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Trait relationship and path analysis under sodicity in Nagina 22 rice mutants

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Abstract
The present study was conducted for evaluating EMS induced mutants for sodicity tolerance in rice. A set of 402 Nagina 22 rice mutants along with three sodicity tolerant check varieties namely TRY2, TRY3 and TRY4 were screened at Anbil Dharmalingam Agricultural College and Research Institute, Trichy under sodic soil condition and also screened under hydroponics condition at the seedling stage. A total of 13 biometrical traits and salt injury scores were recorded and subjected to association analysis and path analysis. Correlation analysis showed that there was a significant and positive correlation observed for flag leaf length, flag leaf breadth, the number of total tillers per plant, the number of productive tillers for the plant, tillering efficiency percentage, panicle length, panicle weight, panicle harvest index and hundred seed weight and also showed significant and negative correlation for salt injury index and vegetative vigour. Both the scores at the field (vegetative vigour) and salt injury score showed a negative correlation with single plant yield. Path analysis revealed a high positive direct effect on the number of productive tillers per plant, panicle weight, hundred seed weight and panicle length and the remaining traits showed negligible effects on single plant yield. As a result, enhancing the correlating trait as well as reducing the effect of negative correlating trait leads to the development of better tolerant varieties.

Key words: Nagina 22 mutants, correlation, path analysis, sodicity

INTRODUCTION

Rice (*Oryza sativa*), the staple crop for over one-third of the world ‘s population, is vital for providing 20-80 per cent of the daily calories. Asia produces and consumes about 90 per cent of the total rice (www.indiastat.com) of which India alone produces one fourth (22%). India is the second largest rice producing country in the world with a production of 116.4 million tonnes and productivity of 2638 kg /ha as reported during 2019-20 occupying an area of 44.15 million hectares (www.indiastat.com). In Indian agriculture, rice occupies a pivotal place and has been grown under diverse ecological conditions; hence it gets exposed to different environmental stresses. Among abiotic stress, salinity approximately affects 6 per cent of the global farming area, *i.e.,* nearly 1 billion ha area (Kakar *et al.,* 2019). In rice yield loss due to salinity and sodicity was up to 50 per cent (Mass, 1986). The crop is sensitive to salinity and sodicity at the early seedling stage (Aslam *et al.,* 1993). High yield losses were observed because of high mortality and poor crop establishment. Because of salt accumulation, most of the fertile area around the coastal region and inland saline tracks becomes unproductive. In general, crop adaptation towards these stresses will be the best alternative to overcome an unproductive environment as well as enhancing the

production and productivity of the crop under stress. Salt stress causes plant growth reduction, photosynthetic reduction and partial sterility, which all leads to drastic yield reduction (Pardo, 2010 and Todaka *et al*., 2012). Studying the association as well as the relationship of various traits with yield will be helpful in the selection and identification of elite genotypes with tolerance capacity (Fiyaz *et al.,* 2011). The exploitation of mutants can be used for the identification of tolerant genotypes for different biotic and abiotic stresses. Some of the useful mutants of N22 were identified for various traits including salinity under a limited screening facility (Mohapatra *et al.,* 2014). In the present investigation, EMS induced mutant population was evaluated under field sodicity in order to found out the relationship among various traits with grain yield. Salinity stress at the early seedling stage manifests on the first leaf followed by the second and finally on the growing leaf. Salinity suppresses leaf elongation and the formation of new leaves (Gregario *et al.,* 1997). Seedling screening for sodicity under hydroponics was done along with the field experiment. The highly associated traits could be possibly used as target traits for the development of tolerant varieties through classical breeding programmes or marker assisted backcross programmes.

MATERIALS AND METHODS

Nagina 22, an upland rice cultivar were mutagenized using 0.5 % ethyl methane sulfonate and the seeds were evaluated for various traits as well as forwarded to subsequent generations at the Department of Rice, Tamil Nadu Agricultural University, Coimbatore and those mutants were used in this study. A set of 402 EMS induced M_4 generation mutants along with its wild type parent Nagina 22 and sodicity tolerant check varieties namely, TRY2, TRY 3 and TRY 4 were raised in Anbil Dharmalingam Agricultural College and Research Institute, Trichy under the sodic condition in the field (EC – 1.5 dSm^{-1}, pH – 8.75 and ESP 42.4). The experiment was conducted during December 2020 using an Augmented design I by adopting a spacing of 20× 20 cm. Data on thirteen traits *viz*., vegetative vigour (score), days to 50 per cent flowering, plant height (cm), flag leaf length (cm), flag leaf breadth (cm), the number of total tillers per plant, the number of productive tillers per plant, tillering efficiency (%), panicle length (cm), panicle weight (g), panicle harvest index, hundred seed weight (g) and single plant yield (g) were recorded in five randomly selected plants in each genotype.

The same set of mutant genotypes were screened for sodicity stress (@100 mM Sodium bicarbonate in Yoshida medium using hydroponics method along with control in the seedling stage. For the first 7 days, seedlings were maintained in Yoshida solution (Yoshida *et al.,* 1976) without any stress. Later, on the 8th day, 50 mM sodium bicarbonate was added and gradually on the 11th day, the seedlings were subjected to 100 mM sodic stress (Gregario *et al.,* 1997). Salt injury score was observed after the 17th day (SES, IRRI, 1986). All the 13 traits with salt injury scores were subjected to correlation (Pearson, 1897) and path analysis (Dewey and Lu, 1959) using TNAUSTAT software.

RESULTS AND DISCUSSION

Among the 14 characters studied, nine characters namely, flag leaf length, flag leaf breadth, the number of total tillers per plant, the number of productive tillers for the plant, tillering efficiency percentage, panicle length, panicle weight, panicle harvest index and hundred seed weight showed a significant and positive correlation with single plant yield **(Table 1).** The salt injury score and the vegetative score showed a negative significant correlation with single plant yield. On the other hand, plant height and days to 50 per cent flowering had no correlation with a single plant yield. Kalaiselvan *et al.* (2019) reported that days to 50 per cent flowering, plant height, the number of productive tillers, panicle length recorded a positive correlation with grain yield under sodicity. Priyanka *et al*. (2019) reported a significant correlation for grain yield with flag leaf length and Nanda *et al.* (2019) for panicle length.

Salt injury score had a significant and positive association with vegetative vigour (0.213), while the number of total tillers per plant (-0.199), the number of productive tillers per plant (-0.235), tillering efficiency percentage (-0.180), panicle length (-0.225), panicle weight (-0.138) and hundred seed weight (-0.245) recorded a negative significant correlation with salt injury score. Vegetative vigour recorded a positive significant correlation with days to 50 per cent flowering (0.202) whereas recorded significant and negative correlation with flag leaf length (-0.338), flag leaf breadth (-0.283), total tillers per plant (-0.506), the number of productive tillers per plant (-0.515), tillering efficiency percentage (-0.281), panicle length (-0.381) and hundred seed weight (-0.399). Gopikannan and Ganesh (2013) reported that panicle length had a positive and significant association with spikelet fertility, the number of filled grains per panicle, proline content, total chlorophyll content under sodicity.

Days to 50 per cent flowering recorded significant and positive correlation with flag leaf length (0.160), panicle weight (0.160) and panicle harvest index (0.114), whereas it had shown negative correlation with tillering efficiency percentage (-0.161). Plant height recorded a significant and positive correlation with tillering efficiency percentage (0.205). Tillering efficiency percentage recorded a significant and positive correlation with panicle length (0.411) and hundred seed weight (0.391) whereas, panicle weight (-0.102) recorded a significant and negative correlation.

Flag leaf length and flag leaf breadth recorded a significant and positive correlation with the number of total tillers per plant, the number of productive tillers

Table 1. Pearson Correlation coefficient of 14 morphological traits of rice mutants under sodicity stress

Traits	SIS	VV	DFF	PH	FLL	FLB	NT	NPT	TE	PL	PW	PHI	HSW	SPY
SIS	1.000	0.213**	0.027	0.089	-0.005	-0.071	-0.199**	-0.235**	-0.180**	-0.225**	-0.138**	-0.038	-0.245**	-0.294**
VV		1.000	0.202**	-0.046	-0.338**	-0.283**	-0.506**	-0.515**	-0.281**	-0.381**	0.007	-0.004	-0.399**	-0.407**
DFF			1.000	0.053	0.160**	-0.062	-0.031	-0.078	-0.161**	0.016	0.160**	0.114*	-0.027	0.037
PH				1.000	0.095	0.057	0.025	0.072	0.205**	0.080	-0.008	0.048	0.067	0.044
FLL					1.000	0.294**	0.175**	0.188**	0.149**	0.142**	-0.012	0.014	0.170**	0.174**
FLB						1.000	0.217**	0.219**	0.099*	0.181**	0.052	0.098*	0.203**	0.232**
NT							1.000	0.967**	0.320**	0.923**	-0.117*	-0.066	0.694**	0.677**
NPT								1.000	0.527**	0.927**	-0.113*	-0.056	0.731**	0.710**
TE									1.000	0.411**	-0.102*	-0.057	0.391**	0.362**
PL										1.000	0.057	0.059	0.730**	0.770**
PW											1.000	0.739**	0.374**	0.583**
PHI												1.000	0.380**	0.496**
HSW													1.000	0.890**
SPY														1.000

SIS - Salt Injury Score, VV - Vegetative Vigour, DFF - Days to Fifty Per cent Flowering, PH - Plant Height, FLL - Flag Leaf Length, FLB - Flag Leaf Breadth, NT - Number of Total Tillers per plant, NPT - Number of Productive Tillers per plant, TE - Tillering Efficiency Percentage, PL - Panicle length, PW - Panicle Weight, PHI - Panicle Harvest Index, HSW - Hundred Seed Weight, SPY - Single Plant Yield.

** Significant at the 0.01 level, * Significant at the 0.05 level

per plant, tillering efficiency percentage, panicle length and hundred seed weight. The number of total tillers per plant and the number of productive tillers per plant recorded significant and positive correlation with tillering efficiency percentage, panicle length and hundred seed weight, whereas panicle weight recorded significant and negative correlation. Panicle length, panicle weight and panicle harvest index recorded significant and positive correlation with hundred seed weight. Vijaya Durga *et al*. (2020) claimed that plant height showed a negative correlation with panicle length and productive tillers per plant. A positive and significant correlation was observed between the number of productive tillers and panicle length, the number of filled grains per panicle, spikelet fertility percentage and harvest index (Ali *et al*., 2018 and Ramesh *et al*., 2018).

Path coefficient analysis provides an effective way of finding the direct and indirect sources of correlations with a residual effect of 0.171 (**Table 2**). Path analysis revealed that a high positive direct effect on the number of productive tillers per plant (0.505), panicle weight (0.492), hundred seed weight (0.242) and panicle length (0.131). Moderate to negligible direct effect was observed on panicle harvest index (0.056), flag leaf length (0.026), flag leaf breadth (0.018) and tillering efficiency percentage (0.010). Such results coincide with the findings of Abhilash *et al*. (2018) and Kalaiselvan *et al*. (2019) the number of productive tillers per plant had shown direct positive effect on yield and emphasis may be given to the number of productive tillers per plant can be used for selection of best segregants under sodic conditions. Priyanka *et al.* (2020) reported that days to 50 per cent flowering, plant height and the number of productive tillers per plant exhibited a positive direct effect on grain yield per plant. The negative direct effect was expressed by days to 50 per cent flowering (-0.003), vegetative vigour (-0.014), salt injury score (-0.020), plant height (-0.020) and the number of total tillers per plant (-0.062).

Salt injury score exhibited a positive indirect effect on single plant yield through the number of tillers per plant (0.0122) and a high negative indirect effect through single plant yield (-0.2935). All other characters had moderate to a negligible negative indirect effects. Vegetative vigour exhibited a positive indirect effect on single plant yield through plant height (0.001), the number of total tillers per plant (0.031) and panicle weight (0.003). It recorded negative indirect effect through salt injury score (-0.004), days to 50 per cent flowering (-0.001), flag leaf length(-0.009), flag leaf breadth(-0.005), number of productive tillers per plant (-0.260), tillering efficiency percentage (-0.003), panicle length (-0.050), panicle harvest index (-0.0002), hundred seed weight (-0.097) and single plant yield (-0.407).

Table 2. Path analysis of 14 morphological traits of rice mutants under sodicity stress

Traits	SIS	VV	DFF	PH	FLL	FLB	NT	NPT	TE	PL	PW	PHI	HSW	SPY
SIS	**-0.020**	-0.003	-0.0001	-0.002	-0.0001	-0.001	0.012	-0.119	-0.002	-0.029	-0.068	-0.002	-0.059	-0.294
VV	-0.004	**-0.014**	-0.001	0.001	-0.009	-0.005	0.031	-0.259	-0.003	-0.050	0.003	-0.0002	-0.097	-0.407
DFF	-0.0001	-0.003	**-0.003**	-0.001	0.004	-0.001	0.002	-0.039	-0.002	0.002	0.079	0.006	-0.007	0.037
PH	-0.002	0.001	-0.0002	**-0.020**	0.003	0.001	-0.007	0.036	0.002	0.010	-0.004	0.003	0.016	0.044
FLL	0.0001	0.005	-0.001	-0.002	**0.026**	0.005	-0.011	0.095	0.002	0.019	-0.006	0.001	0.041	0.174
FLB	0.001	0.004	0.0002	-0.001	0.008	**0.018**	-0.013	0.111	0.001	0.024	0.025	0.005	0.049	0.232
NT	0.004	0.007	0.0001	-0.001	0.005	0.004	**-0.062**	0.488	0.004	0.121	-0.058	-0.004	0.168	0.6769
NPT	0.005	0.007	0.0002	-0.001	0.005	0.004	-0.059	**0.505**	0.006	0.122	-0.056	-0.003	0.176	0.710
TE	0.004	0.004	0.0001	-0.004	0.004	0.002	-0.019	0.266	**0.011**	0.054	-0.050	-0.003	0.0946	0.362
PL	0.005	0.005	0.0001	-0.002	0.004	0.003	-0.057	0.468	0.005	**0.131**	0.028	0.003	0.177	0.770
PW	0.003	-0.0001	-0.0001	0.0002	-0.0003	0.001	0.007	-0.057	-0.001	0.008	**0.492**	0.041	0.091	0.583
PHI	0.001	0.0001	-0.0003	-0.001	0.0004	0.002	0.004	-0.028	-0.001	0.008	0.363	**0.056**	0.092	0.496
HSW	0.005	0.006	0.0001	-0.001	0.005	0.004	-0.043	0.369	0.004	0.096	0.184	0.021	**0.242**	0.890

Residual effect = 0.171

Diagonal and bold indicates the direct effects

SIS - Salt Injury Score, VV - Vegetative Vigour, DFF - Days to Fifty Per cent Flowering, PH - Plant Height, FLL - Flag Leaf Length, FLB - Flag Leaf Breadth, NT - Number of Total Tillers per plant, NPT - Number of Productive Tillers per plant, TE - Tillering Efficiency Percentage, PL - Panicle length, PW - Panicle Weight, PHI - Panicle Harvest Index, HSW - Hundred Seed Weight, SPY - Single Plant Yield. **Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level

Days to 50 per cent flowering exhibited a positive indirect effect on single plant yield through flag leaf length (0.004), the number of total tillers per plant (0.002), panicle length (0.002), panicle weight (0.079), panicle harvest index (0.006) and single plant yield (0.037). It recorded a negative indirect effect on single plant yield through salt injury score (-0.001), vegetative vigour (-0.004), plant height (-0.001), flag leaf breadth (-0.001), the number of productive tillers per plant (-0.039), tillering efficiency percentage (-0.002) and hundred seed weight (-0.007).

Plant height exhibited a positive indirect effect on single plant yield through vegetative vigour (0.001), flag leaf length (0.003), flag leaf breadth (0.001), the number of productive tillers per plant (0.036), tillering efficiency percentage (0.002), panicle length (0.010), panicle harvest index (0.003), hundred seed weight (0.016) and single plant yield (0.044). It recorded a negative indirect effect on single plant yield through salt injury score (-0.002), days to 50 per cent flowering (-0.0002), the number of total tillers per plant (-0.002) and panicle weight (-0.004).

Flag leaf length exhibited a positive indirect effect on single plant yield through salt injury score (0.0001), vegetative vigour (0.005), flag leaf breadth (0.005), the number of productive tillers per plant (0.095), tillering efficiency (0.002), panicle length (0.019), panicle harvest index (0.001), hundred seed weight (0.041), single plant yield (0.174). It recorded a negative indirect effect on single plant yield through days to 50 per cent flowering (-0.001), plant height (-0.002), the number of total tillers per plant (-0.011), and panicle weight (-0.006).

Flag leaf breadth exhibited a positive indirect effect on single plant yield through salt injury score (0.001), vegetative vigour (0.004), days to 50 per cent flowering (0.0002), flag leaf length (0.008), the number of productive tillers per plant (0.111), tillering efficiency percentage (0.001), panicle length (0.024), panicle weight (0.025), panicle harvest index (0.005), hundred seed weight (0.049), and single plant yield(0.232). It recorded a negative indirect effect on single plant yield through plant height (-0.001) and the number of tillers (-0.013).

The number of total tillers per plant exhibited a positive indirect effect on single plant yield through salt injury score (0.004), vegetative vigour (0.007), days to 50 per cent flowering (0.0001), flag leaf length(0.005), flag leaf breadth(0.004), the number of productive tillers per plant (0.488), tillering efficiency percentage (0.004), panicle length(0.121), hundred seed weight(0.168) and single plant yield(0.677). It recorded a negative indirect effect on single plant yield through plant height (-0.001), panicle weight (-0.058) and panicle harvest index (-0.004).

The number of productive tillers per plant exhibited a positive indirect effect on single plant yield through salt injury score (0.005), vegetative vigour (0.007), days to 50 per cent flowering (0.0002), flag leaf length (0.005), flag leaf breadth (0.004), tillering efficiency percentage (0.006), panicle length (0.122), hundred seed weight (0.177) and single plant yield (0.710). It recorded a negative indirect effect on single plant yield through plant height (-0.001), the number of total tillers per plant (-0.059), panicle weight (-0.056), and panicle harvest index (-0.003).

Tillering efficiency percentage exhibited a positive indirect effect on single plant yield through salt injury score (0.004), vegetative vigour (0.004), days to 50 per cent flowering (0.001), flag leaf length (0.004), flag leaf breadth (0.002), the number of productive tillers per plant (0.266), panicle length (0.054), hundred seed weight (0.095) and single plant yield (0.362). It recorded a negative indirect effect on single plant yield through plant height (-0.004), the number of total tillers per plant (-0.019), panicle weight (-0.050) and panicle harvest index (-0.003).

Panicle length exhibited a positive indirect effect on single plant yield through salt injury score (0.005), vegetative vigour (0.005), days to fifty per cent flowering (0.0001), flag leaf length (0.004), flag leaf breadth (0.003), the number of productive tillers per plant (0.468), tillering efficiency (0.005), panicle weight (0.028), panicle harvest index (0.003), hundred seed weight (0.177), single plant yield (0.770). Gopi Kannan and Ganesh (2013) reported similar results that panicle length expressed high and indirect effect on single plant yield through the number of productive tillers per plant under sodicity. However, it recorded a negative indirect effect on single plant yield through plant height (-0.002) and the number of total tillers per plant (-0.057).

Panicle weight exhibited a positive indirect effect on single plant yield through salt injury score (0.003), plant height (0.0002), flag leaf breadth (0.001), the number of total tillers per plant (0.007), panicle length (0.008), panicle harvest index (0.041), hundred seed weight (0.091) and single plant yield (0.583). It recorded a negative indirect effect on single plant yield through vegetative vigour (-0.0001), days to 50 per cent flowering (-0.0015), flag leaf length (-0.0003), the number of productive tillers per plant (-0.057) and tillering efficiency percentage (-0.001). Harvest index exhibited a positive indirect effect on single plant yield through salt injury score (0.001), vegetative vigour (0.0001), flag leaf length (0.0004), flag leaf breadth (0.002) , number of total tillers per plant (0.004), panicle length (0.008), panicle weight (0.363), hundred seed weight (0.092) and single plant yield (0.496). It recorded a negative indirect effect on single plant yield through days to 50 per cent flowering (-0.0003), plant height (-0.001), the number of productive tillers per plant (-0.028) and tillering efficiency (-0.0001).

Hundred seed weight exhibited a positive indirect effect on single plant yield through salt injury score (0.005), vegetative vigour (0.006), days to 50 per cent flowering (0.0001), flag leaf length (0.005), flag leaf breadth (0.004), number of productive tillers per plant (0.369), tillering efficiency percentage (0.004), panicle length (0.096), panicle weight (0.184), panicle harvest index (0.021) and single plant yield (0.890). It recorded a negative indirect effect on single plant yield through plant height (-0.001) and the number of total tillers per plant (-0.043). Sari *et al*. (2019) and Akshaya (2020) reported that the plant height on grain yield had a high positive indirect effect through flag leaf length. However, Afrin *et al.* (2017) reported negative indirect effects through days to fifty50 per cent flowering, panicle length, plant height and the number of productive tillers per plant.

In the present investigation most of the characters studied showed a significant correlation with single plant yield except salt injury score and vegetative score. It showed that, whenever the crop experiences stress, the score was high and reflected the negative impact on yield. Only the mutants with better sodicity tolerance will have a lower score under stress conditions. Susceptible mutants failed to give better yield. Hence, correlation and path analysis will depict the association of various traits with a single plant yield under sodic conditions. Yield improvement of rice cultivars under sodicity stress could be achieved by enhancing the traits associated with single plant yield.

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