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Full Length Research Paper

Variation in streptomycin-induced bleaching and dark induced senescence of rice (*Oryza sativa*) genotypes and their relationship with yield and adaptability

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Variation in streptomycin sensitivity and dark sensitivity of 36 rice genotypes of 3 different maturity groups was studied. Streptomycin sensitivity and dark sensitivity of rice genotypes were expressed in terms of bleaching index (BI) and senescence index (SI) respectively. Genotypes of each maturity group showed wide variation in their BI / SI value. The objective of this investigation was to find relationship of BI / SI parameter with yield, adaptability and stability in yield performance of rice genotypes. Yield performance of rice genotypes were evaluated over 12 environments. Adaptability and stability analysis were done following linear regression model of Eberhart and Russell and AMMI Stability Value (ASV) of purchase. BI parameter showed positive correlation with yielding ability and deviation from regression and negative correlation with adaptability parameter (b) for all the 3 maturity groups. But SI parameter showed negative correlation with yielding ability and positive correlation with adaptability parameter (b) for all the 3 maturity groups. This experimental study revealed that sensitivity of rice genotypes to SM in terms of BI could be used to predict yielding ability of genotypes and dark sensitivity (SI) could be used to indicate adaptability to rich environments or poor environments. This novel approach may help the breeder in indirect selection of high yielding genotypes and genotypes well adapted to rich or poor environments at an early seedling stage before going for multilocation trials.

Key words: Streptomycin, dark treatment, *Oryza sativa,* adaptability.

INTRODUCTION

Rice (*Oryza sativa*) occupies a pivotal place in Indian agriculture. It is grown in an area of 44.6 million hectares in India with a production of about 90 million tonnes and productivity of 2.07 ton/ha (Economic Survey, 2007). Rice accounts for 43% of food grain production and 55% of cereal production in the country. It is the staple food of more than two-thirds of the population of India and occupies a key position in national food security. All the high yielding varieties of rice released so far for cultivation have not gained equal popularity due to their unstable performance over wide range of environmental conditions. Thus, multilocation testing of genotypes under diverse agro-ecological conditions for evaluation of yield potential, adaptability and stability is essential before recommending a genotype for release as variety. But multilocation trials need large quantity of seeds, more money, manpower, land, labour and most important of all, time. Though apparently a non-monetary input, time contributes to cost in diverse ways. It would be of great help and immense value if some method (s) could be developed to screen genotypes for their adaptability and stability before taking them to multilocation trials.

The present study aimed at developing some simple, rapid and inexpensive laboratory methods for evaluating adaptability and stability of performance of crop varieties that could be used for a preliminary selection of breeding lines before going for the more expensive multi-location trials. The study took the cue from works of Sinha and Satpathy (1979), Das and Sinha (1992) and Mohapatra

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Table 1. Parentage of mid early, mid-late and late rice genotypes.

	Name of genotype	Parentage
	Mid-early (115-125 days)	
1.	OR 1739-47	Sankar/IR 72
2.	OR 1916-19	Lalat/Ratna
3.	OR 1929-4	OR 929-3-2/RP 2423-108-97
4.	OR 1976-11	TRC 87-125//IR 49517/Prana
5.	OR 2006-12	Sarathi/IR 36
6.	OR 2168-1	IR 36/UPRI 3
7.	OR 2172-7	IR 64///IR 72//Jagannath/NCJ 10
8.	OR 2200-5	RP 2423-108-97/ORS 199-2
9.	Konark	Lalat/OR 135-3-4
10.	Lalat	Obs 677/IR 2071// Vikram/W1263
11.	Bhoi	Gouri/RP 825-45-1-3
	Mid-late (126-140 days)	
1.	OR 1681-11	Bhoi/Surendra
2.	OR 1912-25	Swarna/Lalat
3.	OR 1914-8	Swarna/IR 36
4.	OR 1964-8	RTN 14-1-1//IR 72
5.	OR 1967-15	RTN 14-1-1//IR 49517/OR 1301-32
6.	OR 2156-15	Swarna/IR 72
7.	OR 2310-12	Swarna/Birupa
8.	Pratikshya	Swarna/IR 64
9.	Gouri	Rajeswari/Vikram
10.	Surendra	OR 158-5/Rasi
11.	Gajapati	OR 136-3/IR13429-196-1-20
12.	Kharavela	Daya/IR 13240-108-2-2-3
13.	MTU 1001	MTU 5249/MTU 7014
	Late (145-165 days)	
1.	OR 1885-16-34	IR 72/Kanchan
2.	OR 1898-2-15	Mahalaxmi/OR 633-7
3.	OR 1898-3-16	Mahalaxmi/OR 633-7
4.	OR 1901-14-32	Manika/IR 72
5.	OR 2001-1	RP 1125-606-32/Rambha
6.	OR 2109-2	Indravati//IR 72/Salivahan
7.	OR 2119-13	Manika/Manasarovar
8.	Savitri	Pankaj/Jagannath
9.	Salivahan	RP 5-32/Pankaj
10.	Mahanadi	IR 19661/Savitri
11.	Kanchan	Jajati/Mahsuri
12.	Jagabandhu	Savitri/IR 4819-77-3-2//IR 27301-154-3

(1997) who found certain relationship between sensitivity to streptomycin (SM) and dark treatment and adaptation pattern of rice and ragi varieties and indicated the possibility of SM and dark sensitivity serving as aids in preliminary laboratory evaluation of broad adaptation of crop varieties.

So in this investigation, an attempt has been made to find indicators of adaptability and stability of yield performance of rice genotypes of three different maturity groups in terms of their response to streptomycin (SM) induced bleaching and dark induced senescence at early seedling stage.

MATERIALS AND METHODS

Materials of the present study comprised of 36 rice genotypes of 3 different maturity groups (11 mid-early, 13 mid-late and 12 late group). The list of genotypes along with their parentage was presented in Table 1.

Streptomycin (SM) treatment

Streptomycin (SM) is an amino-glycoside antibiotic and it induces bleaching of leaves in seedlings by inhibiting chlorophyll synthesis. For SM treatment, 50 seeds of each genotype were soaked in 5 ml of 500 ppm SM solution for 48 h along with control (seeds soaked only in distilled water).

After 48 h, the treated and control seeds were washed and put on moist blotting paper in petridishes for germination at room temperature. Observations were recorded on SM-induced seedling bleaching on the 9th day using a random sample of 30 seedlings per genotype. Bleaching of seedlings in each genotype was scored in a 0 - 2 scale where 0 for green/normal, 1 for partially bleached and 2 for fully bleached seedlings (Sinha and Satapathy, 1977).

Estimation of bleaching index

SM sensitivity of each genotype was measured in terms of bleaching index and it was calculated following Sinha and Satapathy (1977) as follows.

$$BI = \frac{n_1 \times 0 + n_2 \times 1 + n_3 \times 2}{2N}$$

where:
n_1, n_2 and n_3 are numbers of green, partially bleached and fully bleached seedlings, respectively, in a genotype and
N is total number of seedlings scored for bleaching.

Dark treatment

One hundred seeds of each genotype were soaked in distilled water for 48 h. The soaked seeds were then transferred to blotting papers in petri dishes for germination at room temperature. Forty fully expanded first leaves were excised from 9 days old seedlings and floated on nutrient solution. The nutrient solution was prepared as: 2 ml each of 1 M solutions of KNO_3, KH_2PO_4 and ($MgSO_4$, $7H_2O$) + 3 ml of 1 M solution of $CaCl_2$ + 1 ml of 1 M solution of $FeSO_4$ + 1 ml of micronutrient solution, made to 1 L by adding distilled water. Finally, the excised leaves were incubated in dark at room temperature for 48 h.

For control, the excised leaves were floated on nutrient solution and kept in sun light. Observations were recorded on the senescence (yellowing) pattern of the 40 excised leaves in treated and control samples of each genotype. The leaves in the dark-exposed samples were scored for degree of senescence in a 0 - 2 scale where 0 for green/normal, 1 for partially senesced and 2 for fully senesced excised leaves, was measured by eye estimation. All the excised leaves in control were normal green.

Estimation of dark-induced senescence index (SI)

As a measure of the effect of dark-exposure on chlorophyll development, an index called dark-induced senescence index (SI) based on the senescence scores of the dark-exposed leaves, was calculated for each genotype (following Sinha and Satpathy, 1977). The SI was computed as follows:

$$SI = \frac{n_1 \times 0 + n_2 \times 1 + n_3 \times 2}{2N}$$

Where:
n_1, n_2 and n_3 are numbers of green, partially senesced and fully senesced excised leaves, respectively, in a treatment and
N is total number of excised leaves scored for senescence.

The experiments on streptomycin and dark were repeated four times at intervals of 15 -20 days during the period July 2004 to April 2005. Analysis of variance was carried out on SI and BI in completely randomized design using repetitions of experiments as replications. The significance of differences among genotypes for this parameter was tested by F-test and t-test through critical difference (CD). Means of genotypes for SI and BI were the averages over the four replications.

Field evaluation

Three multi-location-year trials were conducted for the three duration groups of rice. The genotypes were evaluated at four different locations of Orissa (Bhubaneswar, Chiplima, Jeypore and Ranital), over three years during 2003 - 2005 in 'kharif' season using a randomized block design with three replications. For all trials, nursery sowing was done during last week of June to 1st week of July. Twenty-five to thirty days old seedlings were transplanted with 20 × 15 cm spacing and 2 seedlings per hill. In each trial, the plot size was 2 × 3 m containing 10 rows of 3 m length each. Normal cultural practices and plant protection measures were followed in each trial to raise the crop. In all trials, data were recorded on net plot grain yield. Stability analysis was performed following the linear regression model of Eberhart and Russell (1966) and AMMI Stability Value (ASV) of Purchase (1997).

Analysis of relationship of BI and SI with yield, adaptability and stability

Correlation study was done for each maturity groups separately to find out the relationship of SI/BI parameter with yield, adaptability and stability parameters. Correlation study by combining each maturity groups is not possible as the yield level of each maturity group is different. Therefore a 2 x 2 contingency classification method was followed to analyse the relationship of SI/BI parameter with yield, adaptability and stability of all the rice genotypes irrespective of their maturity duration and done as follows. For SM and dark sensitivity, the genotypes in a trial were classified into two classes, those having above average BI/SI value as highly sensitive (HS) and those having below average BI/SI value as less sensitive (LS). Similarly, for yield, adaptability and each stability parameter, the genotypes in a trial were classified into 2 classes, those having above average value for the parameter as 'above average' and those having below average value as 'below average'. The frequencies of genotypes in the four contingency classes, were determined for each maturity group. Then the frequencies of genotypes in the 4 contingency classes of each maturity group were combined to get a single 2 × 2 contingency Table. Means of HS and LS classes for yield, adaptability and stability parameters were also computed. The relationship of BI / SI parameter with yield, adaptability and stability parameters was inferred from χ^2 test. A significant χ^2 value indicated the presence of relationship.

RESULTS

Analysis of variance for G x E interaction in mid-early, mid-late and late groups over 12 environments (Table 2) showed significant differences due to genotypes, environments and genotype x environment interactions. Highly significant interaction component indicated differential response of the genotypes to environmental changes.

Mean yield, adaptability parameter that is regression coefficient (b) and stability parameters (S_d^2 and ASV) along with BI and SI of mid-early, mid-late and late group genotypes are presented in Table 3, 4 and 5 respectively. In case of mid-early group, average yield of the genotypes ranged from 34.41 to 38.42 q/ha with a grand mean of 36.55 q/ha and six genotypes were found to be high yielder. Seven genotypes had b-values less than one indicating their adaptation to poor environments like less fertile soils and the rest four had b-values more than one indicating their adaptation to rich environments like highly fertile soils. S_d^2 of genotypes Lalat, OR 2200-5, Konark, OR 1929-4 , OR 1916-19 and Bhoi were not significantly different from zero, indicating stability of performance over environments. S_d^2 of the remaining five genotypes were significantly different from zero, indicating that the genotypes were not stable.

In case of mid-late group, the genotypes OR 1912-25, Pratikshya, MTU 1001, OR 2156-15, Surendra, OR 2310-12 and OR 1964-8 gave above average yield and the rest gave below average yield. The regression coefficient/adaptability parameter (b-values) of the genotypes varied from 0.59 to 1.49. Seven genotypes had b-values less than one indicating their adaptation to poor environments and the rest six had b-values more than one indicating their adaptation to rich environments. On the basis of S_d^2 values, the genotypes OR 1912-25, OR 1914-8, OR 2310-12, Gajapati and MTU 1001 were classified as stable ($S_d^2 \approx 0$). The remaining 8 genotypes showed high deviation from regression (S_d^2 significantly different from zero), indicating that these genotypes lacked stability in yield performance.

In late group, seven genotypes were found to be high yielder and five were low yielder. The regression coefficient (b-values) of the genotypes ranged from 0.39 to 1.64. On the basis of the magnitude of b-values, five genotypes were found to have b-values greater than unity (b > 1) and seven genotypes had b-values less than unity (b < 1). Based on S_d^2 values, four genotypes were found

Table 2. Pooleanalysis of variance for grain yield (q/ha) in mid-early rice genotypes

Source	Df	MS	F
Genotypes (G)	10	24.94	3.85**
Environments (E)	11	395.70	61.16**
G x E	110	17.03	2.63**
E + G x E	121		
Environment (linear)	1	4352.71	296.65**
G x E (linear)	10	28.90	1.97*
Pooled deviation	10	14.67	2.26**
Pooled error	240	6.47	
Pooled analysis of variance for grain yield (q/ha) in mid-late rice genotypes			
Genotypes (G)	12	83.19	10.57**
Environments (E)	11	900.88	114.50**
G x E	132	24.19	3.08**
E + G x E	143		
Environment (linear)	1	9909.73	483.94**
G x E (linear)	12	44.29	2.16*
Pooled deviation	130	20.48	2.60**
Pooled error	288	7.87	
Pooled analysis of variance for grain yield (q/ha) in late rice genotypes			
Genotypes (G)	11	167.12	17.20**
Environments (E)	11	404.01	41.60**
G x E	121	39.93	4.11**
E + G x E	132		
Environment (linear)	1	4444.08	125.30**
G x E (linear)	11	52.26	1.47
Pooled deviation	120	35.47	3.65**
Pooled error	264	9.71	

Table 3. BI, SI, mean yield, S_d^2, ASV and b values of mid-early rice genotypes.

Genotype	SM-BI	Dark-SI	Mean yield (q/ha)	S_d^2	ASV	b
1.OR 1739-47	0.23	0.17	36.04	10.21*	1.26	0.78
2.OR 1916-19	0.36	0.14	34.95	6.15	2.08	0.94
3.OR 1929-4	0.43	0.24	35.24	3.09	0.61	0.76
4.OR 1976-11	0.56	0.20	37.63	19.50**	0.38	0.99
5.OR 2006-12	0.54	0.28	37.72	14.46**	2.44	0.92
6.OR 2168-1	0.51	0.40	35.07	24.95**	0.93	0.69
7.OR 2172-7	0.55	0.13	37.82	9.28*	2.10	1.23
8.OR 2200-5	0.53	0.59	37.87	0.30	1.23	1.47
9.Konark	0.45	0.68	36.87	0.34	1.38	1.35
10.Lalat	0.37	0.47	38.42	-3.95	0.40	1.08
11.Bhoi	0.37	0.75	34.41	7.16	1.95	0.79
Average	0.44	0.38	36.55	8.20	1.34	1.00

* and ** implies significant at 5 and 1% level respectively.

Table 4. BI, SI, mean yield, S_d^2, ASV and b values of mid-late rice genotypes.

Genotype	SM-BI	Dark-SI	Mean yield (q/ha)	S_d^2	ASV	b
1.OR 1681-11	0.45	0.22	41.30	16.59**	0.60	0.58
2.OR 1912-25	0.68	0.35	47.45	6.29	1.57	0.83
3.OR 1914-8	0.31	0.68	40.84	4.26	0.65	1.08
4.OR 1964-8	0.63	0.40	42.41	19.69**	1.55	1.01
5.OR 1967-15	0.46	0.52	40.11	7.81*	0.94	1.17
6.OR 2156-15	0.31	0.39	43.05	15.68**	1.31	0.59
7.OR 2310-12	0.42	0.39	42.66	6.00	0.56	0.97
8.Pratikshya	0.83	0.37	46.05	38.26**	2.61	0.93
9.Gouri	0.43	0.16	39.60	12.55**	0.90	0.93
10.Surendra	0.57	0.82	42.71	19.01**	1.05	0.93
11.Gajapati	0.63	0.58	39.61	4.45	1.26	1.49
12.Kharavela	0.57	0.61	38.27	15.59**	1.50	1.31
13.MTU 1001	0.63	0.36	44.08	-2.26	0.92	1.08
Average	0.53	0.45	42.16	12.61	1.19	1.0

* and ** implies significant at 5% and 1% level respectively

Table 5. BI, SI, mean yield, S_d^2, ASV and b values of late rice genotypes

Genotype	SM-BI	Dark-SI	Mean yield (q/ha)	S_d^2	ASV	b
1.OR 1885-16-34	0.44	0.85	32.15	52.42**	2.33	0.71
2.OR 1898-2-15	0.52	0.30	37.02	11.09*	0.88	1.06
3.OR 1898-3-16	0.68	0.37	43.94	3.83	0.75	1.12
4.OR 1901-14-32	0.61	0.46	44.45	8.11	2.43	0.68
5.OR 2001-1	0.55	0.42	40.72	11.46*	2.56	0.93
6.OR 2109-2	0.74	0.32	42.99	22.39**	1.22	0.92
7.OR 2119-13	0.65	0.54	41.46	72.37**	6.47	0.39
8.Savitri	0.45	0.77	38.59	36.52**	2.94	1.61
9.Salivahan	0.52	0.61	35.87	38.50**	3.32	1.33
10.Mahanadi	0.36	0.27	41.50	0.46	0.74	0.84
11.Kanchan	0.55	0.69	37.26	49.40**	4.37	1.64
12.Jagabandhu	0.42	0.37	42.65	2.47	0.88	0.77
Average	0.54	0.43	39.88	15.60	2.41	1.0

* and ** implies significant at 5% and 1% level respectively

to be stable and rest eight were unstable. Data pooled over the three maturity groups showed that of the 36 rice genotypes (11mid-early + 13 mid-late + 12 late), 20 (6 mid-early + 7 mid-late + 7 late) were found to be HY, 15 (4 mid-early + 6 mid-late + 5 late) had b>1 and 15 (6mid-early + 5 mid-late + 4 late) genotypes were found to be stable.

Bleaching response of rice genotypes

Rice genotypes treated with streptomycin showed varying degree of bleaching in seedlings, which was measured in terms of bleaching index (BI). From Table 3 it was observed that the genotypes OR 1739-47, OR 1916-19, OR 1929-4, Lalat and Bhoi of mid-early group had BI values less than group average (that is < 0.44) and considered as lowly sensitive (LS); the rest six genotypes had BI values greater than group average (> 0.44) and considered as highly sensitive (HS). The genotypes OR 1681-11, OR 1914-8, OR 1967-15, OR 2156-15, OR 2310-12 and Gouri of mid-late group (Table 4) showed low degree of bleaching (BI < 0.53), while OR 1912-25, OR 1964-8, Pratikshya, Surendra, Gajapati, Kharavela

Table 6. Correlation of BI and SI parameters with yield, S_d^2 , ASV and b.

	Mid-early				Mid-late				Late			
	Yield	S_d^2	ASV	b	Yield	S_d^2	ASV	b	Yield	S_d^2	ASV	b
BI	0.445	0.351	-0.062	-0.524	0.480	0.401	0.755*	-0.395	0.443	0.135	0.210	-0.367
SI	-0.072	-0.373	-0.039	0.301	-0.235	-0.071	-0.024	0.493	-0.683*	0.738*	0.557	0.335

* Significant at 5% probability

Table 7. 2 x 2 contingency Tables of BI and SI parameters and yield and adaptability parameters**.**

Sensitivity parameter	Class	No. of genotypes	Yield class				b class			
			LY	HY	c2	Av. Yield (q/ha)	b < 1	b > 1	c2	Av.b-value
SM-BI	HS	19	4	15		40.8	10	9		1.04
	LS	17	12	5	8.92**	38.5	11	6	0.54	0.94
Dark-SI	HS	16	9	7		38.4	6	10		1.10
	LS	20	7	13	1.62	40.7	15	5	5.14*	0.92

HS: Highly sensitive, LS: Lowly sensitive, LY: Low yielder, HY: High yielder.

and MTU 1001 showed high degree of bleaching (BI > 0.53). Six genotypes of late-group (Table 5) were found to be less sensitive (LS) to the bleaching action of SM, while other six were highly sensitive (HS). This result revealed that rice genotypes showed wide variation in their bleaching response (Tables 3, 4 and 5). Mean BI value of the mid-early genotypes was 0.44, while those of mid-late and late groups were 0.53 and 0.54, respectively, indicating that the bleaching effect was generally low on mid-early genotypes and higher on those of mid-late and late genotypes. Pooled data indicated that out of 36 rice genotypes, 17 were LS and 19 were HS to the bleaching action of SM.

Dark-response

Dark response of a genotype was measured in terms of senescence index (SI), which was calculated from scores for the proportion of the leaves turning yellow. The genotypes of different maturity groups showed differences in their SI values (Tables 3, 4 and 5). The genotypes OR 2172-7, OR 1916-19 and OR 1739-47, OR 1976-11, OR 1929- 4 and OR 2006-12 of the mid-early group showed low degree of senescence (SI < 0.38) and considered as less sensitive (LS) to dark treatment, while the rest five had high response to dark treatment. Eight genotypes of the mid-late group were less sensitive to dark treatment (SI < 0.45), while the rest five were highly sensitive (SI > 0.45). The SI values of the late group genotypes ranged from 0.27 to 0.85 with a mean of 0.43. Six genotypes of the late group showed low response to dark treatment (SI < 0.43), and the rest six genotypes had high response to dark treatment (SI > 0.43). Mean SI values of the three maturity groups ranging between 0.38 and 0.45, were quite similar, indicating that genotypes of high and low dark sensitivity occurred evenly in all maturity groups. Pooled data revealed that out of 36 rice genotypes, 20 were LS and 16 were HS to dark treatment.

Relationship of BI parameter with yield, adaptability and stability parameter

Correlation study (Table 6) indicated that BI parameter showed positive correlation (though high but non significant) with yielding ability and deviation from regression (S_d^2) and negative correlation with adaptability parameter (b) for all the three maturity groups. It showed a significant positive correlation with the ASV parameter of mid-late group.

The 2 × 2 contingency Table (Table 7) revealed that on the basis of SM-BI values, 19 rice genotypes of the 36 were HS and 15 of the 19 HS genotypes were high yielder (HY). In contrast, 12 genotypes of the 17 lowly sensitive (LS) genotypes were low yielder (LY). Contingency chi-square value was found to be significant (Table 7); indicating that the distribution was non-random and HS class had high frequency of HY genotypes, while LS class had high frequency of LY genotypes. In conformity, the HS class had higher average yield of 40.8 q/ha as against 38.5 q/ha of the LS class. Nine genotypes of HS class had b > 1 and 10 had b < 1. The LS class contained 11 genotypes with b < 1 and 6 genotypes with b > 1 (Table 7). The contingency

Table 8. 2 x 2 contingency Tables of BI and dark-SI parameters and stability parameters (S_d^2 and ASV) in rice.

Sensitivity parameter	Class	No. of genotypes	S_d^2 Class				ASV Class			
			S	U	χ^2	Av. S_d^2	S	U	χ^2	Av.ASV
Rice										
SM-BI	HS	19	7	12		15.34	7	12		2.02
	LS	17	8	9	0.39	15.97	12	5	3.54	1.22
Dark-SI	HS	16	7	9		21.69	7	9		2.08
	LS	20	9	11	0.01	11.36	12	8	0.94	1.36

chi-square was non significant, indicating the distribution to be random. The HS class had average b-value of 1.04 as against 0.94 of the LS class. Moreover, both HS and LS classes of SM-BI had very similar class means for b, both close to 1. Thus, sensitivity to SM does not appear to have any significant relationship with b-values of genotypes. The HS class also had higher average values for S_d^2 and ASV than LS class (Table 8). However, contingency chi-square values in all three cases were not significant at 5% level, though it was quite high (chi-square = 3.54) in case of ASV, indicating almost random distribution of genotypes in SM - BI classes.

Relationship of SI parameter with yield, adaptability and stability parameter

Table 6 showed correlation of SI parameter with yield, stability and adaptability parameters. For all the 3 maturity groups the SI parameter showed negative correlation with yield indicating that highly dark sensitive genotypes may be low yielder. It showed positive correlation with adaptability parameter (b) for all the 3 maturity groups and a significant positive correlation with the S_d^2 parameter only for late maturity group. Sensitivity to dark treatment was measured as senescence index (SI) and 16 of the 36 genotypes were HS of which 7 were HY and 9 were LY (Table 7). The remaining 20 genotypes were lowly sensitive (LS) to dark exposure and 13 of these were HY and 7 were LY. The contingency chi-square was non significant. But the LS group had higher average yield (as it included more number of high yielders) than HS group genotypes. This study indicates that the SI parameter has some relationship with yield.

Ten genotypes of dark HS class had b > 1 and 6 had b < 1. The remaining 20 genotypes of dark LS class included 15 genotypes with b < 1 and 5 with b > 1 (Table 7). The contingency chi-square was significant, indicating the distribution to be non- random. In addition, the HS class had high average b-value of 1.10 as against 0.92 of the LS class. Thus, most rice genotypes showing high sensitivity to dark (Dark-SI) had b > 1, indicating that genotypes have better adaptation to rich environments. Similarly, most LS genotypes had b < 1, indicating that they could have better adaptation to poor environmental conditions.

The HS and LS classes of Dark-SI included similar number of genotypes with stable and unstable performance as assessed by S_d^2 and ASV (Table 8). The contingency chi-square value was non-significant indicating the distributions to be random. This implies that Dark-SI parameter does not have any significant relationship with stability of performance of rice genotypes.

DISCUSSION

Photosynthesis is the cornerstone of crop production. It serves as the primary source of all energy for mankind. The yield of agricultural plants depends on the size and efficiency of the photosynthetic system. The green plastids or chloroplasts that constitute the photosynthetic apparatus is likely to contribute to photosynthetic efficiency and ultimately to crop productivity. Therefore, variation in chloroplast behaviour either due to chemical or physical stress might help the breeder in preliminary selection of superior genotypes.

Streptomycin (SM) is an amino-glycoside antibiotic and acts as a protein synthesis inhibitor. In plants, it induces bleaching of leaves in seedlings by inhibiting chlorophyll synthesis. The bleaching effect of SM was first reported by Von Euler (1947) in barley seedlings. Similar bleaching effect of SM on seedling leaves due to inhibition of plastid development has been reported by Khudairi (1961), Babayan et al. (1975), Mancinelli et al. (1975), Pretova and Anna (1980) and Zubko and Dey (1998, 2002) in various plant species. Kinoshita and Reiko (2001) studied SM sensitivity of 103 rice varieties of *Japonica* and *Indica* types and 17 isogenic lines of cv. Shiokari in terms of seedling bleaching. Varieties of both *Japonica* and *Indica* groups showed wide range of variation in SM-sensitivity and the near isogenic lines of Shiokari also showed wide variation in SM-sensitivity.

In the present study, seeds of 36 rice genotypes of three duration groups were treated with 500 ppm SM solution for 48 h and seedling-bleaching index (BI) was estimated. The BI of genotypes of all duration groups showed wide variation ranging from 0.23 to 0.83, indicating differences in SM-sensitivity of genotypes in terms of bleaching. Similar differences in bleaching effect of SM treatment in different genotypes have been reported by Sinha and Satapathy (1979), Das (2001) and Kinoshita and Reiko (2001) in rice; Sinha and Swain (1978), Das and Sinha (1986), Sinha et al. (1996) in ragi, Rath (1977) in wheat, Sinha and Satapathy (1977) in maize and Singh and Nanda (1997) in green gram.

In the present investigation, an attempt was made to find out if sensitivity of genotypes to SM treatment has any relationship with their yield potential, adaptability and stability of performance. So the genotypes in each duration group of rice was classified as highly sensitive (HS) and lowly sensitive (LS) on the basis of SM-BI value. Similarly, genotypes in each group were classified as high yielder (HY) and low yielder (LY), $b > 1$ and $b < 1$ and stable and unstable. Of the 36 rice genotypes, 19 were HS on the basis of SM-BI and 15 of them were high yielder, while 12 of the 17 LS genotypes were low yielder. The HS class of genotypes had higher average yield than LS class. Thus, higher degree of seedling bleaching due to SM treatment would be an indicator of high yield potential of genotypes in rice. Sinha and Swain (1978) observed that ragi mutant lines showing SM-sensitivity in terms of bleaching were generally earlier in maturity, shorter in height and higher yielding than SM-resistant lines. Sinha and Satapathy (1979) reported that semi-dwarf high-yielding rice varieties showed more SM bleaching than low-yielding tall *indica* varieties. Das and Sinha (1986) suggested that selection of ragi genotypes showing more SM-bleaching could lead to identification of lines with early maturity, short height and more tillers per plant. SM-response could be used as a criterion in preliminary laboratory evaluation of broad adaptation pattern of new high-yielding rice varieties and for germplasm screening for drought tolerance (Das and Sinha, 1992).

SM-sensitivity in terms of bleaching in the present study does not appear to have any definite relationship with adaptability of genotypes to poorer or rich environments and also with stability. However, Sinha et al. (1996) reported that ragi genotypes showing low SM-sensitivity would show general adaptability.

Senescence in green plants is a complex and highly regulated process that occurs as a part of growth and development. Senescence reduces leaf area duration adversely affecting photosynthesis. Exposure of leaves to dark induces senescence by inhibiting the expression of light regulated genes, responsible for chloroplast development and causes etiolation which may be termed as dark-induced senescence. It reduces leaf area duration (LAD) adversely affecting photosynthesis, respiration, transpiration and also translocation of nutrients. So in plants early senescence would affect supply of photosynthates leading to inadequate filling of the sink. Thus, plant breeders often look for genotypes showing slow and late senescence of leaves. Saulescu et al. (2001) observed significant correlation between rate of chlorophyll loss following exposure to dark and chloroplast loss during aging in stress free environments. They concluded that seedling test for dark-induced senescence is a potential tool in breeding of wheat for optimum senescence pattern. Dark-induced senescence of seedling leaves has also been used as parameter of aging senescence by Grover et al. (1986), Annamalainathan et al. (1995), Saulescu and Kronstad (1998), Saulescu et al. (1998) and Spano et al. (2003).

The genotypes of each duration group of rice were classified as highly sensitive (HS) and lowly sensitive (LS) to dark treatment on the basis of senescence index (Dark-SI) values. The LS class included more number of genotypes with higher yield and the HS class included more number of genotypes with low yield. The LS class also had high average yield than the HS class. Thus, it appears that low SI of genotypes, which can be attributed to slow or late senescence of leaves give some indication about high yield potential of genotypes in rice. Mohapatra (1997) evaluated senescence response of ragi genotypes to dark treatment in terms of etiolation index and found that in case of early duration group, moderately resistant and resistant classes included more number of higher yielding varieties.

Rice genotypes falling in HS class for high Dark-SI included greater number of genotypes with $b > 1$ and the LS class included greater number of genotypes with $b < 1$. Moreover, class mean for b-values of HS class was 1.10 and LS class was 0.92. Thus, it appears that, genotypes showing low senescence under dark treatment would be better adapted to poorer environments and those showing high senescence would be better adapted to rich environments. Pattanaik (1994) working on dark response of ragi genotypes reported that genotypes showing moderate response to dark treatment in terms of etiolation index would show most desirable pattern of adaptation. Saulescu and Mustatea (2002) reported that slow senescence under dark treatment seemed to be a characteristic of wheat cultivars adapted to more favourable environments, whereas fast senescence was found in cultivars adapted to stress environments. However, for stability parameter S^2_d, Dark-SI would not give any lead for identifying stable genotypes.

The present study indicated that the rice genotypes showed wide differences in sensitivity to streptomycin induced bleaching (SM-BI) and dark induced senescence (Dark-SI). High sensitivity of genotypes to streptomycin in terms of BI could be used for laboratory screening of rice genotypes for their yielding ability at an early seedling stage. Use of other chemicals like maleic hydrazide in predicting yielding ability was also suggested by Das et al. (2008). Rice genotypes showing high sensitivity to dark treatment in terms of senescence (SI) would show better adaptation to rich environments and those showing low sensitivity would be better adapted to poorer environments. Selection of SM-HS class may help the breeder in indirect selection of high yielding genotypes at an early seedling stage and makes the multilocation trials more economic.

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