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Research Note

Association analysis of F_2 generation in rice (*Oryza sativa* L.) under salinity condition

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Abstract
Rice occupies a pivotal place in the Indian agriculture and has been grown under diverse ecological conditions and gets exposed to different environmental stresses like drought, salinity and submergence. Development of rice varieties for salinity affected areas is emphasized on the improvement of rice yield potential in a specific environment. Information related to the relationship between yield and its components in the breeding programme particularly for salinity is very limited. Hence, the present investigation was carried out to study the correlation and path analysis in F_2 generation derived from two crosses namely ADT 43 x FL478 (Cross 1) and Improved White Ponni x FL478 (Cross 2) were evaluated at a farmer's field at Vedapatti village, Tuticorin district of Tamil Nadu which is a saline track. Another rice variety FL478 (IR 66946-3R-178-1-1, derived from crossing between Pokkali and IR 29), has been promoted as an improved donor for breeding programs, as it has a high level of seedling stage salinity tolerance and is photoperiod insensitive, shorter and ûowers earlier than the original Pokkali. FL478 also maintains a lower Na^+/K^+ ratio than both the parent lines (Gregorio *et al*. 2002). Based on its ability to tiller well and maintain high potassium content under salinity stress, FL478 appears to be a good candidate for salinity stress tolerance in rice, particularly at the vegetative stage of growth. In Vedapatti village of Tuticorin district, due to over-pumping of groundwater in the past several years, normal irrigation water has become saline water. Moreover, this village is considered as a hot spot area for the saline condition. Hence, the six generations developed through hybridization techniques were evaluated for salinity tolerance at Vedapatti village. The soil and water samples were collected from the field to analyze the EC and pH. The soil salinity and water quality in the experimental plot were 4.82 $ECdSm^{-1}$ and 8.09 (pH) for soil and 4.78 $ECdSm^{-1}$ and 8.19 (pH) for water respectively. From the present findings, it is clear that the characters *viz.,* number of tillers per plant, number of productive tillers per plant, number of filled grains per panicle, total number of grains per panicle and spikelet fertility have to be given prime importance during selection since they expressed significant and positive correlation with single plant yield and also a positive inter-correlation among themselves. Therefore, selection for anyone of the above characters would bring in the simultaneous improvement of other traits and also finally resort to improve the grain yield under salinity condition. Path analysis also revealed that selection for the number of productive tillers per plant and the number of filled grains per panicle are to be given prior importance during selection since they had a positive correlation and high direct and indirect effect on grain yield under salinity condition in rice.

Keywords
Rice, Salinity, Correlation, Direct effect, Filled grains per panicle

The productivity of rice is greatly affected by soil salinity which is the second most widespread soil problem next to drought in rice-growing areas of the world. Salinity affects the soil texture and creates unfavourable conditions for rice production by severe inhibition of plant growth and development (Miller and Donahue 1995). Globally 45 mh of irrigated and 32 mh of rainfed agriculture are being affected by salinity (www.fao.org/soils-portal). Furthermore, irrigation with brackish water, tidal waves and tsunami continue to increase the soil salinity (Schroeder *et al.*2013). There are two types of salinity, inland salinity which is due to irrigation practices with sloppy water and coastal salinity which is mainly due to high tides of the ocean in the coastal region.

Approximately 21.5 million hectares of arable land in Asia are facing salinity problem and estimated crop loss up to 50% of fertile land by 21st mid-century. Salinity affects rice growth in all the growth stages with varying degrees starting from germination to maturity. Rice is very sensitive during early seedling and later at reproductive stages. However, it is comparatively tolerant during germination, active tillering and at maturity. Salinity affects yield components such as panicle length, spikelet number per panicle, grain yield and also delays panicle emergence and flowering. There are some traditional cultivars and landraces which are naturally tolerant to salt stress due to their adaptation to thrive in salt-affected lands for generations. However, they generally have poor agronomic characteristics such as tall plant stature, poor grain quality, low yield and photosensitivity. This situation warrants the development of saline tolerant rice variety along with the high yielding ability to improve rice productivity.

The present investigation was carried out at Vedapatti village of Tuticorin district Tamil Nadu. Due to over-pumping of groundwater in the past several years, normal irrigation water has become saline water. Moreover, this village is considered as a hot spot area for the saline condition. Hence, the six generations developed through hybridization techniques were evaluated for salinity tolerance at Vedapattivillage. The soil and water samples were collected from the field to analyze the EC and pH. As per the Richards (1973) classification the irrigation water, used in the present study comes under very high salinity level with 4.82 $ECdSm^{-1}$ and 8.09 pH. Hence experimental field taken for the study is more appropriate to reveal the association pattern of different traits with yield under salinity stress condition.

The P_1 (ADT 43 and Improved White Ponni), P_2 (FL 478), F_1s ((ADT 43 x FL 478) and (IWP x FL 478)), F_2s (selfed seeds of ADT 43 x FL 478 and IWP x FL 478)) were raised under saline condition in farmers field at Vedapatti village, Tuticorin district to study the association between the traits for salinity tolerance. The F_2 generation of the two cross combinations (cross 1 (ADT 43 x FL 478) and cross 2 (IWP x F L478)) was raised in nursery beds at Agricultural College and Research Institute, Madurai under non-saline condition. Twenty-five days old seedlings were transplanted to main field at Vedapatti village in a Randomized Block Design under saline stress condition with two replications, adopting a spacing of 20 cm between rows and 15 cm between plants. Ten plants each in P_1, P_2 and F_1, 250 plants in F_2 for each cross in each replication were maintained for the study. After 21 days of transplanting, the phenotypic scoring for all the four generations was evaluated for their tolerance level to salinity using IRRI standard protocol (Gregorio *et al.,* 1997).

Observations were recorded in all the available plants in P_1, P_2, F_1 and F_2generations for the biometrical traits.

Score	Observation	Tolerance
1	Normal growth, no leaf symptoms	HT- Highly tolerant
3	Nearly normal growth, but leaf tips of few leaves whitish and rolled.	T - Tolerant
5	Growth severely retarded most leaves rolled, only a few are elongating.	MT- Moderately tolerant
7	Complete cessation of growth, most leaves dry some plants dying	S - Susceptible
9	Almost all plants dead or dying	HS – Highly susceptible

The phenotypic correlation coefficients between grain yield and its component traits and inter-correlation among different traits in F_2generation of two crosses were presented in **Tables 1 and 2** respectively.

F_2 generation – Cross 1(ADT 43 x FL 478)

The correlation coefficients of cross 1 revealed that the single plant yield recorded positive and significant association with the number of filled grains (0.903), the total number of grains (0.875), spikelet fertility (0.622) and the number of productive tillers (0.312) under salinity in F_2. It had a negatively significant association with days to flowering (-0.263) and plant height (-0.205). There was a positive association was observed with the number of tillers per plant and the negative with panicle length (**Table 1 and Fig. 1**). Days to flowering registered positive and significant association with the plant height (0.453) and 1000 grain weight (0.272), while it had a negatively significant association with the number of filled grains (-0.213), the total number of grains (-0.186) and spikelet fertility (-0.195) in F_2 (**Table 1**). A positive and significant relationship was noticed between plant height and the number of tillers (0.224) under salinity in cross 1 of F_2. It had a significantly negative association with the number of filled grains (-0.279), the total number of grains (-0.257) and spikelet fertility (-0.251). The number of productive tillers (0.151) and 1000 grain weight (0.043) registered a positive association. The F_2 generation of cross 1 under saline condition, none of the traits had a positive association with panicle length.The number of tillers exhibited positively significant association with the number of productive tillers (0.701) alone. However it had a positive association with 1000 grain weight. It had a negative and significant correlation with the number of filled grains (-0.242), the total number of grains (-0.186) and spikelet fertility (-0.273) in F_2. The relationship of number of productive tillers with all other traits in the F_2 generation was negatively non-significant except for spikelet fertility, where it was significantly negative (-0.172)

The number of filled grains had a positive significant association with the total number of grains (0.945) and

spikelet fertility (0.726) and the positive association with 1000 grain weight (0.034) in F_2 of cross 1. The association between total number of grains and spikelet fertility (0.472) in F_2 generation was positive and highly significant in cross 1 and positive with 1000 grain weight (0.033). Spikelet fertility had a positive association with 1000 grain weight (0.058) alone in F_2 generation of the cross 1 under saline condition.

Table 1. Phenotypic correlation coefficients between different traits in F_2 generation – cross 1

Traits	Days to flowering	Plant height	Panicle length	Number of tillers	Number of productive tillers	Number of filled grains	Total number of grains	Spikelet fertility	1000 grain weight	Single plant yield
Days to flowering	**1.000**	0.453**	-0.063	-0.100	-0.150	-0.213*	-0.186*	-0.195*	0.272**	-0.263**
Plant height		**1.000**	-0.051	0.224*	0.151	-0.279**	-0.257**	-0.251**	0.043	-0.205*
Panicle length			**1.000**	-0.100	-0.108	-0.047	-0.033	-0.130	-0.077	-0.099
Number of tillers				**1.000**	0.701**	-0.242**	-0.186*	-0.273**	0.135	0.073
Number of productive tillers					**1.000**	-0.109	-0.049	-0.172*	-0.121	0.312**
Number of filled grains						**1.000**	0.945**	0.726**	0.034	0.903**
Total number of grains							**1.000**	0.472**	0.033	0.875**
Spikelet fertility								**1.000**	0.058	0.622*
1000 grain weight									**1.000**	-0.000

*Significant at 5 % level, **Significance at 1 % level

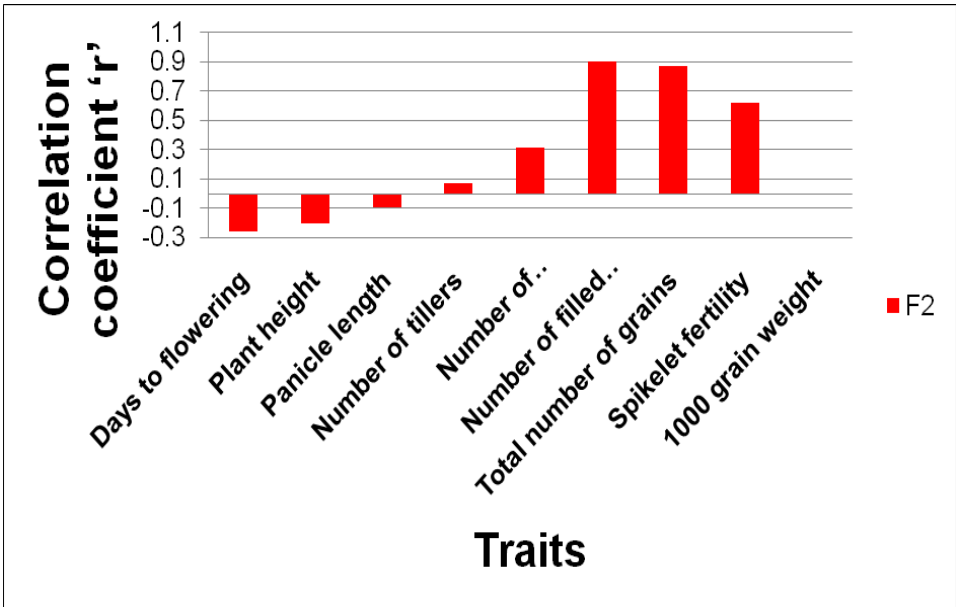

Fig. 1. Phenotypic correlation coefficients between yield and yield components in cross 1

F_2 generation – Cross 2(IWP x FL 478)

The association of single plant yield with other traits *viz*., number of filled grains (0.859), the total number of grains (0.716), number of productive tillers (0.552), spikelet fertility (0.502) and the number of tillers (0.387) in F_2 generation was positively significant. It had a positive association with plant height (0.056) in cross 2 under salinity (**Table 2**). In cross 2, none of the traits registered significant association with days to flowering in F_2 generation under saline condition. However, days to flowering exhibited a positive association with plant height (0.111), panicle length (0.014), number of tillers (0.048), the total number of grains and 1000 grain weight (0.078). The characters *viz.,* number of productive tillers (0.143), number of tillers (0.122) and spikelet fertility (0.009) exhibited a positive association with plant height under salinity in cross 2 of the F_2 generation. The association of panicle length in F_2 generation with the number of filled

grains (-0.163) was negative and significant, whereas positive and non-significant correlation existed with the number of tillers (0.098), the number of productive tillers (0.072) and 1000 grain weight (0.095) (**Table 2**). In F_2, the inter-correlation for the number of tillers with a number of productive tillers (0.839) alone showed a positive and highly significant association. It also expressed a positive correlation with the total number of grains and 1000 grain weight. The number of productive tillers in F_2 generation of cross 2 expressed positive but non-significant association with the number of filled grains and the total number of grains. Negative inter-correlation existed with rest of the characters *viz.,* spikelet fertility (-0.078) and 1000 grain weight (-0.029) (**Table 2**). A highly significant positive association was existed in F_2generation, with the traits namely total number of grains (0.786) and spikelet fertility (0.647) by this trait. The total number of grains possessed positive association with spikelet fertility (0.046) and 1000 grain weight (-0.013) in cross 2 of the F_2 generation (**Table 2 and Fig. 2**).

Table 2. Phenotypic correlation coefficients between different traits in F_2 generation – cross 2

Traits	Days to flowering	Plant height	Panicle length	Number of tillers	Number of productive tillers	Number of filled grains	Total number of grains	Spikelet fertility	1000 grain weight	Single plant yield
Days to flowering	**1.000**	0.111	0.014	0.048	-0.050	-0.074	0.026	-0.136	0.078	-0.095
Plant height		**1.000**	-0.013	0.122	0.143	-0.015	-0.015	0.009	-0.061	0.056
Panicle length			**1.000**	0.098	0.072	-0.163*	-0.116	-0.122	0.095	-0.114
Number of tillers				**1.000**	0.839**	-0.038	0.069	-0.149	0.024	0.387**
Number of productive tillers					**1.000**	0.054	0.128	-0.078	-0.029	0.552**
Number of filled grains						**1.000**	0.786**	0.647**	-0.087	0.859**
Total number of grains							**1.000**	0.046	0.013	0.716**
Spikelet fertility								**1.000**	-0.133	0.502**
1000 grain weight									**1.000**	-0.091

*Significant at 5 % level, **Significance at 1 % level

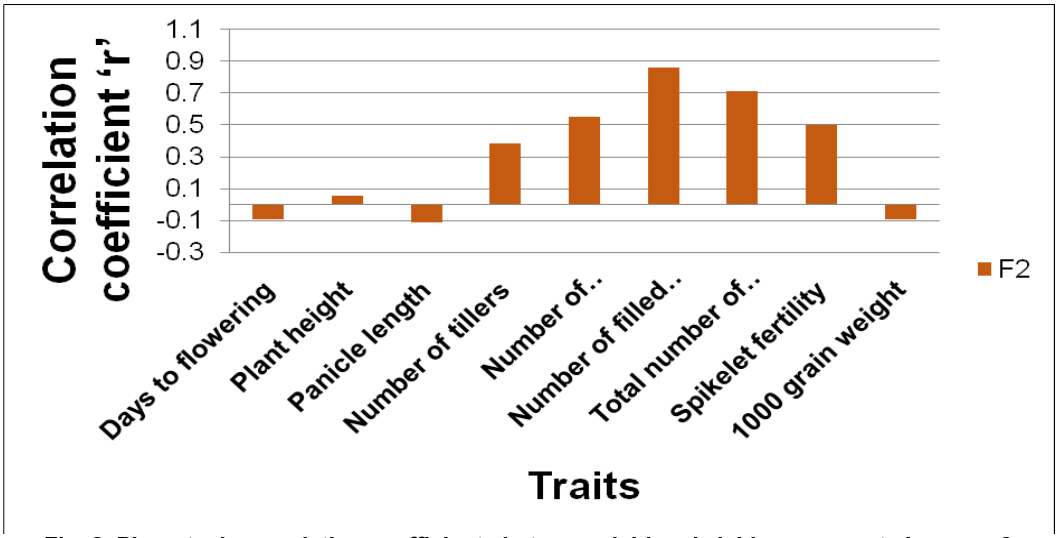

Fig. 2. Phenotypic correlation coefficients between yield and yield components in cross 2

In the F_2 generation**,** days to flowering had a significantly negative association with single plant yield in cross 1 (ADT43 x FL478)(-0.263). The plant height had significantly negative association (-0.205) with single plant yield of F_2 generation in cross 1. The trait panicle length had a non-significantly negative association with single plant yield. Its indirect effect through all other traits was either low or negligible in F_2(**Table 3**). In cross 1, the association for the number of tillers was positively non-significant with single plant yield (-0.100). The number of productive tillers showed positive and significant association (0.313) with single plant yield in F_2 of cross 1. In cross 1, the association of the number of filled grains with single plant yield was positive and significant (0.903) in the F_2generation. In the F_2 generation, cross 1 exhibited positive and significant association with grain yield for the trait total number of grains (0.875). Both direct and indirect effects on single plant yield through other traits

were either negligible or low in F_2 generation except for the trait number of filled grains, while it had a highly positive association in F_2 (0.814) of cross 1. The direct effect of 1000 grain weight and spikelet fertility on single plant yield was either low or negligible in F_2 generation under salinity condition (**Table 3**).

In F_2, the trait days to flowering had non-significantly negative association with single plant yield in cross 2(IWP x FL478)(-0.96).Its direct effect on single plant yield was negligible in F_2 of cross 2. In cross 2, the single plant yield exhibited positive and non-significant association with plant height in $F_2$of cross 2 studied under salinity condition (**Table 4**).

Table 3. Direct and indirect effects of different traits on single plant yield in F_2 generation– cross 1

Traits	Days to flowering	Plant height	Panicle length	Number of tillers	Number of productive tillers	Number of filled grains	Total number of grains	Spikelet fertility	1000 grain weight	Phenotypic correlation with single plant yield
Days to flowering	**0.002**	-0.003	0.000	-0.003	-0.060	-0.184	-0.012	-0.008	0.005	**-0.263****
Plant height	0.001	**-0.007**	0.000	0.007	0.060	-0.240	-0.017	-0.010	0.001	**-0.205***
Panicle length	0.000	0.000	**-0.004**	-0.003	-0.043	-0.041	-0.002	-0.005	-0.001	**-0.100**
Number of tillers	0.000	-0.002	0.000	**0.029**	0.281	-0.209	-0.012	-0.011	-0.002	**0.074**
Number of productive tillers	0.000	-0.001	0.000	0.020	**0.400**	-0.094	-0.003	-0.007	-0.002	**0.313****
Number of filled grains	-0.001	0.002	0.000	-0.007	-0.044	**0.860**	0.063	0.029	0.001	**0.903****
Total number of grains	0.000	0.002	0.000	-0.005	-0.020	0.814	**0.066**	0.019	0.001	**0.875****
Spikelet fertility	-0.001	0.002	0.001	-0.008	-0.069	0.625	0.031	**0.040**	0.001	**0.623***
1000 grain weight	0.001	0.000	0.000	-0.004	-0.048	0.030	0.002	0.002	**0.017**	**-0.000**

Diagonal and bold indicates the direct effect **Residual effect = 0.107**

Table 4. Direct and indirect effects of different traits on single plant yield in F_2 generation– cross 2

Traits	Days to flowering	Plant height	Panicle length	Number of tillers	Number of productive tillers	Number of filled grains	Total number of grains	Spikelet fertility	1000 grain weight	Phenotypic correlation with single plant yield
Days to flowering	**-0.005**	0.000	0.000	-0.001	-0.026	-0.070	-0.002	0.009	0.000	**-0.096**
Plant height	-0.001	**-0.002**	0.000	-0.002	0.075	-0.015	0.001	-0.001	0.000	**0.056**
Panicle length	0.000	0.000	**-0.015**	-0.002	0.038	-0.155	0.011	0.008	0.000	**-0.114**
Number of tillers	0.000	0.000	-0.002	**-0.018**	0.440	-0.036	-0.006	0.010	0.000	**0.388****
Number of productive tillers	0.000	0.000	-0.001	-0.015	**0.524**	0.051	-0.012	0.005	0.000	**0.552****
Number of filled grains	0.000	0.000	0.003	0.001	0.028	**0.944**	-0.071	-0.045	0.000	**0.860****
Total number of grains	0.000	0.000	0.002	-0.001	0.068	0.743	**-0.091**	-0.003	0.000	**0.717***
Spikelet fertility	0.001	0.000	0.002	0.003	-0.041	0.611	-0.004	**-0.069**	0.000	**0.502****
1000 grain weight	0.000	0.000	-0.001	0.000	-0.016	-0.083	-0.001	0.009	**0.002**	**-0.091**

Diagonal and bold indicates the direct effect **Residual effect = 0.065**

Panicle length had a negative but significant association with single plant yield in F_2 of cross 2 under saline condition. The number of productive tillers possessed positive and significant association with single plant yield in F_2 (0.552) of cross 2. Its direct effect on single plant yield was positive and high in F_2 (0.524). The direct effect of the number of filled grains on a single plant yield was positive and high in F_2 (0.944). The association between spikelet fertility and single plant yield was positive and significant (0.502) in F_2 of cross 2. Its direct and indirect effects on single plant yield through other traits were either negligible or low in F_2. The 1000 grain weight had a negative and non-significant association with single plant yield in F_2. The direct and indirect effects of 1000 grain weight on single plant yield was either ignorable or low in F_2 generation studied under salinity condition.

In the present investigation, the grain yield showed positive and significant association with the number of tillers per plant, number of productive tillers per plant, number of filled grains per panicle, the total number of grains per panicle and spikelet fertility in both the crosses in F_2, (**Table 1 and 2**). The positive and significant association of number of tillers per plant with single plant yield was reported by Gopikannan and Ganesh (2013), Touhiduzzamam *et al.* (2016) and Singh *et al.* (2016); the number of productive tillers per plant with grain yield per plant by Krishnamurthy *et al.* (2014); the number of filled grains per panicle with grain yield per plant by Singh et al. (2016) and Pradhan *et al.* (2017);the total number of grains per panicle with grain yield per plant by Gunasekaran *et al.* (2010), Shiva Prasad *et al.* (2013) and Singh *et al.* (2016); Spikelet fertility with grain yield

per plant by Gopikannan and Ganesh (2013), Touhiduzzaman *et al.* (2016) and Pradhan *et al.* (2017); 1000 grain weight with grain yield per plant by Shiva Prasad *et al.* (2013) and Singh *et al.* (2016). The negative and significant association of days to first flowering with grain yield per plant was reported by Dhurai*et al.* (2016), plant height with grain yield per plant by Shiva Prasad *et al.* (2013) and Salim *et al.* (2016); panicle length with grain yield per plant by Vanniarajan *et al.* (1996) and Gopikannan and Ganesh (2013).

In the present study, the number of productive tillers per plant and number of filled grains per panicle had a high direct effect on single plant yield in F_2 generation of both cross 1 and cross 2. This was in accordance with earlier findings of Gopikannan and Ganesh (2013), Krishnamurthy *et al.* (2014) and Singh *et al.* (2016) for number of productive tillers per plant; Gunasekaran *et al.* (2010), Akhtar *et al.* (2010), Gopikannan and Ganesh (2013) and Pradhan *et al.* (2017) for number of filled grains per panicle. The remaining traits mostly showed either negligible or low direct effect on single plant yield. As far as indirect effects are concerned, the yield component traits had moderate to high indirect effects on grain yield only through the number of productive tillers per plant and number of filled grains per panicle. This was supported by Singh *et al.* (2016) and Touhiduzzaman *et al.* (2016). Hence from the above delibration it may be concluded that the selection for number of productive tillers per plant and number of filled grains per panicle should be given due weightage to increase the grain yield in rice under salinity condition.

The association study for salinity tolerance in rice revealed that the characters *viz.,* number of tillers per plant, number of productive tillers per plant, number of filled grains per panicle, total number of grains per panicle and spikelet fertility have to be given prime importance during selection as they expressed significant and positive correlation with single plant yield and also a positive inter correlation among themselves. Therefore, these traits are to be given priority during the selection programme for improving yield under both salinity condition in rice. Path analysis also revealed that selection for the number of productive tillers per plant and the number of filled grains per panicle are to be given prior importance during selection since they had a positive correlation and high direct and indirect effect on grain yield under both salinity condition in rice.

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