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Variation in seedling growth inhibition due to Maleic Hydrazide treatment of rice (*Oryza sativa*) and ragi (*Eleusine coracana*) genotypes and its relationship with yield and adaptability

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Abstract

Multilocation trials on 36 rice (*Oryza sativa*) genotypes of 3 different maturity groups were conducted at four different locations of Orissa for 3 years and 30 ragi (*Eleusine coracana*) genotypes of 2 different maturity groups were evaluated in three environmental conditions for 3 years. Grain yield data were subjected to stability analysis following linear regression model to estimate adaptability and stability parameters, i.e. b, and S^2d Stability of performance of genotypes was also estimated by two other stability parameters *viz*., ecovalence W and AMMI stability value ASV. The rice and ragi genotypes of different duration groups showed wide variation in their mean yield, b, S^2d, W and ASV parameters. Seeds of the 36 rice and 30 ragi genotypes were treated with 500 and 100 ppm aqueous solution of maleic hydrazide (MH) for 24 hours, respectively to study MH-sensitivity. Sensitivity of genotypes to MH treatment was estimated in terms of seedling growth inhibition index (SGI). The rice and ragi genotypes showed wide differences in their MH-sensitivity in terms of SGI. Relationship of MH- sensitivity of genotypes with their yielding ability, adaptability and stability of performance was tested by contingency x^2 test. Low sensitivity of rice and ragi genotypes to MH in terms of SGI appeared to be good indicators of high yielding ability of genotypes. Also, low and high MH-sensitivity of genotypes would be a good indicator of better adaptability to rich and poor environments, respectively, in ragi but not in rice. Low MH-sensitivity of genotypes could be the good indicator of stability of yield performance in rice but not in ragi.

Key words: adaptability and stability of performance, maleic hydrazide, ragi, rice

Introduction

Maleic hydrazide (MH) is a growth regulator, known to cause inhibition of seedling growth by inhibiting mitotic cell division in plants (Zukel 1950). Several effects of this chemical on plants have been reviewed by Moore (1950). Growth inhibitory effect of MH was also reported by Larry (1969). It also acts as a mutagen mostly causing chromosomal breaks more frequently in heterochromatin regions (Darlington and McLeish 1951). Das and Sinha (1965) studied MH-sensitivity of rice varieties and reported that the high yielding varieties were less sensitive to the growth inhibitory effect of MH than the low yielder, which indicated the possibility of using MH in preliminary screening for yield potential. Development of high yielding varieties is a major plant breeding objective for substantial improvement in productivity. Many newly developed high yielding varieties fail to gain popularity due to their unstable performance. 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. However, multilocation trials involve considerable effort, time and expenditure. Breeders develop and identify large

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number of lines with high yield potential in a particular location and take only the top ones for multilocation testing. Whether or not those lines contain genotypes with desired adaptability and stability is a matter of chance. It would be of great help and immense value if some inexpensive and quick laboratory methods can be developed for preliminary evaluation of adaptability and stability characteristics of genotypes, even in off season. This would help in identifying high yielding genotypes more likely to show stable performance over diverse agro-ecological conditions. In the present study, an attempt was made to find indicator of adaptability and yield stability of rice and ragi genotypes in terms of their sensitivity to maleic hydrazide at seedling stage.

Materials and Methods

Field study

The materials used for the present study were 36 rice genotypes with 3 different maturity groups (11 mid-early, 13 mid-late and 12 late group) and 30 ragi genotypes with two different maturity groups (15 early and 15 late). Three multi-location-year trials were conducted for the three duration groups of rice and two multi-location-year trials conducted for the two duration groups of ragi. The rice trials were conducted in randomized block design with three replications at 4 locations of Orissa (Bhubaneswar, Chiplima, Jeypore and Ranital) over 3 years during 2003-2005 in *kharif* season. For all trials, nursery sowing was done during last week of June to 1st week of July. Plot size was 2 m × 3 m and twenty-five to thirty days old seedlings were transplanted with 20 cm × 15 cm spacing. Normal cultural practices and plant protection measures were followed in each trial and data on net plot grain yield was recorded. The ragi genotypes were evaluated at Bhubaneswar (transplanted - 2 dates) and Berhmpur (directed seeded) for 3 years during 2004-2006 in *kharif* season using a randomized block design with three replications. At Bhubaneswar, for both early and late planted trials, twenty-one to twenty-five days old seedlings were transplanted with 22.5 cm × 10 cm spacing and plot size was 1.8 m × 3 m. At Berhampur, direct seeding was done in rows with 22.5 cm spacing between rows with plot size of 1.8 m × 3 m. Normal cultural practices and plant protection measures were followed in each trial and data on net plot grain yield was recorded. The yield data of the 3 rice and 2 ragi multilocation trials were subjected to genotype-environment (G×E) interaction analysis following the linear regression model of Eberhart and Russell (1966) and adaptability parameter- regression coefficient b and stability parameter- deviation from regression S^2d of the genotypes were estimated. Two other stability parameters, i.e. ecovalence W and AMMI stability value ASV, which measure the magnitude of G×E interaction of each genotype, were estimated following Wricke (1962) and Purchase (1997), respectively.

MH treatments

Fifty seeds of each rice genotype were soaked in 10 ml of 500 ppm MH solution for 24 hours and for control 50 seeds were soaked in distilled water for the same period. After 24 hours, the treated and control seeds were put on moist blotting paper in petridishes for germination. The blotting paper in petridishes was moistened periodically with just enough water to allow proper germination and growth. The procedure of seed treatment in case of ragi was the same as for rice except that the seeds were soaked in 3.5 ml of 100 ppm MH solution. Observations on seedling root length (longest root) and shoot length in treatment and control samples of each genotype were recorded on the 9th day for rice and on 7th day for ragi following treatment, using a random sample of 10 seedlings per treatment and control. Separate experiments were conducted on each maturity group of rice and ragi and all experiments were repeated 4 times at intervals of 15 - 20 days during the period August 2004 to March 2005. Reduction in seedling root length and shoot length due to MH treatment in comparison to the control was expressed as percentage of the control both in rice and ragi. The combined parameter of seedling growth inhibition index (SGI) was estimated as the average of percent reduction in root length and percent reduction in shoot length for each genotype.

Analysis of relationship of MH sensitivity with yield, adaptability and stability

The relationship of MH-SGI with yield potential, adaptability parameter b and 3 stability parameters - S^2d, W and ASV, of genotypes was analysed following 2 × 2 contingency classification method. For MH sensitivity, the genotypes in each maturity group of rice and ragi were classified into two classes - those having above average SGI value as highly sensitive (HS) and those having below average SGI value as lowly sensitive (LS). Similarly, for yield, adaptability and each stability parameter, the genotypes of each maturity group were classified into 2 classes - those having above average value for the parameter as 'above average' (AA) and those having below average value as 'below average' (BA). The frequencies of genotypes in the 4 contingency classes, *i.e.*, HS-AA, HS-BA, LS-AA and LS-BA, were determined for each maturity group of each crop. Then, the frequencies of genotypes in the corresponding contingency

Table 1. Mean yield (q/ha), b, S^2d, W and ASV parameters by rice genotypes

Genotypes	Mean	b	S^2d	W	ASV
Mid-early group					
1. OR 1739-47	36.04	0.78	10.21	186.4	1.26
2. OR 1916-19	34.95	0.94	6.15	127.6	2.08
3. OR 1929-4	35.24	0.76	3.09	119.1	0.61
4. OR 1976-11	37.63	0.99	19.50	259.7	0.38
5. OR 2006-12	37.72	0.92	14.46	212.0	2.44
6. OR 2168-1	35.07	0.69	24.95	349.9	0.93
7. OR 2172-7	37.82	1.23	9.28	178.1	2.10
8. OR 2200-5	37.87	1.47	0.30	147.7	1.23
9. Konark	36.87	1.35	0.34	110.2	1.38
10. Lalat	38.42	1.08	-3.95	28.0	0.40
11. Bhoi	34.41	0.79	7.16	154.5	1.95
Average	**36.55**	**1.00**	**8.20**	**170.3**	**1.34**
CD (5%)	1.20				
Mid-late group					
1. OR 1681-11	41.30	0.58	16.59	17.6	0.60
2. OR 1912-25	47.45	0.83	6.29	22.2	1.57
3. OR 1914-8	40.84	1.08	4.26	22.5	0.65
4. OR 1964-8	42.41	1.01	19.69	25.7	1.55
5. OR 1967-15	40.11	1.17	7.81	27.2	0.94
6. OR 2156-15	43.05	0.59	15.68	15.0	1.31
7. OR 2310-12	42.66	0.97	6.00	27.7	0.56
8. Pratikshya	46.05	0.93	38.26	31.8	2.61
9. Gouri	39.60	0.93	12.55	24.9	0.90
10. Surendra	42.71	0.93	19.01	34.1	1.05
11. Gajapati	39.61	1.49	4.45	40.6	1.26
12. Kharavela	38.27	1.31	15.59	34.1	1.50
13. MTU 1001	44.08	1.08	-2.26	24.0	0.92
Average	**42.16**	**1.00**	**12.61**	**26.7**	**1.19**
CD (5%)	1.32				
Late group					
1. OR 1885-16-34	32.15	0.71	52.42	652.0	2.33
2. OR 1898-2-15	37.02	1.06	11.09	209.2	0.88
3. OR 1898-3-16	43.94	1.12	3.83	140.7	0.75
4. OR 1901-14-32	44.45	0.68	8.11	217.0	2.43
5. OR 2001-1	40.72	0.93	11.46	213.7	2.56
6. OR 2109-2	42.99	0.92	22.39	323.3	1.22
7. OR 2119-13	41.46	0.39	72.37	959.1	6.47
8. Savitri	38.59	1.61	36.52	600.5	2.94
9. Salivahan	35.87	1.33	38.50	522.8	3.32
10. Mahanadi	41.50	0.84	0.46	110.7	0.74
11. Kanchan	37.26	1.64	49.40	741.1	4.37
12. Jagabandhu	42.65	0.77	2.47	140.9	0.88
Average	**39.88**	**1.00**	**15.60**	**402.6**	**2.41**
CD (5%)	1.47				

Table 2. Mean yield (q/ha), b, S^2d, W and ASV parameters by ragi genotypes

Genotypes	Mean	b	S^2d	W	ASV
Early group					
1. Bhairabi	24.53	0.68	12.63	133.9	0.79
2. Dibyasinha	16.07	0.26	4.10	163.7	2.40
3. Neelachal	24.11	0.75	3.47	61.4	1.48
4. OEB 65	21.73	1.36	2.90	71.2	1.57
5. VL 149	21.53	1.17	-0.47	26.8	0.64
6. RAU 8	24.08	1.37	0.33	54.8	1.11
7. VR 708	17.44	1.01	-1.43	14.4	0.14
8. BM 107-2	25.12	1.36	-0.57	47.1	1.12
9. SRS-2	24.68	1.35	4.44	79.5	1.38
10. KM 231	18.04	0.78	3.86	60.7	1.20
11. HR 374	21.76	1.38	5.56	91.7	0.94
12. PES 400	17.96	0.90	0.94	33.0	0.54
13. VL 322	17.73	0.84	9.06	93.1	1.35
14. DM 7	24.13	1.55	0.85	92.0	1.67
15. AKP 2	13.55	0.25	15.22	245.8	2.61
Average	**20.83**	**1.00**	**4.06**	**84.6**	**1.26**
CD (5%)	1.02				
Late group					
1. OEB 82	23.10	0.50	13.62	202.4	3.98
2. OEB 56	27.82	0.80	11.79	129.4	3.83
3. OEB 71	27.21	0.78	12.91	138.7	3.59
4. PR 202	22.61	0.79	1.59	58.3	2.24
5. GPU 57	23.13	1.64	6.73	201.6	6.81
6. PES 110	27.73	1.10	9.05	101.0	0.75
7. VR 849	26.51	1.10	1.70	49.5	0.51
8. VR 822	27.23	0.70	20.95	207.3	3.12
9. MR 33	24.02	1.61	5.10	179.7	6.41
10. VR 768	23.27	0.84	3.45	65.9	1.82
11. GPU 58	25.67	1.34	4.25	106.1	3.45
12. Indaf 5	25.98	0.87	1.76	52.0	0.59
13. AKP 7	25.09	0.76	6.64	98.0	1.19
14. OEB 52	26.13	0.73	14.28	155.7	2.85
15. Chilika	26.09	1.39	-0.62	74.4	4.45
Average	**25.49**	**1.00**	**7.55**	**121.3**	**3.04**
CD (5%)	1.21				

classes of all maturity groups of a crop were combined to get a single 2 × 2 contingency table for each crop. Means of HS and LS classes for yield, adaptability and stability parameters in the combined contingency table for a crop were also computed. Presence/absence of relationship between MH sensitivity and any stability parameter was inferred from the observed and expected frequencies of the four classes in the 2 × 2 contingency table and the class means of HS and LS classes for the stability parameter. The presence/absence of relationship was tested by contingency x^2 test.

Results

Multilocation trials - adaptability and stability

The genotypes in each maturity group of rice showed significant difference in mean yield performance over the 12 environments (4 locations and 3 years). Average yield of the 11 mid-early genotypes ranged from 34.41 to 38.42 q/ha with a grand

Table 3. Effect of maleic hydrazide (MH) treatment on seedling root and shoot growth of rice genotypes

Genotypes	Root length (cm)			Shoot length (cm)			SGI
	Cont.	Tr.	Reduction (%)	Cont.	Tr.	Reduction (%)	(%)
Mid-early group							
1. OR 1739-47	5.91	2.87	51.4	5.18	2.89	44.2	47.8
2. OR 1916-19	7.58	2.28	69.9	5.70	3.09	45.8	57.9
3. OR 1929-4	6.71	3.46	48.4	5.10	3.91	23.3	35.9
4. OR 1976-11	5.77	2.76	52.2	4.52	3.59	20.6	36.4
5. OR 2006-12	8.01	3.90	51.3	4.63	2.89	37.6	44.4
6. OR 2168-1	9.25	3.73	59.7	5.42	3.33	38.6	49.1
7. OR 2172-7	7.19	2.33	67.6	4.87	2.35	51.8	59.7
8. OR 2200-5	7.63	3.92	48.6	5.15	3.43	33.4	41.0
9. Konark	5.11	1.83	64.2	3.88	2.07	46.6	55.4
10. Lalat	6.58	4.49	31.8	4.29	2.69	37.3	34.6
11. Bhoi	6.33	3.56	43.8	5.73	2.89	49.6	46.7
Average			53.5			39.0	46.3
CD (5%)			11.2			10.1	8.8
Mid-late group							
1. OR 1681-11	5.81	0.59	89.8	5.62	1.35	76.0	82.9
2. OR 1912-25	6.36	1.45	77.2	4.76	2.94	38.2	57.7
3. OR 1914-8	5.56	0.59	89.4	5.66	1.41	75.1	82.2
4. OR 1964-8	5.31	1.11	79.1	5.73	3.01	47.5	63.3
5. OR 1967-15	7.73	1.03	86.7	6.54	2.27	65.3	76.0
6. OR 2156-15	6.77	0.79	88.3	5.60	1.90	66.1	77.2
7. OR 2310-12	6.06	1.15	81.0	4.53	1.66	63.4	72.2
8. Pratikshya	5.16	0.64	87.6	4.33	1.28	70.4	79.0
9. Gouri	5.86	0.47	92.0	4.78	1.44	69.9	80.9
10. Surendra	4.87	0.65	86.7	4.42	2.01	54.5	70.6
11. Gajapati	5.70	1.17	79.5	4.99	2.93	41.3	60.4
12. Kharavela	4.85	0.50	89.7	4.05	1.12	72.3	81.0
13. MTU 1001	5.37	1.10	79.5	5.99	2.75	54.9	67.2
Average			85.1			61.1	73.1
CD (5%)			5.7			12.7	8.6
Late group							
1. OR 1885-16-34	3.12	0.83	73.4	5.34	2.02	62.2	67.8
2. OR 1898-2-15	4.96	1.10	77.8	4.55	3.39	25.5	51.7
3. OR 1898-3-16	4.16	0.93	77.6	4.19	3.09	26.3	52.0
4. OR 1901-14-32	3.18	0.91	71.4	4.36	1.99	54.4	62.9
5. OR 2001-1	3.20	0.86	73.1	4.72	3.06	35.2	54.2
6. OR 2109-2	2.91	0.86	70.5	3.82	1.69	55.8	63.1
7. OR 2119-13	3.02	0.86	71.5	4.55	1.92	57.8	64.7
8. Savitri	2.56	0.47	81.6	4.25	1.37	67.8	74.7
9. Salivahan	2.94	0.57	80.6	4.26	1.33	68.8	74.7
10. Mahanadi	3.14	0.97	69.1	4.29	1.95	54.5	61.8
11. Kanchan	3.52	0.58	83.5	4.58	1.17	74.5	79.0
12. Jagabandhu	5.06	1.05	79.2	4.91	2.86	41.8	60.5
Average			75.8			52.1	64.0
CD (5%)			4.8			16.4	9.0

Table 4. Effect of maleic hydrazide (MH) treatment on seedling root and shoot growth of ragi genotypes

Genotypes	Root length (cm)			Shoot length (cm)			SGI
	Cont.	Tr.	Reduction (%)	Cont.	Tr.	Reduction (%)	(%)
Early group							
1. Bhairabi	6.65	4.97	25.3	2.29	1.38	39.7	32.5
2. Dibyasinha	5.47	2.52	53.9	2.32	1.45	37.5	45.7
3. Neelachal	6.49	2.68	58.7	2.43	1.51	37.9	48.3
4. OEB 65	6.15	3.50	43.1	2.30	1.62	29.6	36.4
5. VL 149	6.81	5.51	19.1	2.37	2.17	12.7	15.9
6. RAU 8	6.36	3.97	37.6	2.32	1.57	32.3	35.0
7. VR 708	6.40	5.21	18.6	2.43	1.64	32.5	25.6
8. BM 107-2	6.02	3.97	34.0	2.30	1.43	37.8	35.9
9. SRS-2	5.53	2.02	63.5	2.53	1.53	39.5	51.5
10. KM 231	6.83	3.89	43.0	2.68	1.35	49.6	46.3
11. HR 374	6.07	3.53	41.9	2.62	2.33	11.1	26.5
12. PES 400	6.64	2.68	59.6	2.86	1.85	35.3	47.5
13. VL 322	5.74	2.54	55.8	1.98	1.39	29.8	42.8
14. DM 7	5.41	3.61	33.3	2.59	1.64	36.7	35.0
15. AKP 2	5.79	3.19	44.9	2.84	1.60	43.7	44.3
Average			42.2			33.7	38.0
CD (5%)			14.4			10.2	9.9
Late group							
1. OEB 82	5.59	2.49	55.5	2.45	1.70	30.6	43.0
2. OEB 56	5.39	3.89	27.8	2.08	1.83	12.0	19.9
3. OEB 71	5.34	3.64	31.8	2.11	1.62	23.2	27.5
4. PR 202	5.93	3.03	48.9	2.37	1.80	24.1	36.5
5. GPU 57	4.71	3.59	23.8	1.99	1.83	8.0	15.9
6. PES 110	4.54	3.26	28.2	2.21	1.50	32.1	30.2
7. VR 849	5.37	4.68	12.9	2.37	2.13	10.1	11.5
8. VR 822	5.10	3.41	33.1	2.31	1.91	17.3	25.2
9. MR 33	5.13	2.81	45.2	2.18	1.53	29.8	37.5
10. VR 768	6.94	3.38	51.3	2.57	1.43	44.4	47.9
11. GPU 58	6.44	5.70	11.5	2.26	2.09	7.5	9.5
12. Indaf 5	5.38	3.61	32.9	2.27	1.84	18.9	25.9
13. AKP 7	4.35	2.71	37.7	2.24	1.34	40.2	39.0
14. OEB 52	5.84	3.70	36.6	2.01	1.63	18.9	27.8
15. Chilika	6.39	3.69	42.3	2.24	1.72	23.2	32.7
Average			34.6			22.7	28.7
CD (5%)			12.9			11.2	10.7

mean of 36.55 q/ha (Table 1). Regression coefficient (b values) of genotypes varied from 0.69 to 1.47. The genotypes showed wide range of variation in the stability parameters deviation from regression S^2d (-3.95 - 24.95), Wricke's ecovalence W (28.0 - 349.9) and AMMI stability value ASV (0.40 - 2.44). The 13 mid-late genotypes showed average yield variation of 38.27 to 47.45 q/ha with a grand mean of 42.16 q/ha. Regression coefficients (b) of the genotypes varied from 0.59 to 1.49. The genotypes also showed wide range of variation in the stability parameters S^2d (-2.26 - 38.26), W (15.0 - 40.6) and ASV (0.56 - 2.44). The average yield of the 12 late genotypes ranged from 32.15 to 44.45 q/ha with a mean of 39.88q/ha. Regression coefficients (b) of the genotypes varied from 0.39 to 1.64. The genotypes also showed wide range of variation in the stability parameters S^2d (0.46 - 72.37), W (110.7 - 959.1) and ASV (0.74 - 6.47).

The ragi genotypes of each maturity group also exhibited significant differences in mean yield performance over the 9 environments (3 environmental conditions and 3 years). Average yield of the 15 early genotypes ranged from 13.55 to 25.12 q/ha with a grand mean of 20.83 q/ha (Table 2). Regression coefficients (b values) of genotypes varied from 0.25 to 1.55. The genotypes showed wide range of variation in the stability parameters deviation from regression S^2d (-1.43 - 15.22), Wricke's ecovalence W (14.4 - 245.8) and AMMI stability value ASV (0.14 - 2.61). Mean yield of 15 late ragi genotypes varied from 15.69 to 31.97q/ha with a grand mean of 25.49q/ha. Regression coefficient (b) values of genotypes ranged from 0.50 to 1.64. The genotypes also showed wide range of variation in the stability parameters S^2d (-0.62 - 20.95), W (49.5 - 207.3) and ASV (0.51 - 6.81).

MH-Seedling growth inhibition

MH treatment of rice and ragi seeds caused reduction in seedling root and shoot growth. Sensitivity of genotypes to MH treatment was assessed in terms of SGI. The genotypes of the three maturity groups of rice showed significant differences in percent reduction of root and shoot length and SGI values (Table 3). Reduction in root length was more conspicuous than that in shoot length in all the three maturity groups. In mid-early group, the root-growth reduction ranged from 31.8 to 69.9 % and shoot growth reduction varied from 20.6 to 51.8 %. SGI values of the mid-early genotypes varied from 34.6 to 59.7 % with a mean of 46.3 % (Table 3).The genotype Lalat had the lowest SGI value (34.6 %), while OR 2172-7, OR 1916-19 and Konark had high SGI values (> 55.0 %). The thirteen mid-late genotypes showed root length reduction ranging from 77.2 to 92.0 % and shoot growth reduction varied from 38.2 to 76.0 %. The SGI values of the mid-late genotypes ranged from 57.7 to 82.9% with a mean of 73.1 %. The genotype OR 1912-25 had low SGI value (57.7 %) and OR 1681-11, OR 1914-8, Kharavela and Gouri had very high SGI values (>80.0 %). In case of late group genotypes, root length reduction varied from 69.1 to 83.5 % and shoot growth reduction ranged from 25.5 to 74.5 %. The SGI values of late-group genotypes varied from 51.7 to 79.0 % with a mean of 64.0 %. SGI was low (<55.0 %) in case of OR 1898-2-15, OR 1898-3-16 and OR 2001-1 and high (> 70.0 %) in case of Kanchana, Savitri and Salivahan.

Table 5. Frequency of rice and ragi genotypes in MH sensitivity and stability parameter classes

MH sensitivity class	No. of genotypes	Yield [†]		b		S^2d		W		ASV	
		LY	HY	<1	>1	S[#]	U	S	U	S	U
Rice											
HS Class[*]											
Mid early	6	4	2	4	2	3	3	3	3	2	4
Mid late	7	5	2	4	3	1	6	3	4	3	4
Late	5	4	1	2	3	0	5	0	5	1	4
Pooled	18	13	5	10	8	4	14	6	12	6	12
LS Class											
Mid early	5	1	4	3	2	3	2	3	2	4	1
Mid late	6	1	5	3	3	4	2	3	3	3	3
Late	7	1	6	5	2	4	3	7	0	5	2
Pooled	18	3	15	11	7	11	7	13	5	12	6
Ragi											
HS Class											
Early	7	5	2	6	1	2	5	4	3	2	5
Late	7	5	2	4	3	4	3	5	2	4	3
Pooled	14	10	4	10	4	6	8	9	5	6	8
LS Class											
Early	8	1	7	1	7	6	2	5	3	6	2
Late	8	1	7	5	3	3	5	3	5	2	6
Pooled	16	2	14	6	10	9	7	8	8	8	8

[*] HS, Highly Sensitive; LS, Lowly Sensitive to MH treatment
[†] LY, Low Yielder; HY, High Yielder; [#]S, Stable; U Unstable

Treatment of ragi genotypes with MH also caused varying degree of reduction in seedling root and shoot length. In case of early group, root length reduction ranged from 18.6 to 63.5 % and shoot growth reduction ranged from 11.1 to 49.6 % (Table 4). SGI values of genotypes in early group ranged from 15.9 to 51.5 % with a mean of 38.0 %. The genotypes VL 149, VR 708 and HR 374 had low SGI values (< 27.0 %), while SRS-2 and Neelachal had high SGI values (> 48.0%). In case of late group, root length reduction varied from 11.5 to 55.5 % and shoot length reduction ranged from 7.5 to 44.4 %. SGI values in late group ranged from 9.5 to 47.9 % with a mean of 28.7 %. The genotypes GPU 58, VR 849 and GPU 57 had low SGI values (<16.0 %), while VR 768 and OEB 82 had high SGI values (> 40.0 %).

Relationship of MH sensitivity with yielding ability, adaptability and yield stability

Sensitivity of genotypes to MH treatment was assessed in terms of SGI both in rice and ragi. The genotypes of both crops showed wide variation in their SGI values, yield performance, b-values and stability parameters like S^2d, W and ASV. In both the crops, the genotypes of each duration group were classified as highly sensitive (HS) and lowly sensitive (LS) to MH treatments. Similarly, in each maturity group, genotypes having above group average yield were classified as high yielder (HY) and those having below average yield were classified as low yielder (LY). On the basis of b-values, genotypes were classified into two groups as b > 1 (genotypes adapted to rich environments) and b < 1 (genotypes adapted to poor environments). Classification of the genotypes for yield stability was done on the basis of three parameters: (i) S^2d of Eberhart and Russell

Table 6. 2 x 2 contingency tables of MH-sensitivity parameter (SGI) and yield and adaptability parameters in rice and ragi

MH sensitivity	Rice		Ragi	
	HS Class[a]	LS Class	HL Class	LS Class
No. of genotypes	18	18	14	16
Yield class				
LY (BA)[b]	13 (8.0)[c]	3 (8)	10 (5.6)	2 (6.4)
HY (AA)	5 (10.0)	15 (10.0)	4 (8.4)	14 (9.4)
x^2 -value	11.25**		10.80**	
Av. yield	37.6	41.8	21.8	24.3
b-class				
b<1 (BA)	10 (10.5)	11 (10.5)	10 (7.5)	6 (8.5)
b>1 (AA)	8 (7.5)	7 (7.5)	4 (6.5)	10 (7.5)
x^2 -value	0.11		3.45	
Av. b-value	1.01	0.99	0.87	1.13

[a] HS, Highly Sensitive; LS, Lowly Sensitive to MH treatment

[b] LY, Low Yielder; HY, High Yielder; BA, Below Average; AA, Above Average

[c] Number in parenthesis indicate expected frequency of the contingency class

Table 7. 2 x 2 contingency tables of MH-sensitivity parameter with yield stability parameters (S^2d, W & ASV) in rice and ragi

MH sensitivity	Rice		Ragi	
	HS Class[a]	LS Class	HL Class	LS Class
No. of genotypes	18	18	14	16
S^2d class				
Stable (BA)	4 (7.5)	11 (7.5)	6 (7.0)	9 (7.0)
Unstable (AA)	14 (10.5)	7 (10.5)	8 (7.0)	7 (8.0)
x^2 -value	5.60**		0.54	
Average S^2d	23.75	8.14	5.72	5.89
W-class				
Stable (BA)	6 (9.5)	13 (9.5)	9 (7.9)	8 (9.1)
Unstable (AA)	12 (8.5)	5 (8.5)	5 (6.1)	8 (6.9)
x^2 -value	5.46**		3.45	
Average W	364	186	104	102
ASV-class				
Stable (BA)	6 (9.0)	12 (9.0)	6 (6.5)	8 (7.5)
Unstable (AA)	12 (9.0)	6 (9.0)	8 (7.5)	8 (7.5)
x^2 -value	4.00**		0.11	
Average ASV	1.19	2.08	2.18	1.83

[a] HS, Highly Sensitive; LS, Lowly Sensitive to MH treatment

[b] BA, Below Average; AA, Above Average

[c] Number in parenthesis indicate expected frequency of the contingency class

(1966), (ii) Wricke's ecovalence W and (iii) AMMI stability value (ASV). The genotypes having below group average value for S^2d/W/ASV were classified as stable (S) and those with above average value, classified as unstable (U). The above classification of genotypes was done for each of the three duration groups of rice and two duration groups of ragi and then pooled crop wise (Table 5).

In case of rice, of the 36 genotypes, 18 were found to be HS and 18 LS (Table 5). The frequency of HY in HS class was 5 and LY was 13, whereas in LS class 15 were HY and 3 were LY. So the observed frequencies in the 4 contingency classes i.e. HS-AA, HS-BA, LS-AA and LS-BA, were much different from the expected frequencies on random distribution. The contingency x^2 value was highly significant (Table 6) indicating the distribution to be non-random and most genotypes showing low sensitivity to MH were high yielder. In conformity, the LS class had higher average yield of 41.8 q/ha as against 37.6 q/ha of the HS class. In case of ragi, of the 30 genotypes, 14 were HS and 16 LS (Table 5). Ten of the 14 genotypes of HS group had low yield (LY). In contrast, 14 of the 16 genotypes of LS group had high yield (HY). The observed frequencies in the HS-AA, HS-BA, LS-AA and LS-BA classes were very much different from the expected frequencies and x^2 value was also highly significant indicating that most HS genotypes were low yielder and most LS genotypes were high yielder. In conformity, the LS group had high average yield of 24.3 q/ha and the HS group had low average yield of 21.8 q/ha.

In analysis of adaptability and stability of performance by linear regression model, the regression coefficient b indicates adaptability of a genotype to specific environmental conditions. Genotypes with $b < 1$ would show better adaptation to poor environments and genotypes with $b > 1$ would show better adaptation to rich environments. In rice, the high sensitivity (HS) and low sensitivity (LS) classes of MH-SGI showed almost equal number of genotypes with $b < 1$ and $b > 1$ and the contingency x^2 was non-significant (Table 6) indicating the distribution to be random. Moreover, both HS and LS classes of MH-SGI had very similar class means for b, both close to 1. Thus, sensitivity to MH does not appear to have any significant relationship with b-values of genotypes in rice. In case of ragi, 14 of the 30 genotypes were HS of which only 4 had $b > 1$ and 10 had $b < 1$ .The remaining 16 genotypes were LS, of which 10 had $b > 1$ and 6 had $b < 1$. The contingency chi-square was quite high ($x^2 = 3.45$), though not significant at 5 % level. The HS class also had low average b-value of 0.87 compared to 1.12 of LS class. Thus it appears that ragi genotypes showing low sensitivity to MH would show better adaptation to rich environments and those showing high sensitivity would show better adaptation to poorer environments.

For stability analysis, three different stability parameters, i.e. deviation from regression (S^2d), Wricke's ecovalence (W) and AMMI stability value (ASV) were considered. Eighteen of the 36 rice genotypes were LS on the basis of MH-SGI, which included 11, 13 and 12 genotypes with stability of performance as assessed by S^2d, W and ASV, respectively and it included fewer genotypes with unstable performance (Table 7). The remaining 18 genotypes were HS on basis of MH-SGI, which included 14, 12 and 12 genotypes with unstable performance as assessed by S^2d, W and ASV, respectively and included fewer genotypes with stable performance. The contingency x^2 values in all three cases were significant, indicating the distributions to be non-random. In conformity, the LS group had lower average values for S^2d, W and ASV than HS group. Thus, low sensitivity to MH as measured by SGI could be a good indicator of stability of performance of rice genotypes. But, both the HS and LS classes of ragi genotypes included almost equal number of genotypes with stable and unstable performance as measured by three stability parameters- S^2d, W and ASV (Table 7). In conformity, the HS and LS classes did not show much difference in average values for S^2d, W and ASV. The contingency x^2 values were also non-significant in all three cases, indicating the distributions to be random. Thus, MH-SGI of genotypes does not have any significant relationship with yield stability of ragi genotypes.

Discussion

MH is an anti-auxin growth regulator and acts as a growth retardant and inhibits mitotic cell division in plants (Zukel 1950). Growth inhibitory effect of MH has been reported by Schoene and Hoffman (1949), Aurbey and Naylor (1950), Sircar and Ray (1962), Larry (1969) and Kumar and Pal (2004) in various plant species. These reports indicated that the growth inhibitory effect was dose dependent and more conspicuous at seedling stage affecting both root and shoot growth. In the present study, seeds of 36 rice and 30 ragi genotypes of different duration groups were treated with 500 and 100 ppm MH solution, respectively. MH treatment resulted in conspicuous reduction of root and shoot length and SGI in the genotypes ranged from 34.6 to 82.9 % in case of rice and 9.5 to 51.5% in ragi, indicating wide differences in growth inhibitory effect of MH in different genotypes in both crops. Tatum and Curme (1951) reported a pronounced differential response of the various strains of corn to MH treatment. Differential seedling growth inhibitory effect of MH in different genotypes has been reported by Das and Sinha (1965) in rice and Dash (1988) in wheat.

Of the 36 rice genotypes, 18 were HS and 13 of these were low yielder. On the other hand, 15 of the 18 LS genotypes were high yielder. Similarly, in case of ragi, 10 of the 14 HS class genotypes were low yielder, whereas 14 of the 16 LS genotypes were high yielder. In both crops, the LS class had much higher average yield than HS class. Thus, low MH sensitivity in terms of seedling growth inhibition could be a good indicator of high yield potential of genotypes, both in rice and ragi. Das and Sinha (1965) estimated MH sensitivity of 19 rice genotypes in terms of seedling growth inhibition and observed that MH resistant varieties were higher yielding than sensitive varieties.

In case of rice, the LS and HS classes on the basis of MH-SGI included almost equal number of genotypes with $b < 1$ and $b > 1$ and both classes had similar average b values. So, it appears that MH sensitivity did not have any relationship with specific adaptability pattern of rice genotypes. But, in case of ragi, 10 of the 16 genotypes of LS class had $b > 1$ and 10 of the 14 genotypes of HS class had $b < 1$.The LS class had higher average b value of 1.12 as against 0.87 for HS class. Thus, it appears that ragi genotypes showing low MH-sensitivity would be better adapted to rich environments and those showing high MH-sensitivity would be better adapted to poor environments. Dash (1988) working on wheat observed that genotypes showing moderate response to MH were more stress (heat/drought) tolerant.

Rice and ragi genotypes were classified as stable and unstable on the basis of three stability parameters i.e., S^2d, W and ASV. Majority of the rice genotypes falling in LS class on the basis of MH-SGI showed stable performance according to all the three stability parameters, while most genotypes of HS class showed unstable performance. The LS class also had much smaller average for S^2d, W and ASV than LS class. Thus, rice genotypes showing low seedling growth inhibition due to MH treatment would generally show stability of yield performance over a range of environmental conditions. But, in case of ragi, both LS and HS classes on the basis of MH-SGI included almost equal number of genotypes with stable and unstable performance, indicating that MH sensitivity of ragi genotypes did not have any definite relationship with stability of yield performance.

Low MH-sensitivity in terms of seedling growth inhibition index was a good indicator of high yield potential of genotypes both in rice and ragi. Also, low MH-sensitivity of genotypes was good indicator of better adaptability to rich and high MH-sensitivity to poor environments in ragi but not in rice. On the other hand, low MH-sensitivity of genotypes was a good indicator of stability of yield performance in rice but not in ragi. The differential relationship of MH-sensitivity with adaptability and stability in the two crops could be due to the fact that rice is a C_3 plant and ragi is a C_4 plant. Thus, MH-sensitivity measured in terms of seedling growth inhibition can be used for a preliminary selection of breeding lines for yielding ability and stability of performance over environments in rice and yielding ability and adaptability to rich or poor environments in ragi, before going for expensive multilocation trials. The laboratory method evaluated in the study is simple, rapid and inexpensive and also offers the advantage of off-season testing.

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