RESEARCH ARTICLE

SABRAO Journal
of Breeding and Genetics
48 (3) 266-276, 2016

GENETICS OF YIELD AND COMPONENT CHARACTERS IN POKKALI SOMACLONES – A TALL, TRADITIONAL, PHOTO-SENSITIVE CULTIVAR FROM INDIA

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SUMMARY

We report comprehensive information about genetics of diverse characters in a set of somaclones developed from a salt tolerant indica cultivar – Pokkali for the first time, which are novel, unique and deemed to be useful to devise breeding strategies to exploit somaclonal variation. 2nd degree statistics, correlation and path coefficient analyses were performed involving 31 most productive somaclones, evaluated for 3 consecutive years (SC_6-SC_8 generation). By adjudging the results appropriate breeding strategies are envisaged to improvise Pokkali rice. A wide range of variations for all major agronomic characters was observed. Phenotypic coefficient of variation (PCV) was higher than Genetic coefficient of variation (GCV) for all characters, indicating substantial influence of the environment for major characters. Plant height, flag leaf area, leaf dry weight; harvest index had high-moderate heritability with high genetic advance, indicating predominance of additive gene actions. Plant height, panicle length, flag leaf area, biomass yield and harvest index had significant positive associations with grain yield at genetic level convey their predominant role in governing grain yield. Leaf area, leaf dry weight, panicle length and number of productive tillers per plant had direct effect on grain yield. Direct selection is advocated for improving panicle length and restriction selection is recommended to enhance leaf area, leaf dry weight, and number of tillers per plant. Biomass yield bore maximum negative effect on grain yield. Maximum 81.08% of the variability was contributed by grain yield/plant. Amongst all somaclones, BTS 24 was found to produce maximum of 3.7 tonnes per hectare, which is recommended for large-scale cultivation.

Key words: Rice, Pokkali somaclones, variability, correlation studies, path coefficient analysis, salt tolerance

Key findings: Quantification, inter-relationship and contribution of component characters on grain yield, accrued from *in vitro* culture-induced variations in a set of Pokkali somaclones.

Manuscript received: August 29, 2015; Decision on manuscript: May 5, 2016; Manuscript accepted: May 19, 2016.

Communicating Editor: Bertrand Collard

INTRODUCTION

India is a gene rich country albeit the bio-resources are declining as is evident globally. Variation in respect of characters in plants, be it agronomic traits including tolerance to biotic and abiotic stresses represent a vast treasure-house of variation to augment productivity. Large number of indigenous cultivars/land races was inherited since the onset of agriculture in India and those were cultivated under subsistence mode with virtually near zero scientific intervention and the country was running under chronic deficit to support the livelihood.

Rice is the principal staple food crop in India, grown on 43.4 M hectares with production of 106 M tonnes (Government of India, 2015), providing life -line across the country. Majority of the traditional varieties have been replaced with modern high yielding varieties (HYV), however, a few are still being cultivated. Pokkali is a tall (~1.8 m) traditional, stringently photosensitive, extremely long duration (~140 d) salt tolerant rice cultivar conventionally grown in the Kerala state of Indian Republic. This cultivar show marginal reduction in economic threshold in respect of grain yield up to 8 dSm^{-2} under saline soil and is highly popular among the consumers because of its attractive red kernel and high amylose content, the cooked rice is considered to be highly delicious in comparison to other traditional cultivars and modern medium yielding varieties (MYV). Nowadays to mitigate the fall-out in rice requirement MYV salt-tolerant lines are being cultivated in Kerala on large-scale, which is compelling the area under Pokkali cultivation to shrink drastically. This salt tolerant cultivar grows under low-lying island and coastal belt constrained with excess salt (saline soil) especially is the coastal districts. However, this cultivar provides exceedingly poor yield (1.5-1.8 tonne/hectare) with a low cost: benefit ratio, which is a serious bottleneck to produce and popularize amongst the people and used as check in evaluation of salt tolerant trials of the entries developed globally both at international level (IRSATON, IRTP, IRRI, Philippines) and at domestic trials (AICRP, Hyderabad). However, despite of massive efforts mounted through conventional breeding no salt tolerant Pokkali varieties with very high yield could be developed.

Genetic variations with high heritability predominantly make foundation of any crop genetic improvement programme. The estimates of different genetic parameters like PCV, Genetic and Environmental factors (GCV), heritability (h^2) and Genetic advance in percent of mean (GAM) are the key parameters, which decide the fate of a genetic improvement programme and thus immensely important. Besides available variation in the germplasm *in natura*, plant breeders employ diverse techniques for *de novo* synthesis of variation in the existing population of diverse crops

In vitro culture induced somaclonal variation assumes key importance since it does not drastically alter the genetic background and thereby agronomic values are not adversely affected. In many cases greater frequency and magnitude of somaclonal variations were observed by Larkin and Scowcroft (1981) in comparison to conventional mutagenesis (Chopra *et al*., 1989). In rice, Nishi *et al*., 1968, Henke *et al*., 1978, Mandal *et al*., 2000 reported occurrence of phenotypic variants among the primary regenerants. Genetic variation was amply observed in regenerated plants for diverse characters of agronomic importance like number of tillers per plant, grain number and weight, plant height, panicle length, yield and protein content in the grains etc. Zapata *et al.*, 1983 observed variation for panicle length, panicle number, and spikelet sterility in plants developed through anther culture too. Substantial somaclonal variation in ratooned rice was also observed for plant height, panicle length and number of tillers per plant (Mandal and Pramanik 1998).

Somaclones were found to vary significantly from parent in respect of grain yield and component characters (Mandal *et al*., 2000). However, variations and interrelationships among the somaclones for yield and yield component characters were not studied earlier. Characters more particularly, the grain yield is found to be considerably influenced by the surrounding environment. Therefore, it is essential to understand the behaviour of the characters in a particular environment. Furthermore and more correctly over years across locations, G×E interactions often changes correlation patterns and magnitudes among diverse characters and contributes differentially towards grain yield. It is to be mentioned that information available on these aspects in Pokkali somaclones of rice is scanty. An attempt therefore was made to study the genetic variability in respect of 10 agronomic characters viz. plant height, panicle length, number of productive tillers per plant, flag leaf area, leaf fresh weight, leaf dry-weight, leaf area, biomass yield, harvest index and yield per plant in a set of 31 highly productive somaclones of Pokkali, which were developed earlier to pinpoint key characters governing grain yield and associated component characters, so that their genetic improvisation may be undertaken in future with confidence.

At the interface of failure of substantial yield improvement through conventional breeding in Pokkali rice, we attempted especially by capitalizing the culture-induced variation. Interestingly, to the contrary of conventional mutagenesis, micro-mutation events get accumulated in course of tissue culture and finally the quantum of somaclonal variation is expressed as a novel character, which has been evident in many crops especially in those having high *in vitro* culture response in respect of dedifferentiation of explants and re-differentiation of calli into plantlets. Duration of callus at cellular level also help enhancing occurrence of more somaclonal variation. To explore this possibility of capturing the somaclonal variation, elaborate experimentation over 8 years' time was conducted, very systematically. Plant tissue culture technologies have emerged as a tool to exploit such resources, especially these are deemed to be reservoir of economically important genes like salt tolerance in Pokkali. In cereals, especially rice, which was considered to be recalcitrant to *in vitro* culture response now has become 'role model' for genetic manipulation without resorting sexual process through the process of exploitation of culture induced variation, and by dove-tailing of alien genes from heterologous sources and interesting by gene prospecting, their cloning and use for enhancing productivity and value addition for other desirable traits.

Pokkali is such a highly salt tolerant variety, cultivar which has been used extensively to introgress its inherent salt tolerant characters into modern short statured highly productive varieties. However, the quantum of success was found to be exceedingly low, which compelled us to deploy cell technological approaches especially through development of somaclones following modified standard protocol (Larkin and Scrowcroft, 1981) *en masse*. The long programme emerged with true salt tolerant varieties with almost double yield through tedious selection processes both under *in vitro* culture conditions, artificially simulated saline environments in cement tanks and field evaluation in the coastal and inland saline soils in Bay Islands in the open range, which brought landmark success, contributed immense knowledge and ensured food security in those villages, which got abandoned due to introgression of sea water. The entire study conveys the contribution of manipulation of harvest index by selecting productive culture induced short stature lines with added values. This success story stimulated us to dissect out the genetics of yield and important yield component characters to unzip the genetic grid, which brought such spectacular success with an age-old traditional variety, is detailed below with appropriate interpretation.

MATERIALS AND METHODS

Seeds from a tall traditional salt-tolerant cultivar Pokkali were originally obtained from INGER, IRRI (International Rice Research Institute), Philippines. Plants were grown in an experimental net house and selfed seeds were harvested individually. Healthy mature seeds from individual plants were employed for this study. Seeds were surface-sterilized in 5% aqueous detergent solution (Teepol) with occasional shaking for 5 min. Those seeds were washed thoroughly and then dipped in freshly prepared 0.01% $HgCl_2$ solution with 2-3 drops of Tween 20 as a wetting agent *in vacuo* for 15 min followed by 3 -- washes with sterile double-distilled water. Axenic seeds were blot-dried on sterile tissue paper under laminar air flow and placed on callus-induction medium (CIM) made of MS; Murashige and Skoog (1962) with 3% sucrose and gelled with 0.8% agar (Sigma, St. Louis, MO). Various kinds and doses of synthetic phytohormones viz. 2,4-D (1-3 $mg.l^{-1}$) and Kinetin (0.01-0.05 $mg.l^{-l}$), singly or in combinations, were used to obtain efficient callus induction. The pH of the medium was adjusted to 5.7 before autoclaving and the cultures were incubated at 25-28ºC in dark. After 10 days, primary loose calli which appeared on the scutellar surface, were excised and kept on CIM in the same culture tube (22 cm diameter, Borosil) for another 18 days. Calli were subcultured on freshly prepared medium of the same composition at 28 days intervals. Calli from the fourth subculture were transferred onto a regeneration medium (RM) containing MS supplemented with different levels of Kinetin (1-3 $mg.l^{-l}$) and NAA (0.5-2.0 $mg.l^{-l}$) singly or in combinations and kept at 25-28ºC under illumination (2500 lux approx.) from cool fluorescent tubes (Philips make) in 16/8 h light/dark cycle. Green spots started appearing within 10-15 days on calli surfaces and subsequently green plantlets with roots concurrently were developed following somatic embryogenesis. The plants at 6-8 cm height were transplanted in plastic pots with wet soil. The pots were covered with polyethylene bags for the initial 3-4 days and watered regularly. The established plants were shifted to experimental net house in big cement pots after 20 days. At maturity seeds from individual plants were collected separately. SC_2 somaclones were evaluated under rainfed conditions at Port Blair (11°41'13.04"N Latitude, 92°43'30.16"E Longitude). About 35,000 plants from 1190 somaclone families were evaluated under saline soil (3.2 dSm^{-1} during transplanting of 1month old seedling), followed by selection in every generation (6 dSm^{-1} at vegetative phase and 8.5 dSm^{-1} during flowering time). Finally, a set of 31 elite lines were selected for yield trial for 3 consecutive seasons during the rainy season of 1993 (SC_6, SC_7 & SC_8 generation). To ensure proper growth standard package of practices were adopted. The mean data in respect of 10 agronomic characters (Anon, 1988) were processed using the software 'IRRISTAT' and the results were interpreted following Panse and Sukhatme (1961).

Thirty one Pokkali somaclones (Table 1) the most productive lines as identified in SC_6 generation were studied along with parental check – Pokkali (Data not presented except mentioning the designation of the entries designated as BTS (Biotechnology Selection) of the genotypes). Mature clean seeds were harvested in the preceding generation and raised in 3 replications during 3 consecutive *kharif* seasons at Field Crops Research Farm, ICAR-Central Island Agricultural Research Institute, Port Blair. Twenty five days old seedlings were transplanted on $3m^2$ plots at 20-25 cm space between plants and rows. Standard dose of fertilizer and plant protection measures were adopted to ensure good crop growth (Gangwar *et al*., 1990). Observations for 10 important agronomic characters viz. plant height (cm), panicle length (cm), number of productive tillers per plant, leaf fresh -weight (g), leaf dry -weight (g), leaf area (m^2), biomass yield (g), harvest index (%) and yield per plant (g) were recorded involving 10 randomly selected plants in each replication of individual genotype following Standard Evaluation System of Rice, IRTP IRRI, Philippines 1988. Differences between sister somaclones in respect of aforementioned characters were tested for significance using analysis of variance (ANOVA) technique (Burton, 1951). Genetic advance was worked out following Johnson *et al*., 1956. The phenotypic, genetic and environmental correlations were calculated as suggested by Al-Jibouri *et al*., 1958. Path coefficient analysis was computed following Dewy and Lu (1959) to asses direct and indirect effects of different characters on grain yield per plant. An amenable strategy was framed for genetic improvement of this cultivar having exceedingly high consumers' preference.

Table 1. List of Pokkali somaclones developed and evaluated in Bay Islands for 3 consecutive years.

No.	Designation.	No.	Designation.	No.	Designation.
1.	BTS 18-8	12.	BTS 25	23.	BTS 14-1
2.	BTS 23-4	13.	BTS 11-3	24.	BTS 13(S)
3.	BTS 10-12	14.	BTS 24	25.	BTS 18
4.	BTS 10-10	15.	BTS 17-20	26.	BTS 14-2-1
5.	BTS 9-3	16.	BTS 9-2(S)	27.	BTS 24-1
6.	BTS 11-1	17.	BTS 17(S)	28.	BTS 10-7
7.	BTS 9-3	18.	BTS 11-2	29.	BTS 11-7
8.	BTS 10-5	19.	BTS 10-2	30.	BTS 21
9.	BTS 11-11-1	20.	BTS 2(S)	31.	BTS 17-5
10.	BTS 18-10	21.	BTS 10-8	Parental Check	Pokkali
11.	BTS 28	22.	BTS 13		

* SC6, SC7 & SC8 generations

RESULTS

Pokkali generally produce bold red kernel grains of 1.5-1.8 tons/ha. However, from 1190 primary regenerants and their subsequent evaluation on saline soil ultimately developed short stature (90cm-1m), very high-yielding (3.5-3.7 tonne/hectare) rice with marginal yield loss at even 8 dSm^{-1}. This is reflecting substantial of manipulation of harvest index. The plant height and foliage biomass reduced to almost half. The cultivar flowered 20-25 days, earlier than the parental check and to our belief, this is one of the landmark research in the past 20 years in the parlance of saline land rice husbandry. Individual genetic performance in respect of 10 agronomic characters was documented (data not presented) and the major findings have been narrated synoptically. Range, genetic variance, phenotypic variance, GCV, PCV, environmental coefficient of variation (ECV), h^2 and expected GAM showed diverse range of variation for all the characters (Table 2). The maximum range was observed for leaf area (600.00-1392.66 cm^2) followed by biomass yield (46.00-95.33 g), plant height (97.9-140.11 cm) and flag leaf area (34.11-62.55 cm^2), whereas narrow range was observed for leaf dry- weight (1.27-3.96 g) followed by number of productive tillers per plant (4.40-9.73), panicle length (20.30-26.30 cm), yield per plant (5.30-14.0 g), leaf fresh weight (7.50-17.41 g) and harvest index (8.07-22.16%). Distinct differences between PCV and GCV were found to be high for harvest index (21.54 and 32.37%, respectively), yield per plant (17.55 and 33.97%) and leaf dry weight (14.03 and 25.87%), but low values were observed for panicle length (4.98 and 8.48%) and leaf fresh weight (9.65 and 21.05%). The estimates were found to be moderate for the remaining characters.

Table 2. Mean, range, variance and genetic parameters for different characters in a set of somaclones derived from salt-tolerant Pokkali rice.

Character	Range	Mean±SE	Variance Components			Genetic Parameter				
			$\sigma^2 g$	$\sigma^2 p$	$\sigma^2 v$	GCV	PCV	ECV	h^2	Genetic advance as (%) mean (GAM)
Plant height(cm)	97.9-140.1	115.7±6.9	123.7	195.4	71.7	9.6	12.1	7.3	63.3	15.8
Panicle length(cm)	20.3-26.3	23.1±1.2	1.3	3.8	2.5	5.0	8.5	6.9	34.6	6.0
No. of productive tillers/ plant	4.4-9.7	6.2±0.9	0.6	1.9	1.3	12.1	22.3	18.7	29.5	13.6
Flag leaf area(cm^2)	34.1-62.5	48.4±5.8	40.2	91.6	51.4	13.1	19.7	14.8	43.9	17.9
Leaf fresh weight(g)	7.5-17.4	13.1±2.0	1.6	7.7	6.0	9.7	21.1	18.7	21.0	9.1
Leaf dry - weight(g)	1.2-3.9	2.3±0.4	0.1	0.3	0.2	14.3	25.9	21.6	30.6	16.3
Leaf area(cm^2)	600.0-1392.6	1041.4±5.1	12241.1	58223.9	45982.9	10.6	23.2	20.6	21.0	10.0
Biomass yield(g)	46.0-95.3	46.0±11.7	79.8	285.3	205.6	12.6	23.9	20.3	28.0	13.7
Harvest index (%)	8.0-22.1	12.6±2.5	7.3	16.5	9.2	21.5	32.4	24.2	44.3	29.5
Yield/plant(g)	5.3-14.0	8.5±2.0	2.2	8.4	6.2	17.6	34.0	29.1	26.7	18.7

Preponderance of moderate to high magnitude of GCV for all the characters except panicle length and leaf fresh-weight indicates the presence of greater genetic variation among the somaclones, which may be used for genetic improvement. PCV was found to be higher than the corresponding GCV for all the characters due to influence of the environment and G×E interactions thereof (Table 3). It is to be mentioned that a population having high range in respect of diverse characters offers ample scope to shuffle and re-shuffle the characters by diverse techniques simply by improved recurrent selection. Maximum broad sense heritability was recorded for plant height (63.31%) while moderate values were observed for harvest index (44.2%), flag leaf area (43.89%), panicle length (34.57%) and leaf dry-weight (30.56%). Since the magnitude of genetic advance is influenced by units of measurements, it was further expressed as percent of mean. It is to be mentioned that the GCV determines the breeding progress along with high heritability values, considered to be extremely important in developing breeding population and ultimately releasing a variety. For most of the characters, GCV was found to be satisfactory; therefore, ample scope is discernible for further genetic improvement by recurrent selection. Similar results were observed in conventional materials by Lokaprakash *et al*., 1992 and Ganesan *et al*., 1995 for PCV and Sawant *et al*., 1995; Saidaiah *et al.*, 2009 for GCV.

Table 3. Estimates of genetic (G), phenotypic (P) and environmental (E) correlation values between grain yield and other component characters in Pokkali somaclones of rice.

Character		Plant height (cm)	Panicle length (cm)	No. of productive tillers/ plant	Flag leaf area (cm^2)	Leaf fresh weight (g)	Leaf dry weight (g)	Leaf area (cm^2)	Biomass yield (g)	Harvest Index (%)	Yield/ plant (g)
Plant height	G	1.000	0.363**	-0.155	0.329	0.671**	0.773**	0.792**	0.813**	0.012	0.653**
(cm)	P	1.000	0.165	-0.028	0.134	0.244	0.335	0.269	0.461	-0.093	0.225
	E	1.000	-0.010	0.077	-0.087	-0.001	-0.010	-0.038	0.233	-0.219	-0.084
Panicle	G		1.000	-0.602**	0.064	0.461**	0.398*	0.564**	0.459**	0.743**	0.789**
length (cm)	P		1.000	-0.263	0.240	0.140	0.123	0.124	-0.046	0.295	0.158
	E		1.000	-0.104	-0.288	-0.029	-0.009	-0.038	-0.275	0.007	-0.118
No of	G			1.000	-0.833**	-0.816**	-0.370*	0.823**	-0.140	-0.331	-0.374*
productive	P			1.000	-0.350*	-0.154	-0.167	-0.196	0.058	-0.128	0.028
tillers/plant	E			1.000	-0.052	0.066	-0.080	0.012	0.137	-0.013	0.186
Flag leaf	G				1.000	0.525**	0.338	0.579**	0.336	0.554**	0.541**
area (cm^2)	P				1.000	0.203	0.147	0.230	0.109	0.358*	0.319
	E				1.000	0.065	0.038	0.083	-0.013	0.210	0.208
Leaf fresh	G					1.000	0.083	0.095	0.910**	0.031	0.181
weight (g)	P					1.000	0.847**	0.874**	0.231	-0.018	0.086
	E					1.000	0.733**	0.815**	0.013	-0.041	0.057
Leaf dry	G						1.000	0.028	0.050	-0.134	0.175
weight (g)	P						1.000	0.741**	0.172	-0.100	-0.018
	E						1.000	0.614**	-0.191	-0.082	-0.096
Leaf area	G							1.000	0.840**	0.018	0.143
(cm^2)	P							1.000	0.199	-0.002	0.070
	E							1.000	-0.006	-0.012	0.048
Biomass	G								1.000	-0.052	0.755**
yield (g)	P								1.000	-0.127	0.431**
	E								1.000	-0.172	0.309
Harvest	G									1.000	0.676**
index (%)	P									1.000	0.617**
	E									1.000	0.602**
Yield/plant	G										1.000
(g)	P										1.000
	E										1.000

** and * denote significance at 5 and 1% level of probability, respectively

DISCUSSION

Pokkali, a unique, highly salt tolerant rice cultivar, grown sporadically in Kerala, India is famous for its high consumer preference. However, it has exceedingly low yield, which could not be enhanced through conventional plant breeding despite massive efforts mounted, thus necessitating genetic modulation through more powerful biotechnological approaches. Experimentation was undertaken in an elaborate manner scale over a period of 8 years for selection and generation advancement over multi-locations to develop highly productive salt tolerant lines, which could make distinct niche in salt tolerant rice husbandry. Since conventional breeding could not bring substantial yield improvement, we deployed modern cell technological approaches especially for exploitation of culture-induced variation as observed by Larkin and Scrowcroft (1981) and Mandal *et al*., 1999. Interestingly, the cascade of development across 8 concurrent years, sincere efforts could develop true salt tolerant lines with near double yield through selection both under *in vitro* selection under artificially simulated condition and field evaluation in the saline track both under coastal and inland situations endowed with moderate to high salinity. This is a success story, which provided nutritional security especially in the coastal sea water (estuary) regions. This entire gamete of work represents manipulation of harvest index (HI) and good luck, blending high yield with salt tolerance. This success made us interested to dissect out the genetics of grain yield and component characters governing the genetic mechanism, which is congenial to bring paradigm shift in age old traditional cultivar through intervention of a most modern biotechnological tools and techniques to attain farm prosperity especially in constrained rice growing ecosystems.

The ANOVA in this study showed significant differences among all the characters indicating existence of ample genetic diversity among the somaclones. GCV generally measures the extent of genetic variation among the genotypes for a particular character and thus bright possibility of genetic improvement deemed to be a feasible proposition. Narrow differences between PCV and GCV for plant height, panicle length and number of productive tillers per plant indicated that those traits were comparatively stable to environmental fluctuations, PCV values were found to be higher than GCV for all characters owing to substantial influence of the environment; this is corroborative with the findings of Chauhan (1996). The key observation suggests that genetic factors were predominantly responsible for expression of those attributes and selection could be made effectively on the basis of phenotypic performance. Similar findings were reported by Borbora and Hazarika (1998) in inbred lines. The magnitude of heritability was found to be low for the remaining characters, which explained that those characters were more vulnerable to environmental variations and phenotypic selection might not be highly effective in upbringing those characters. Moderate to high heritability estimates indicated that those characters were least influenced by the environmental effects, which prospect moderate scope of genetic improvement. This also suggested that the phenotypes were the true representative of their clones for those characters and selection based on phenotypic values could be reliable to achieve genetic gain. But heritability alone is of little use because it is in broad sense and based on total genetic variance including both fixable (additive) and non-fixable (dominant and epistatic) components. Furthermore, broad sense heritability is subjected to genetic-environment interaction (Burton, 1952). Heritability estimates along with genetic advance are considered to be most effective and reliable (Johnson *et al*., 1955). The characters like plant height, flag leaf area, leaf dry weight, harvest index had high to moderate heritability values along with high GAM, which indicates the operation of additive gene effects and thus, simple selections, deemed to be effective in improving those characters. The present results in this study, except for flag leaf area, are consistent with earlier reports of Sharma *et al.* 2006. Genetic correlations were found higher than corresponding phenotypic correlation values (Rema Bai *et al*., 1992). Heritability estimates in conventional variety were found to be very high as reported by Roy and Kar (1992); Yadav, 1992; Sarawgi and Soni, (1994); Reddy *et al.*, 1997 for 50% flowering and plant height, whereas Sawant and Patil (1995) and Roy and Wu (2001) reported high heritability for number of field grains per panicle, 100 grain weight, panicle length, number of grains per panicle etc. in case of varieties developed through conventional breeding. The expression of characters might be highly influenced by the non-additive gene actions as observed by Rao and Shrivastav (1994), high GCV coupled with high heritability indicates effectiveness of selection based on those characters (Sarma *et al.*, 1996), high heritability with moderate genetic advance (GA) generally indicated predominance of additive gene action and selection of such characters based upon phenotypic value would result in more efficient genetic gain. Simple selection like mass and family selections deemed to be effective to accumulate such additive genes and may further improve upon their performances. On the contrary, low to moderate h^2 with poor GA generally indicates predominance of operative non-additive genes, where restricted selection may be followed for genetic improvement. Character association advocated by many others have opined operation of strong positive correlations among the yield and component characters to attend robust and rapid genetic improvement. But, there are many characters where negative association is also required based on the nature of the crop and nature of desired end product.

Correlation between grain yield per plant and its component characters (Table 3) advocates that 5 characters viz. plant height, panicle length, flag leaf area, biomass yield and harvest index had highly significant positive associations with grain yield per plant at genetic level. Biomass yield and harvest index were found to be significant at phenotypic level. Thus, selections for one of the above characters are expected to simultaneously improve upon the yield potential of the somaclones. Path coefficient analysis at genetic level was worked out to assess direct and indirect contributions of different agronomic characters upon grain yield per plant (Table 4), which indicates that the leaf area (6.693) exerted maximum positive direct effect, followed by leaf dry weight (5.715), panicle length (4.485) and number of productive tillers per plant (3.772).

Table 4. Direct and indirect effects of yield components on grain yield in Pokkali somaclones of rice.

Character	Plant height (cm)	Panicle length (cm)	No of productive tillers/ plant	Flag leaf area (cm^2)	Leaf fresh weight (g)	Leaf dry weight (g)	Leaf area (cm^2)	Biomass yield (g)	Harvest index (%)	Correlation with grain yield (r)
Plant height (cm)	-0.700	1.629	-0.577	-0.558	-2.935	4.418	5.304	-5.925	-0.001	0.653**
Panicle length (cm)	-0.254	4.485	-2.239	-1.807	-0.015	2.275	3.759	-3.346	-0.066	0.789**
No of productive tillers/plant	0.108	-2.698	3.722	1.498	3.571	-2.115	-5.511	1.019	0.029	0.374
Flag leaf area (cm^2)	-0.230	4.773	-3.285	-1.698	-2.296	1.930	3.850	-2.453	-0.048	0.541**
Leaf fresh weight (cm^2)	-0.470	2.067	-3.039	-0.891	-4.374	6.191	7.332	-6.632	-0.002	0.181
Leaf area (cm^2	-0.541	1.785	-1.377	-0.573	-4.738	5.715	7.550	-7.656	0.012	0.175
Biomass yield (g)	-0.555	2.519	-3.065	-0.976	-4.792	6.447	6.693	-6.125	-0.001	0.143
Harvest index (%)	-2.569	2.058	-0.520	-0.571	-3.978	6.000	5.622	-7.291	0.004	0.755**
Correlation with yield (r)	-0.008	3.330	-1.233	-0.924	-0.136	-0.763	0.123	0.377	-0.089	0.676**

Residual effect: 0.1892; Bold figures indicate direct effect; ** denote significance at 5% level of probability

Characters under reference did not show any influence indirectly and if at all were marginal. A positive association was reported earlier by Armugachamy *et al.* (1993) between plant height, panicle length with grain yield and biological yield. Correlations among different characters showed that plant height had significant positive association with panicle length, leaf fresh weight, leaf dry-weight, leaf area and biomass yield at genetic level. Strong positive association of panicle length with leaf fresh weight, leaf dry weight, and leaf area biomass yield and harvest index was observed at genetic level. Thus, selection for plant height or panicle length, expected to increase leaf fresh weight, leaf dry weight, leaf area, biomass yield, and harvest index. Panicle length was found to be negatively correlated with number of productive tillers per plant. Flag leaf area had significant association with leaf fresh weight, leaf area and harvest index. Leaf fresh weight showed significant positive association with biomass yield at genetic level and with leaf dry weight and leaf area at phenotypic and environmental levels. Significant association between leaf area and biomass yield was observed at genetic level. Harvest index also displayed positive correlation with grain yield. Strong positive association of panicle length with leaf fresh weight, leaf dry weight, leaf area biomass yield and harvest index was observed at genetic level. Thus, selection for plant height or panicle length, would increase leaf fresh weight, leaf dry weight, leaf area, biomass yield, and harvest index. Panicle length was negatively correlated with number of productive tillers per plant. Flag leaf area had significant association with leaf fresh weight, leaf area and harvest index. Leaf fresh weight recorded significant positive association with biomass yield at genetic level and with leaf dry weight and leaf area at phenotypic and environmental levels. Significant association between leaf area and biomass yield was observed at genetic level. Direct selection for panicle length would result in substantial improvement in grain yield, since this character also showed significant positive correlation with grain yield. Although leaf area, leaf dry weight and number of productive tillers had maximum positive direct effect however, their correlation values were found to be either non-significant or negative. Therefore, restrictions are to be imposed to nullify the undesirable indirect effect in order to make use of direct effect. Correlation studies also provide better insights in understanding yield components, which help in choosing proper breeding partners for genetic improvisation (Johnson *et al*., 1951). Johnson *et al*., 1951 also suggested that the low phenotypic correlation may be due to masking/modifying effect of the environment in genetic association between characters as similarly observed by Shinde *et al*. (1996) in soybean and Reddy *et al.* (1997) in rice inbreds. Positive associations indicate that increase in one variable would cause increase in the other and *vice versa* (Yadav 1992; Surek *et al.,* 1998; Rao and Saxenna, 1999)

Path coefficient analysis indicates that yield is the multiplicative end product of several component characters (Whitehouse 1958; Grafius 1959). Those are mutually associated, which in turn impair the true association existing between component character and grain yield. The complexity of character relationships among themselves and with grain yield do not provide comprehensive picture of relative importance that is direct and indirect influence of each characters to the yield since the resultant yield is the combined effects of various factors, complimentary or counteracting. Path analysis provides an effective means of untangling direct and indirect causes of association and permits a critical examination of specific forces acting to produce a given correlation. It measures the direct and indirect contributions of independent variables on dependent variables. Therefore, to understand the relationship between yield per plant and related characters, path analysis was computed using simple genetic correlation coefficient values, which showed maximum negative direct effect on grain yield was displayed by biomass yield (-7.291), followed by leaf fresh weight (-4.374), flag leaf area (-1.698), plant height (-0.700) and harvest index (-0.089). Biomass yield and leaf area also exhibited negative indirect effect on grain yield through leaf fresh weight, flag leaf area, number of productive tillers per plant. Biomass yield showed positive and highly significant correlation ship with grain yield. This might have been caused due to high positive indirect effects of leaf area (5.622), leaf dry weight (6.000) and panicle length (2.058). In such situations, the indirect causal factors are to be considered simultaneously for selection. The residual effect in this study was found to be low (0.1892). Therefore, the independent variable explains about 81.08% of variability in grain yield of rice. These causal factors chosen were plausibly contributed maximum for high variability in respect of grain yield.

In conclusion, a set of Pokkali somaclones was identified, having high yield in salt tolerant background. Considerable variation for all the characters was studied with simple statistical tools and techniques. PCV was found to be higher than GCV for all the characters studied. Plant height, flag leaf area, leaf dry weight, harvest index had additive gene effects as evidencedt by from genetic advance values and thus simple selection may be adopted for genetic improvement of these characters. Plant height, panicle length, flag leaf area and biomass yield emerged as most important contributing characters to maximize grain yield and can be exploited for breeding ideal plant types. Panicle length showed maximum direct effect coupled with significant positive correlation values with grain yield and selection for panicle length can be used for genetic improvement of grain yield of somaclones derived from Pokkali - a tall, traditional, highly salt tolerant popular rice cultivars predominately grown in Kerala state of Indian Republic. This experiment show ample scope of genetic improvement of Pokkali endowed with higher productivity, which would be instrumental to fulfill consumers' preference in the people of Kerala and elsewhere.

ACKNOWLEDGEMENTS

Authors express their sincere thanks to the Director, ICAR-Central Island Agricultural Research Institute, Port Blair for his keen interest, constant encouragement and facilities provided to execute this work.

REFERENCES

Al-Jibouri H, Miller PA, Robinson HF (1958). Genotypic and environmental variances and covariances in an upland cotton cross of interspecific origin. *Agronomy Journal*. 50(10): 633-636.

Anon (1988). Standard evaluation system for rice. The International Rice Testing Program. The International Rice Research Institute. Los Banos. Philippines. pp. 1-54.

Bai NR, Regina A, Devika R, Joseph CA (1992). Genetic variability and association of characters in medium duration rice genotypes. *Oryza*. 29: 19-22.

Borbora TK, Hazarika GN (1998). Study of genetic variability, heritability and genetic advance for panicle characters in rice. *Oryza*. 35: 19-21.

Burton GW (1951). Quantitative inheritance in pearl millet (*Pennisetum glaucum*). *Agron. J*. 43(9): 409-17.

Burton GW (1952). Quantitative inheritance in grasses. *Proc. 6th Int. Grassland Cong*. 1: 277-283.

Chauhan JS (1996). Genotypic and phenotypic correlations between grain yield and other associated characters in very early duration elite breeding cultures of rice. *Oryza*. 33: 26-30.

Chopra,VL, Narasimhulu SB, Kirti PB, Prakash S, Anuradha G (1989). Studies of somaclonal variation in *Brassica spp*. and its relevance to improvement of stress tolerance and yield. *Review of advances in plant biotechnology*. 1985-88: 229.

Dewey DR, Lu K (1959). A correlation and path-coefficient analysis of components of crested wheatgrass seed production. *Agronomy Journal* 51(9): 515-518.

Ganesan K, Wilfred W, Vivekanandan MP, Arumugam Pillai M (1997). Character association and path analysis in rice. *Madras Agricultural Journal*. 84: 614-614.

Gangwar B, Mongia AD, Bandyopadhyay AK (1990). Rice based cropping systems for Bay islands. *Research Bulletin-Central Agriculture Research Institute* (2): 29-32.

Government of India (2015). Pocket book of agricultural statistics. Ministry of Agriculture, Department of Agriculture & Cooperation, Directorate of Economics & Statistics, New Delhi.

Grafius JE (1959). Heterosis in barley. *Agronomy Journal*. 51(9): 551-554.

Henke RR, Mansur MA, Constatin MJ (1978). Organogenesis and plantlet formation form organ and seedling derived calli of rice (*Oryza sativa). Physiol. Planta.* 44: 11-14.

Johnson HW, Comstock RE, Harvey PH (1951). Genetic and phenotypic correlations in corn and their implications in selection. *Agronomy Journal*. 43(6): 282-287.

Johnson HW, Robinson HF, Comstock RE (1955). Estimates of genetic and environmental variability in soybeans. *Agronomy Journal*. 47(7): 314-318.

Larkin PJ, Scrowcroft WR (1981). Somaclonal variation-a novel source of variability form cell cultures for plant propagation. *Theoretical and Applied Genetics* 60: 197-214.

Lokaprakash R, Shivashankar G, Mahadevappa M, Gowda BT, Kulkarni RS (1992). Study on genetic variability, heritability and genetic advance in rice. *The Indian Journal of Genetics and Plant Breeding*. 52(4): 416-421.

Mandal AB, Pramanik SC (1998). Somaclonal variation in ratooning ability in Indica and Japonica rice. *Indian Agriculturist*. 42 (2): 89–96.

Mandal AB, Pramaik SC, Chowdhury B, Badyopadhyay AK (1999). Salt tolerant Pokkali somaclones performance under normal and saline soils in Bay Islands. *Field Crops Research*. 61: 13 -21.

Mandal AB, Roy B (2000). Development of Fe tolerant rice somaclones through in vitro screening. In: *4th International Rice*

Genet. Symp. Rice Research Institute, Philippines.
Nakano H, Maeda E (1979). Shoot differentiation in callus of *Oryza sativa* L. *Zeitschrift für Pflanzenphysiologie*. 93(5): 449-458.
Nishi T, Yoshida Y, Takahasi E (1968). Organ dedifferentiation and plant restoration in rice callus. *Nature.* 219: 508-509
Panse VG, Sukhatme PV, Shaw FJF (1961). Statistical methods for agricultural workers. Indian Council of Agricultural Research.
PB Samonte SO, Wilson LT, McClung AM (1998). Path analyses of yield and yield-related traits of fifteen diverse rice genotypes. *Crop Science* 38(5): 1130-1136.
Rao SS, Shrivastav MN (1994). Genetic variation and correlation studies in rainfed upland rice. *Oryza*. 31: 288-288.
Rao SS, Saxena RR (1999). Correlation and regression analysis in upland rice. *Oryza*. 36(1): 82-84.
Reddy JN, De RN, Suriya Rao AV (1997). Correlation and path analysis in lowland rice under intermediate (0-50 cm) water depth. *Oryza*. 34: 187-190.
Roy A, Kar MK (1992). Heritability and correlation studies in upland rice. *Oryza*. 29: 195-195.
Saidaiah P, Kumar SS, Ramesha MS (2009). Combining ability analysis for yield and yield components in rice. *International Journal of Agriculture Environment & Biotechnology* 2(2): 147-150.
Sarma MK, Richharia AK, Agarwal RK (1996). Variability, heritability, genetic advance, and genetic divergence in upland rice. *International Rice Research Notes (Philippines)*.
Sarawgi AK, Soni DK (1994). Induced genetic variability in M_1 and M_2 populations of rice (*Oryza sativa* L.) *Biol. Agr*. 97: 51-56.
Sawant DS, Patil SL (1995). Genetic variability and heritability in rice. *Annals of Agricultural Research*. 16(1): 59-61.
Sharma CL, Misra CH, Kumar K, Pathak VN (2006). Genetic variability for seed yield and its components in rice (*Oryza sativa* L.). *New Botanist*. 33(1/4): 65.
Shinde AK, Birari SP, Bhave SG, Ioshi RM (1996). Correlation and path coefficient analysis in soybean. *Ann. Agric. Res*. 17: 28-32.
Singh RK, Kakar SN (1977). Control on individual trait means during index selection. Proceedings of the 3rd Congress on SABRAO, Canberra, pp. 22-25.
Surek H, Korkut ZK, Bilgin O (1998). Correlation and path analysis for yield and yield components in rice in a 8-parent half diallel set of crosses. *Oryza*. 35: 15-18.
Whitehouse RNH, Thompson JB, Ribeiro MDV (1958). Studies on the breeding of self-pollinating cereals. *Euphytica*. 7(2): 147-169.
Yadav RK (1992). Genetic variability, correlation studies and their implication in selection of high yielding genotypes of rice. *Adv. Plant Sci*. 5: 306-312.
Zapata FJ (1985). Rice anther culture at IRRl. *Biotechnology in International Agricultural Research.* pp. 85.
Zapata FJ, Khush GS, Crill JP, Neu MH, Romero RO, Torrizo LB, Alejar M (1985). Rice anther culture at IRRI. In: Cell and tissue culture techniques for cereal crops improvement, Science Press, Beijing, pp. 27-46.