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Performance of Stress Indices in Assessing High Yield Potential of Rice Genotypes in Sulfur Deficient Soil

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Authors' contributions

The author MVS designed the study and completely wrote the manuscript, author RM conducted the field experiments and the author MR did statistical analysis. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aim: To recognize the rice genotypes based on stress indices which would give higher yield both under sulfur stress and non-stress conditions.
Design Factorial Randomized design with two factors
Place and Duration of Study: It was conducted in the farmers field(Chidambaram and Kuthalam in Tamilnadu, India and during Kharif season (June to September , 2009)
Methodology: Field experiments were conducted in two soils Kondal series (Typic Haplusterts- Vertisol) and Padugai series (Typic Ustifluvents- Entisol). The treatment details are factor A–S levels (0 & 10 mg S kg^{-1}) applied through gypsum and Factor B- Rice genotypes (ADT 43,CO 47,ADT 39,CO 43,ADT 42,ASD 19,ADT 36,ADT 37,ADT 38 and CO45). The yield data from two soils was used to calculate for each genotype 1) Stress tolerance (TOL) 2) Mean productivity (MP) 3) Geometric mean productivity (GMP) 4) Stress susceptibility index (SSI) and 5) Stress tolerance index (STI).
Results: Grain yield varied significantly (P=0.05) among rice genotypes regardless of S treatments. Without added S treatment CO 43 (4865 kg ha^{-1}) and CO 47 (5025 kg ha^{-1}) produced highest grain yield and ADT 36 (3437,3775 kg ha^{-1}) produced lowest yield in Kondal and Padugai series, respectively. Stress susceptibility index (SSI) and stress tolerance index (TOL) was associated with low yield under S sufficient condition. But stress tolerance index, mean productivity (MP) and geometric mean productivity (GMP)

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was able to identify top yielders both under S stress and non stress situations because of very strong correlation with yield. Accordingly best performers based on STI under both S stress and non- stress were ADT 43, CO 47, ADT 39 and CO 43

Keywords: Rice; sulfur; stress indices; grain yield.

1. INTRODUCTION

Rice is a staple food for more than half of the world population and about 95% of the world rice is grown in less developed countries. Due to intensive cropping and increased application of S free fertilizers in the recent years, S deficiency has become the most nutrient limiting factor for increasing rice yields. Plant species and genotypes/cultivars within species differ in optimal environmental requirements and their abilities to tolerate a particular stress. Sufficient genetic variability exists among several crop species and genotypes for nutrient acquisition and utilization under low nutrient environment [1] Manipulating genotypic differences in crop cultivars to adapt them to adverse soil conditions such as low nutrient status is one strategy for sustainable intensification of agricultural system' [2]. Sulfur deficient tolerant plant genotype have the ability to uptake sufficient S from soil and thus less reduction in their growth will happen under S deficient condition compared with S deficient sensitive genotype.

Stress indices proposed by earlier researchers to identify genotype with better stress tolerance and high yield potentials includes TOL=stress tolerance [3]; MP=Mean productivity; GMP=geometric mean productivity [4]; SSI =stress susceptibility index [5] ; STI=stress tolerance index [6] have been proposed as ways to identify genotypes with better tolerance. A high value of TOL and SSI show more sensitivity to stress and therefore low values for above parameters is desired. It is observed by many workers that genotypes that have been screened based on TOL and SSI does not provide high yields under both normal and stress condition. But high yields with better stress tolerance under both conditions could be identified in genotypes if selection is based on STI and GMP [4]. Hence, present study was contemplated to screen ruling rice genotypes which would give high yields both under sulfur stress and non-stress conditions based on stress tolerance indices and use such genotypes for breeding programme.

2. MATERIALS AND METHODS

Field experiments were conducted in two soils Kondal series (Typic Haplusterts- Vertisol) and Padugai series (Typic Ustifluvent- Entisol) deficient in sulfur (critical limit -0.15% $CaCl_2$ extractable S is 10 mg/kg) [7]. The experimental soil was clay loam in texture , pH-8.2, EC-0.26 dSm^{-1}, organic carbon-3.3 g kg^{-1}, available $KMnO_4$-N- 220 kg ha^{-1}, Olsen-P- 12.3 kg ha^{-1}, NH_4OAc-K- 290 kg ha^{-1} and 0.15% $CaCl_2$-S- 8.5 mg kg^{-1} belonging to Vertisol and sandy clay loam in texture , pH-6.8, EC-0.32 dSm^{-1}, organic carbon-6.3 g kg^{-1}, available $KMnO_4$-N-235 kg ha^{-1}, Olsen-P-25 kg ha^{-1}, NH_4OAc-K- 220 kg ha^{-1} and 0.15% $CaCl_2$-S- 7.5 mg kg^{-1} belonging to Entisol. The treatment were Factor A – S levels (0 &10 mg S kg^{-1}) and Factor B- Rice genotypes(ADT 43, CO 47, ADT 39, CO 43, ADT 42, ASD 19, ADT 36, ADT 37, ADT 38 and CO45. The sulfur was applied through gypsum (15% S) because it is cheapest and easily available source of sulfur. The experiment was conducted in a randomly block design with two factors. Correlation matrix was calculated between grain yield and stress tolerance indices. Linear regression between stress indices and grain yield under S stress and non-stress were worked out... Grain and straw yield was recorded at 14% moisture at harvest. The yield data from two soils was used to calculate for each genotype the following stress indices

1. TOL - the yield difference between the stress (Ys) and non-stress conditions (Yp);
2. MP - the average yield of Ys and Yp;
3. GMP – calculated with formula *Ys. Yp;*
4. SSI – stress susceptibility index expressed by following relationships:
   SSI = [1-Ys/Yp] / SI, where SI (stress intensity) and is estimated as [1 - Y_S/ Y_P]\
   i.
5. STI **=** stress tolerance index = [Yp. Y_S / $\bar{Y}_P^2$]

3. RESULTS AND DISCUSSION

3.1 Grain Yield

Grain yield varied significantly among rice genotypes regardless of S treatment (Table 1a and 1b). The grain yield varied from 3437 kg/ha (ADT 36) to 4865 kg/ha (CO 43) in kondal series with an average of 4086 kg/ha and grain yield varied from 3775 kg /ha (ADT 36) to 5057 kg/ha (CO 47) in padugai series with an average of 4316 kg/ha under sulfur stress conditions. Four of these genotypes (40%) produced above average yields in both soils 'Under S adequate conditions, the grain yield varied from 3757 kg/ha (ADT 37) to 5162 kg/ha (CO 43), with an average of 4519 kg/ha in kondal series and grain yield varied from 4025 kg/ha (ADT 37) to 5300 kg/ha (CO 47), with an average of 4771 kg/ha in padugai series. Six of the tested genotypes (60%) produced yields above the average in both soils. Application of S fertilizer increased rice grain yield on average 433 and 453 kg ha^{-1} in Vertisol and Entisol although considerable variation was found among rice genotypes in response to S fertilization. Percent increase in grain yield due to S fertilization among rice genotypes ranged from 2.1 to 20.1% with ASD 19(20.1%) recorded the greatest increase and lowest (2.1%) with ADT 38. Increase in grain yield due to 'S' could be due to improved availability of nutrients and created more favorable environment in the soil which increased the grain yield. Large quantities of sulfur may take part in the synthesis of amino acids and other assimilates in higher amounts which may result in more filled grains and higher yield [8]. The differential yield among rice genotypes could be attributed to root process that increased the bioavailability of soil nutrients to root uptake and translocation of nutrients from root to shoot [9,10] and may also be due to different crop demand to sulfur [11] leading to variability in both S uptake and sulfur use efficiency . Similar response of rice genotypes to sulfur application was reported by [12].

3.2 Stress Tolerance Indices

To screen rice genotypes which would provide high yields under sulfur stress and non-stress condition with high stress tolerance, various stress tolerance indicators were studied (Table 1a and 1b) Stress tolerance level (TOL) is defined as the difference in crop yield between the stress (Y_S) and non stress environment (Y_P). TOL was positively correlated with yield under adequate S condition and negatively correlated with yield under S stress. Larger value of TOL represent relative more sensitivity to stress, thus a smaller value of tolerance index is favoured. Accordingly, lowest value was noticed in genotypes ADT 37 and ADT 38 in both soils. These two genotypes recorded lower yield under sulfur fertilization. The mean productivity (MP) is the average yield of Y_S and Y_P. The highest average yield (MP) and geometric mean yield (GMP) were recorded in ADT 43 (MP=4705, 4893 kg/ha, GMP= 4703, 4884 kg/ha), CO 47(MP=4891,5188, kg/ha, GMP=4889, 5186 kg/ha), ADT 39 (MP=4705,4881 kg/ha, GMP=4697,4873 kg/ha) and CO 43(MP=5014,5138 kg/ha, GMP=5011,5136 kg/ha) in kondal and padugai series respectively.

Table 1a. Stress tolerance attributes in rice genotypes estimated from yields obtained in sulfur fertilized and unfertilized grown in Vertisol

Genotypes	Kondal series						
	Y_S	Y_P	TOL	MP	GMP	SSI	STI
ADT 36	3437	3877	440	3657	3650	1.18	0.65
ADT 37	3637	3757	120	3697	3697	0.33	0.67
ADT 42	3975	4702	727	4339	4323	1.61	0.92
ADT 43	4585	4825	240	4705	4703	0.52	1.08
CO 47	4757	5025	268	4891	4889	0.56	1.17
ADT 38	3755	3832	77	3794	3793	0.21	0.70
ADT 39	4430	4980	550	4705	4697	1.15	1.08
ASD 19	4070	4875	805	4473	4454	1.72	0.97
CO 45	3650	4175	525	3913	3904	1.31	0.75
CO 43	4865	5162	297	5014	5011	0.60	1.22
Mean	4086	4519	433	4303	4297	0.92	0.92

On an average, rice genotypes recorded an MP value of 4544 and 4303 kg /ha and GMP value of 4538, 4297 kg /ha in padugai and kondal series respectively. (Table 1a, 1b).MP and GMP had very strong positive correlation with yield both under S stress and non stress situations Although MP and GMP had very strong correlation with each other (r=0.99), selection based on GMP can be considered to reflect a shade better in the performance under S stress than MP.

Table 1b. Stress tolerance attributes in rice genotypes estimated from yields obtained in sulfur fertilized and unfertilized grown in Entisol

Genotypes	Padugai series						
	Y_S	Y_P	TOL	MP	GMP	SSI	STI
ADT 36	3775	4280	505	4028	4020	1.24	0.71
ADT 37	3880	4025	145	3953	3952	0.38	0.69
ADT 42	4257	5075	818	4666	4648	1.69	0.95
ADT 43	4600	5185	585	4893	4884	1.18	1.05
CO 47	5075	5300	225	5188	5186	0.44	1.18
ADT 38	3925	4045	120	3985	3985	0.31	0.70
ADT 39	4605	5156	551	4881	4873	1.12	1.04
ASD 19	4220	5069	849	4645	4625	1.76	0.94
CO 45	3825	4310	485	4068	4060	1.18	0.72
CO 43	5000	5275	275	5138	5136	0.55	1.16
Mean	4316	4771	455	4544	4538	0.98	0.91

Stress susceptible Index (SSI) is another indicator to screen genotypes. Smaller values of SSI indicate greater tolerance to stress. Selection based on SSI favors genotypes with lower yield potential under non stress and high yield under stress condition. Accordingly rice genotypes ADT 37, CO 47, ADT 38 and CO 43 had greater tolerance to sulfur stress indicated by lower value. Stress susceptible Index had negative correlation with yield under S stress and low positive correlation with yield in S adequate condition. Stress susceptible

Index had very low positive correlation with MP and GMP but a strong positive correlation with TOL. Selection for this parameter would also tend to favor low yield genotypes. It was confirmed by poor linear relationship between SSI and yield under S stress (Y=4304 - 204.8x, R^2=0.047; Fig 1a) and with yield under S adequate (Y= 4296+244.2 x,R^2 = 0.057, Fig 1b). SSI has been used by researchers for identifying sensitive and tolerant genotypes [13]

All the above stress indicators failed to identify genotypes which will yield higher both under stress and non stress conditions. Fernandez [14] proposed stress tolerance index (STI) and claimed that the selection based on stress tolerance index would result in genotype with higher stress tolerance and high yield potential. A high value of STI indicated grater tolerance to stress and high yield potential. STI values in the present study ranged from 0.69 to 1.18 in padugai series and 0.69 to 1.22 in kondal series. Correlations among several stress tolerance indices and between stress indices and yield was studied. (Table 2) STI had a strong positive correlation with both Y_P and Y_S, the correlation with yield under sulfur stress being slightly better (0.977 vs. 0.967).

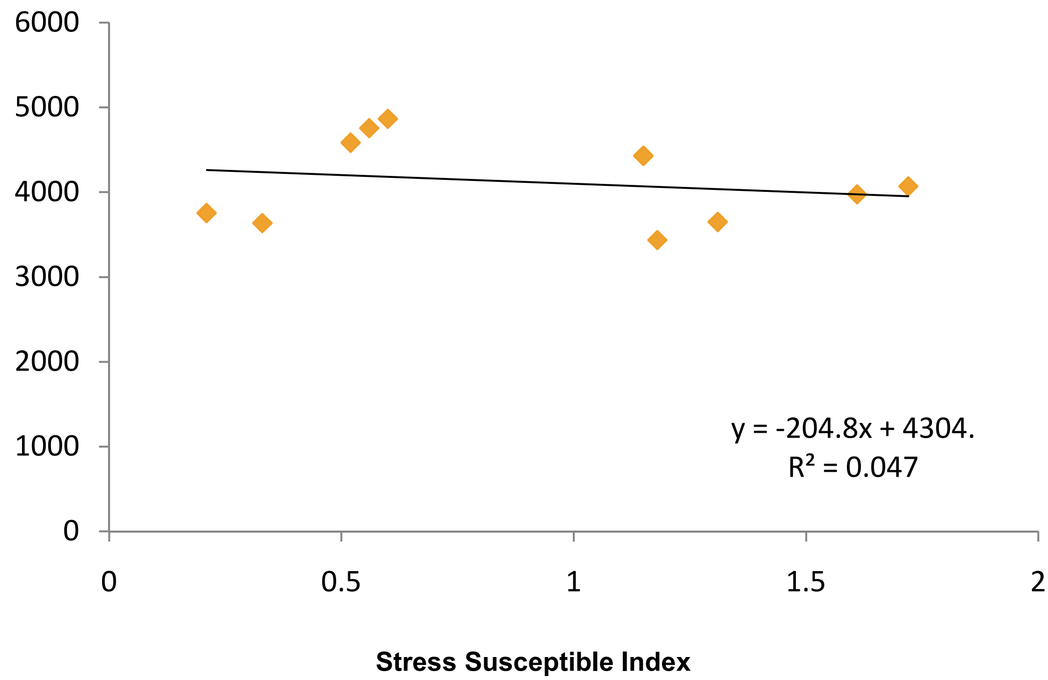

Fig. 1a Linear relationship between grain yield and SSI under S stress

Similarly, STI had strong positive correlation with MP and GMP and negative correlation with TOL and SSI. Linear regression equation between STI with yield under sulfur stress and sulfur adequate condition was developed and it showed that 93.8% variation in yield among rice genotypes was noticed under S stress(Fig. 2a) while 95.5% variation in yield among rice genotypes was noticed under S adequate conditions. (Fig. 2b).

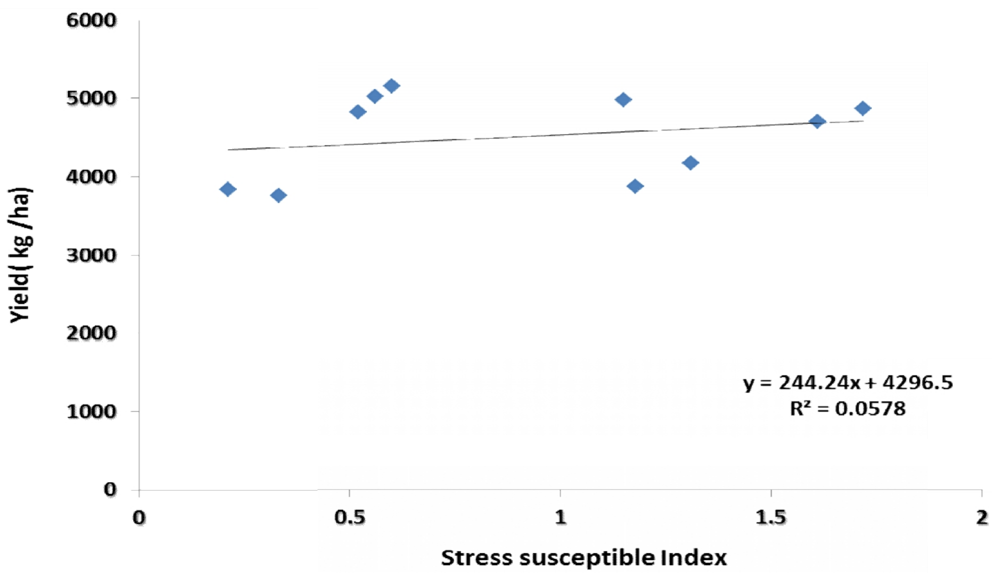

Fig.1b. Linear relationship between grain yield with SSI under S adequate

The observed relations were consistent with those reported by Fernandez [6] in mung bean, Golabadi et al. [13] and Reza Talabi et al., [15] in wheat. Based on STI, mean yield under non stress (Y_P) and mean yield under stress (Y_S), ten rice genotypes were classified into four groups

Group A- Uniform superiority under stress and non-stress - ADT 43, CO 47, ADT 39 and CO 43 which had their high STI> 1.0

Group B- Perform favorably only under non-stress condition- ADT 42 and ASD 19 which had moderate to high STI – 0.70- 1.00

Group C- Genotype yield relatively higher only in stress environment- No genotype

Group D- Genotype perform poorly in both stress and non- stress environmen**t-** ADT 36, ADT 37, ADT 38 and CO 45 which had low STI-<0.70

Khoshgotarmanesh et al. [16] and Sadrarhami et al. [17] concluded that STI could be used to select high grain yield wheat genotype with high stress tolerance for iron and zinc stress soil respectively.

Table 2. Correlation between several stress tolerance indices

Parameters	Y_S	Y_P	TOL	MP	GMP	SSI	STI
Y_S	1						
Y_P	0.894367	1					
TOL	-0.07923	0.375066	1				
MP	0.971182	0.97521	0.160639	1			
GMP	0.974027	0.972421	0.148532	0.999921	1		
SSI	-0.21739	0.240022	0.985358	0.020339	0.008324	1	
STI	0.977164	0.967854	0.131851	0.999033	0.999342	-0.00716	1

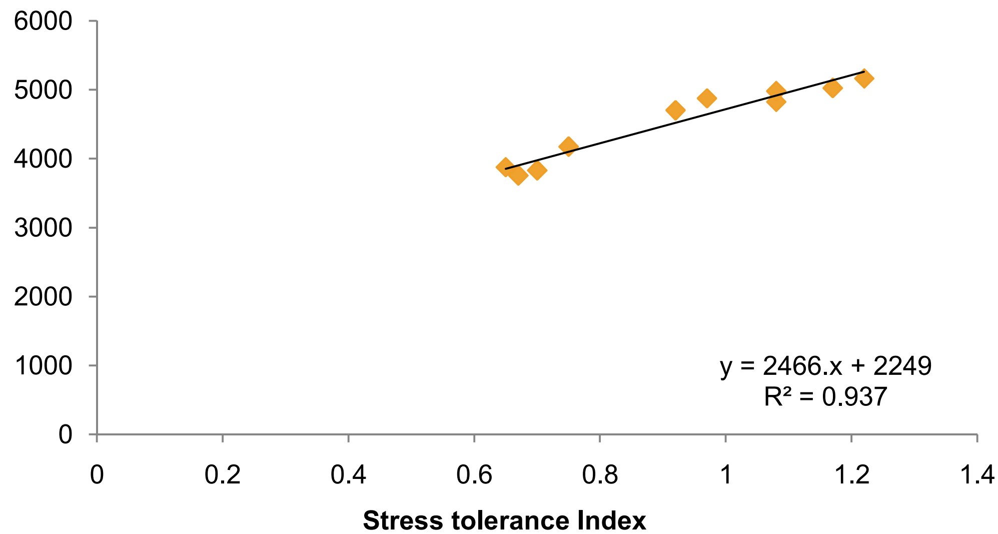

Fig. 2a. Linear relationship between STI and grain yield under S stress

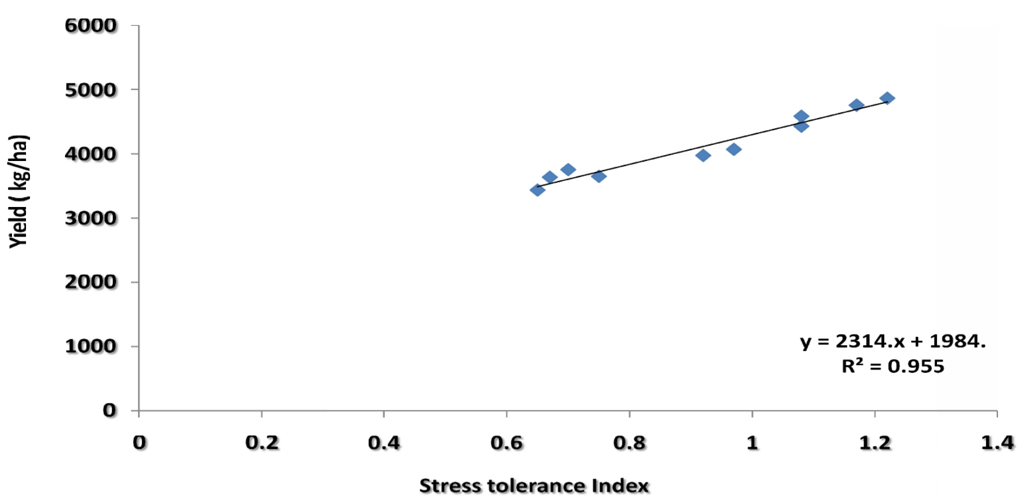

Fig.2b. Linear relationship between STI and grain yield under S adequate

4. CONCLUSION

From the farmer's point of view, best genotypes should provide sufficiently high yield under sulfur non-stress and stress conditions. Accordingly, ADT 43, CO 47, ADT 39 and CO 43 were the best rice genotypes with high tolerance The applicability of this study is that the STI should be considered as an effective criterion for screening programs, if a high potential grain yield together with more stable response to S fertilization in different environment is desired. Performance of rice genotypes between the two soils with respect to sulfur stress was same but magnitude of response to sulfur fertilization varied, being slightly better in Padugai than Kondal series.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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