47
Cophenetic Correlation Coefficient =0.874		
Cluster(Yield)	No of Genotypes	Genotypes
I	40	G1 G2 G3 G4 G6 G7 G8 G11 G13 G15 G16 G17 G18 G19 G21 G24 G25 G26 G27 G28 G29 G30 G31 G32 G33 G35 G36 G37 G38 G39 G40 G41 G42 G43 G44 G45 G46 G47 G49 G50
II	5	G5 G12 G14 G22 G23
III	3	G9 G10 G48
IV	1	G20
V	1	G34
Cophenetic Correlation Coefficient =0.763		

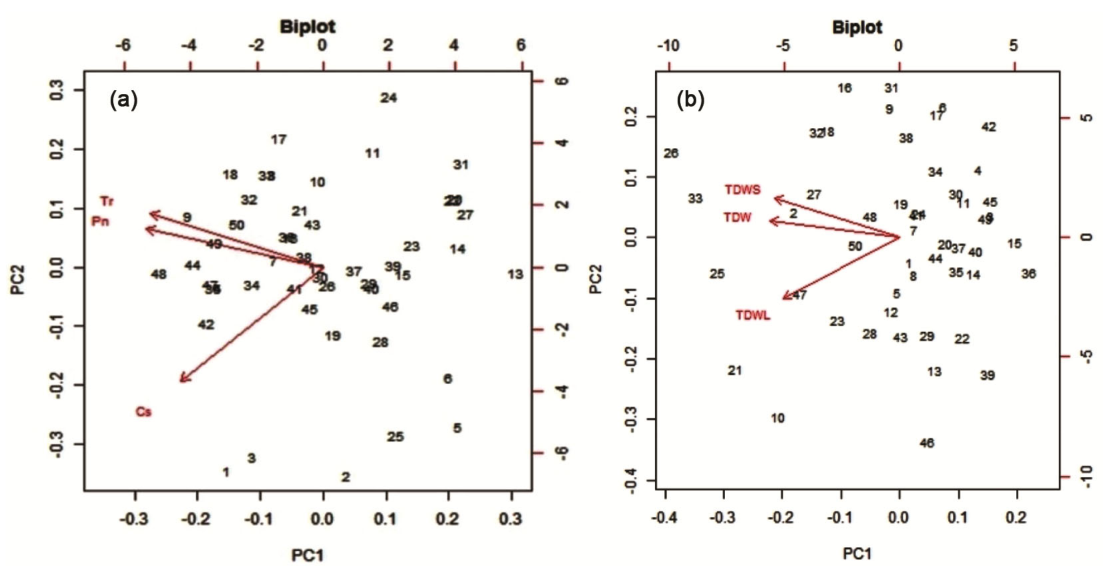

Fig. 3 — Principal Component Analysis for various parameters (a). Bio Physical Traits, (b) Dry Matter Production. (*Contd.*)

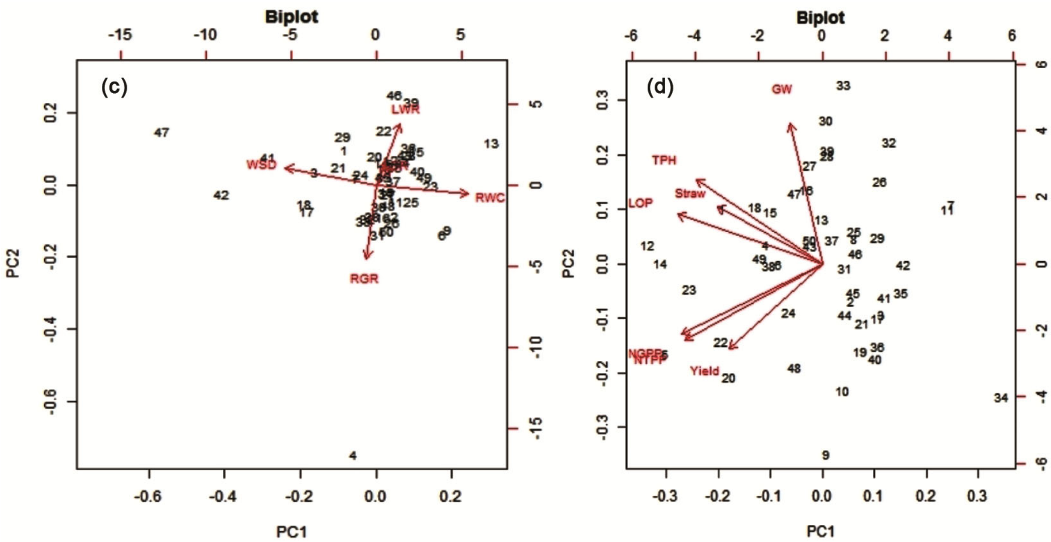

Fig. 3 — Principal Component Analysis for various parameters (c) Growth Analysis and (d) Yield Parameters

confirmed from Euclidian distance. Genotypes from the same geographical origin were grouped together, which also included the less frequent genotypes from different origins. Based on 18 morphological characters, 58 rice varieties were grouped in 04 clusters[49].

Twenty one rice varieties formed 05 clusters based on 14 physiological traits[50]. The strong presence of differences among 50 rice varieties was further confirmed by PCA. Moisture stress tolerance of traditional varieties and their capacity for yield even under adverse environmental conditions were already reported[51].

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