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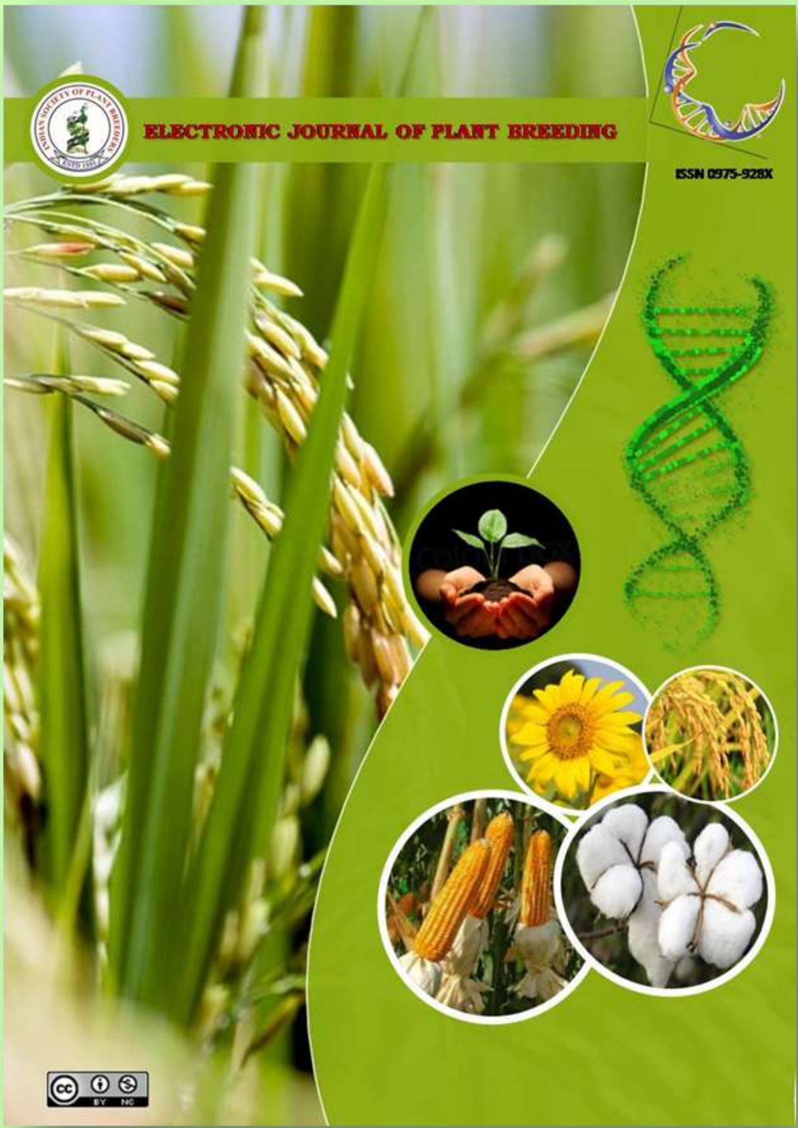

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Research Article

Genetic variability, correlation and path analysis of grain yield, grain quality and its associated traits in EMS derived M_4 generation mutants of rice (*Oryza sativa* L.)

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Abstract
A study was conducted to assess the grain yield and its related yield components to establish a reliable selection criteria for evolving high yielding varieties in rice. The EMS derived M_4 mutants of Anna(R) 4 rice cultivar was used for assessment of variability and association of yield and yield related traits. Phenotypic co-efficient of variation were invariably slightly higher than the genotypic co-efficient of variation, which indicated mild role of environment on the expression of these traits. However, moderate to high heritability estimates coupled with high genetic advance for the traits *viz*., number of grains per panicle, panicle weight and single plant yield renders the phenotypic selection more effective, since these traits were under the control of additive gene action. Association studies revealed that the number of grains per panicle, panicle weight and hundred grain weight showed positive significant correlation and direct effect towards grain yield in mutant population. The reduction of grain size and hundred grain weight ultimately increased the maximum number of grains per panicle.

Key words
Rice Anna(R)4, Ethyl methane sulphonate, genetic variability, correlation, path analysis, grain quality

Introduction

Rice is considered as a pre-eminent crop and cultivated in the region of eastern and southern parts of India. In India rice is cultivated in an area of 44.50 million hectares with a production of 116.00 million metric tons during 2018-19 (USDA 2019). According to DEWS (Drought Early Warning System), a real time monitoring system announced that 42% of the land area has been badly affected by drought. Hence, development of drought tolerant rice varieties is a preferred means to sustain food production for the future. Tamil Nadu is one among the state in India to cultivate rice in large area under irrigated and rainfed conditions. The rice variety, Anna (R) 4 is a drought tolerant variety released exclusively for rainfed tracts of Tamil Nadu with long slender grain type. However, nowadays farmers have not preferring to cultivate Anna(R)4 rice variety owing to its long slender grain type yielding low head rice recovery. The present investigation was aimed to explore genetic variability for various grain quality traits in the mutant population to identify desirable segregants with acceptable quality traits. Induced mutation is one of the most potential tools, which helps to isolate agronomicaly desirable genotypes with preferred grain quality traits in rice. Although variability for a trait of interest is abundantly present in the mutant population, its association with grain yield and yield components is also equally important for the simultaneous improvement of various traits.

Materials and Methods

The seeds of M_3 generation seeds of EMS treated Anna(R) 4 mutant lines were obtained from the Department of Plant Breeding and Genetics, Agriculture College and Research Institute, TNAU, Madurai. A total of thirty Anna(R)4 mutant families of M_3 generation seeds from the different EMS doses *viz.*,100 mM (7 Nos.), 110mM (7 Nos.) and 140mM (16 Nos.) were raised as M_4 generation in a Randomized Block Design (RBD) with two replications during *Rabi* 2017. The biometrical observations in respect of plant height (cm), panicle weight (g), number of filled grains per panicle (nos.), 100- grain weight (g), single plant yield (g) and days to maturity were recorded at harvesting stage. The physical properties of rice like grain length (mm) and grain length to breadth ratio were deduced through SATAKE grain analyser. The genotypic co-efficient of variation (GCV) and phenotypic co-efficient of variation (PCV) were calculated as per the methods of Burton and Devane (1953). Heritability in broad sense and genetic advance were estimated as per the method suggested by Johnson *et al* (1955) and Allard (1960) respectively. The genotypic and phenotypic correlations were worked out as per the method suggested by Singh and Chaudhary (1977). Path coefficient analysis was estimated as per the methods of Dewey and Lu (1959).

Results and Discussion

The ANOVA showed significant difference for yield and yield attributing traits (Table 1). The *first criterion* of selection is to estimate the genetic variability present in the population. Wide range of variability was observed for the plant height (78.51 to 105.30 cm), number of grains per panicle (95.40 to 224.00), panicle weight (2.08 to 5.00 g), hundred grain weight (1.45 to 2.10 g), days to maturity (107.00 to 118.00 days), grain length (5.5 to 6.6 mm), grain L/B ratio (2.62 to 3.30) and single plant yield (22.13 to 41.00g). Phenotypic co-efficient of variation was greater in magnitude than the corresponding genotypic coefficient of variation for all the traits studied, which showed little influence of environment on the expression of these traits. Similar results were earlier reported by Malimar *et al* (2015), Rashid *et al* (2017) and Gyawali *et al* (2018). Plant height, days to maturity, grain length and grain length / breadth ratio observed low levels of GCV which indicated little scope for the improvement of these traits. Similar findings were earlier reported by Vinod Kumar *et al*. (2018), Ravindra *et al*. (2012) and Srujana *et al*. (2017). However number of grains per panicle, panicle weight, hundred grain weight and single plant yield showed moderate levels of GCV which witnessed ample scope for the genetic improvement of these traits. Dev Nidhi Tiwari *et al*. (2019) reported moderate levels of GCV for grain yield.

Heritability is the *second criterion* of selection in a population. Heritability is the ratio of genotypic variance and phenotypic variance. The heritability estimates for different characters under study ranged from 45.63 to 89.26 per cent. High heritability estimates denotes the predominant role of additive gene action, which were recorded for number of grains per panicle (73.18%), hundred grain weight (61.21%), days to maturity (89.26%), plant height (74.90%) and grain length (72.02%). However, panicle weight, grain L/B ratio and single plant yield recorded moderate levels of heritability. Moderate GCV estimates together with higher / moderate levels of heritability noticed for number of grains per panicle, panicle weight, hundred grain weight and single plant yield renders the effectiveness of phenotypic selection.

The *third criterion* of selection is the genetic advance as per cent of mean for the trait of interest. The genetic advance as per cent of mean ranged from 6.62 to 27.39 percent across various traits. Genetic advance as per cent mean was higher for number of grains per panicle (27.39%), panicle weight (26.12%) and single plant yield (23.06%), while, hundred grain weight (17.61%) observed moderate estimate (Table 2). Heritability indicates only the effectiveness of phenotypic selection for a character. However, heritability along with genetic advance as per cent of mean will give a reliable picture on the quantum of genetic enhancement made due to phenotypic selection. Higher heritability along with higher genetic advance observed for number of grains per panicle, panicle weight and single plant yield renders the phenotypic selection more effective. Also, it showed the role of additive gene action in the inheritance of these traits. Similar result was already reported by Nandan *et al*. (2010) for panicle weight and single plant yield. Plant height (cm), days to maturity and grain length (mm) recorded high heritability and low genetic advance which indicated influence of non-additive gene action. Hence, selection for these traits may be postponed to later generations. Sanjukta *et al*. (2007) and Nirmaladevei *et al*. (2015) reported high heritability and low genetic advance for grain length. Low heritability and low genetic advance as per cent of mean for grain length/breadth ratio revealed that the character is highly influenced by environmental effects and selection would be ineffective.

The correlation between different characters represents a coordination of physiological processes, which is often achieved through gene linkages (Mather and Jinks, 1971). The genetic correlation provides reliable information on whether two heritable traits shared genes or not.The magnitude and direction of genetic correlations (negative or positive) can helps in selection of one or more traits. The traits like plant height, number of grains per panicle and panicle weight noticed high and positive association with single plant yield for both phenotypic and genotypic level (Table 3). Hundred grain weight had positive and significant association with grain yield at genotypic level. Similar trends of association were already reported for plant height (Sanghera *et al.* (2013), Kundu Sritama *et al*. (2015), and Ajmera *et al.* (2017), number of grains per panicle (Ratna *et al.* (2015), Saha *et al.* (2015), Ajmera *et al.* (2017) and panicle weight (Rai *et al*. 2013).Studies on character association among the yield component characters showed positive correlation between the plant height with number of grains per panicle, panicle weight and days to maturity; the number of grains per panicle with panicle weight; hundred grain weight with grain length and grain L/B ratio; grain length with grain length breadth ratio at genotypic level (Table 3). On the contrary, negative and significant inter correlation was observed for the trait number of grains per panicle with grain length, hundred grain weight and the panicle weight with grain L/B ratio**.** The results derived from this study showed that the number of grains per panicle increased on an average of 167.93 with reduced grain length of 5.97 mm and hundred grain weight of 1.75g in EMS derived mutants from 100mM, 110mM and 140 mM as compared with the number of grains per panicle (120.50), grain length (6.92 mm) and hundred grain weight (2.23g) of Anna(R)4 rice. Similarly Fang *et al.* (2016) isolated *small grain 11* (*smg11*) mutant from M_2 population of EMS derived *japonica* variety Kuanyejing. The length and width of grain was significantly decreased which resulted in the reduction of hundred grain weight compared with that of Kuanyejing variety. The size of grain restricted by its spkilelet hull which is determined by SPL13 gene promotes grain length through elongation and PGL1, PGL2 for expansion of spikelet hull. But in *smg11* mutant, the expression level of these genes was lower compared to the Kuanyejing variety results in reduction of grain size and hundred grain weight in mutant type.

Path coefficient analysis is a measure to find out the route of causal factor and also examine the direct and indirect effect contributing the correlation among and between the traits. The direct effect of traits *viz.,* number of grains per panicle (2.7384) followed by grain length breadth ratio(2.5070), hundred grain weight (2.006), panicle weight (1.0791) and days to maturity (0.5188) manifested highly positive effects, while the grain length (-1.8367) had negative direct effect towards grain yield per plant(Table 4). Similar results were reported for number of grains per panicle by Ratna *et al.* (2015), Bagudham *et al.* 2018 and Rai *et al*. (2013) for panicle weight. Panicle weight indirectly increased through number of grains per panicle (2.4932) and grain length (0.9244). Though the plant height showed positive correlation with grain yield, but it registered negative direct effect on yield. The positive relationship of plant height with yield indirectly contributed through number of grains per panicle (2.2331) and panicle weight (1.0098). The grain length had negative direct effect (-1.8367) on grain yield, whereas indirectly increased the yield through grain L/B ratio (2.5245) with short slender type. (Fig. 1).

The moderate levels of GCV, higher / moderate levels of heritability estimates coupled with high genetic advance observed for number of grains per panicle, panicle weight, hundred grain weight and single plant yield indicated the role of additive gene action in the inheritance of these traits. Phenotypic selection for these traits will be more effective.

The correlation study revealed that the traits like number of grains per panicle, panicle weight, plant height and days to maturity were strongly associated with single plant yield. However the path analysis showed negative direct effect of plant height with grain yield. Based on character association the selection based on number of grains per panicle, panicle weight, hundred grain weight and days to maturity will helps to improve the grain yield per plant. The number of grains per panicle had negatively correlated with grain length. Therefore reduction of grain size will lead to more number of grains per panicle in later generation that balance the panicle weight and grain yield per plant. Hence understanding these relationship will helps in improvement of grain characters and grain yield in rice.

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Table 1. ANOVA for yield and yield attributing traits in M_4 generation of Anna (R) 4 rice mutants

Source	df	Mean squares							
		Plant height	Number of filled grains per panicle	Panicle weight	Hundred grain weight	Days to maturity	Grain length	Grain L/B ratio	Single plant yield
Replication	1	7.79	200.66	0.03	0.06	56.40	0.04	0.02	66.92
Genotypes	30	61.35**	1611.91**	0.82**	0.82**	29.85**	0.23**	0.08**	51.39**
Error	30	26.07	249.59	0.21	0.21	1.69	0.04	0.03	13.61

*, ** denotes significance of the corresponding mean squares at the 0.05 and 0.01 levels respectively.

Table 2.Estimation of Variability, Heritability and Genetic advance as percent of mean for yield attributing traits in M_4 generation of Anna (R) 4 rice mutants

Characters	Range	PCV	GCV	PCV-GCV	Heritability (%)	Genetic advance as per cent of mean
Plant height (cm)	78.51- 105.30	6.40	5.54	0.86	74.90	9.88
Number of grains per panicle	95.40-224.00	18.17	15.54	2.63	73.18	27.39
Panicle weight(g)	2.08-5.00	21.47	16.50	4.97	59.08	26.12
Hundred grain weight (g)	1.45-2.10	13.97	10.93	3.04	61.21	17.61
Days to maturity	107.00-118.00	3.60	3.40	0.20	89.26	6.62
Grain length(mm)	5.50-6.60	6.12	5.20	0.92	72.02	9.08
Grain L/B ratio	2.62-3.30	7.44	5.03	2.41	45.63	6.99
Single plant yield(g)	22.13-41.00	19.26	14.68	4.58	58.11	23.06

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Table 3. Estimates of phenotypic and genotypic correlation coefficients between yield and yield component characters in M_4 generation of Anna(R) 4 rice mutants

Traits	Plant height (cm)	Number of grains per panicle (nos.)	Panicle weight (g)	Hundred grain weight (g)	Days to maturity	Grain length (mm)	Grain L/B ratio (mm)	Single plant yield (g)
Plant height (cm)	1.000	0.610**	0.560**	0.054^{NS}	0.344*	-0.053^{NS}	-0.168^{NS}	0.485**
	(1.000)	(0.815)**	(0.936)**	(0.044)^{NS}	(0.383)*	(-0.085)^{NS}	(-0.328)*	(0.607)**
Number of grains per panicle (nos.)		1.000	0.628**	-0.369*	0.208^{NS}	-0.388*	-0.298*	0.384**
		(1.000)	(0.910)**	(-0.487)**	(0.199)^{NS}	(-0.482)**	(-0.516)**	(0.600)**
Panicle weight (g)			1.000	-0.011^{NS}	0.255^{NS}	-0.307*	-0.331*	0.532**
			(1.000)	(-0.118)^{NS}	(0.393)*	(-0.503)**	(-0.674)**	(0.660)**
Hundred grain weight (g)				1.000	0.128^{NS}	0.250^{NS}	0.133^{NS}	0.277^{NS}
				(1.000)	(0.120)^{NS}	(0.527)**	(0.304)*	(0.304)*
Days to maturity					1.000	-0.162^{NS}	-0.219^{NS}	0.120^{NS}
					(1.000)	(-0.180)^{NS}	(-0.404)*	(0.184)^{NS}
Grain length (mm)						1.000	0.696**	-0.031^{NS}
						(1.000)	(1.007)	(-0.020)^{NS}
Grain L/B ratio							1.000	-0.029^{NS}
							(1.000)	(-0.341)*
Single plant yield (g)								1.000
								(1.000)

*, ** denotes significance at the 0.05 and 0.01 levels respectively.
Values indicated in parentheses (-) are genotypic correlation coefficient

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Table 4. Direct and indirect effects of biometrical traits on single plant yield in M_4 generation of Anna(R)4 rice mutants

Traits	Plant height (cm)	Number of grains per panicle	Panicle weight (g)	Hundred grain weight (g)	Days to maturity	Grain length (mm)	Grain L/B ratio	Single plant yield (g)
Plant height (cm)	**-2.2579**	2.2331	1.0098	0.0888	0.1988	0.1564	-0.8218	0.485 (0.607)
Number of grains per panicle	-1.8412	**2.7384**	0.9825	-0.9762	0.1035	0.8858	-1.2928	0.384 (0.600)
Panicle weight (g)	-2.1130	2.4932	**1.0791**	-0.2377	0.2040	0.9244	-1.6905	0.532 (0.660)
Hundred grain weight (g)	-0.0999	-1.3325	-0.1279	**2.0061**	0.0623	-0.9674	0.7628	0.277 (0.304)
Days to maturity	-0.8650	0.5463	0.4244	0.2410	**0.5188**	0.3302	-1.0121	0.120 (0.184)
Grain length (g)	0.1923	-1.3206	-0.5431	1.0567	-0.0933	**-1.8367**	2.5245	-0.031 (-0.020)
Grain L/B ratio	0.7402	-1.4121	-0.7277	0.6104	-0.2095	-1.8495	**2.5070**	-0.029 (-0.341)

RESIDUAL EFFECT= 0.36

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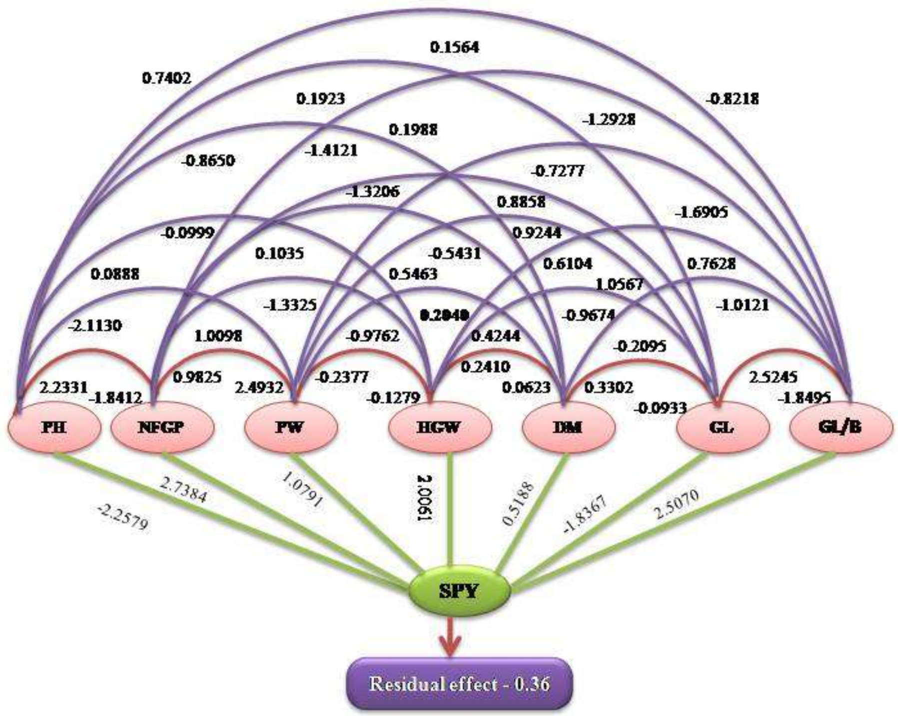

Fig. 1. Path Analysis Diagram for biometrical traits on single plant yield in M_4 generation of Anna(R) 4 rice mutants

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