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Evaluation of Mulberry (*Morus* spp.) Genotypes for Tolerance to Major Abiotic Stresses

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Abstract

Sericulture has played a very important role in the socio-economic empowerment of rural and semi-urban population. The eco-friendly nature of the industry, in addition to its employment generation potential, low investments and frequent returns, has rendered the industry as one of the most suitable land based economic activity, particularly in the context of global movement against environmental degradation and global warming. The present thrust in increasing silk production to meet the growing domestic and international demand however, cannot rely upon horizontal expansion. In light of the competition to mulberry from other food and commercial crops, it has become imperative to utilize marginal, problematic soils for mulberry cultivation. Although soil amendment and management is one of the feasible means, genetic improvement of crops towards tolerance to stress is more effective, less costly, non-polluting and longer lasting. The present study was conducted with six mulberry genotypes selected from a segregating population of 1152 hybrids on the basis of their relative performance in two diverse environments- (i) Optimum growing conditions, wherein the recommended inputs were provided and (ii) Stress conditions, wherein all inputs including irrigation were withdrawn. The six genotypes were further subjected evaluation under different stress conditions like, soil moisture stress, alkalinity and salinity along with control genotypes K-2 and V-1 maintained at optimal conditions. Significant variability was recorded among the genotypes in respect of Leaf yield response index [LYRI], Stress resistance index [SRI] and Varietal score [VS]. The results indicated a high degree of plasticity in G-6, which is now christened as RC-2 [Resource Constraint-2], that would assure sustained leaf production in severe water stress, alkaline and saline conditions. The genotype is recommended for cultivation by the marginal and small farmers for economic utilization of the problematic soils.

Keywords: Alkalinity, Leaf yield response index, Plasticity, Salinity, Stress resistance index, Varietal score, Water stress.

INTRODUCTION

In view of the growing demand for silk in the domestic and international markets, it is most appropriate for any agrarian economy, especially the ones that have a tradition in sericulture, to increase their silk production. While increased productivity per unit area has significantly contributed towards production, it has now become imperative to develop strategies for utilizing problematic soils, and tracts with limited water resources. Larger areas under the semi-irrigated conditions exhibit alkalinity due to poor rainfall and scarcity of irrigation water. These soils contain excessive concentrations of exchangeable carbonates or bicarbonates of sodium that usually exceed 30% of the soil's cation exchangeable capacity and high pH, which affect plant survival and growth due to physiological drought conditions and nutritional deficiencies. Utilization of problematic soils is best achieved by growing tolerant plant species (Epstain, 1985; Epstain and Rains, 1987; Ashraf and Mc Neilly, 1988). Although soil amendment and management is one of the feasible means, genetic improvement of crops towards tolerance to stress is more effective, less costly, non-polluting and longer lasting (Epstain *et al.,* 1980 and Downtown, 1984).

Many studies have been conducted to identify salt tolerant mulberry genotypes by screening under coastal saline soils (Agastian and Vivekanandan, 1997; Chakraborty *et al.,* 2000) and under induced salinity conditions (Shaik and Vivekanandan, 1999; Mogili *et al.,* 1998 and 2002; Prakash *et al.,* 1998; Sarkar *et al.,* 2000). Naidu *et al.*, (1999) reported variability in reaction to alkalinity stress among tree species when screened under natural stress conditions. The studies on evolving soil moisture stress tolerant genotypes have led to the development of mulberry varieties like S-13 and S-34 (Susheelamma, 1987; Susheelamma and Jolly, 1986).

The present study subjected six mulberry genotypes selected from a segregating population of 1152 hybrids on the basis of their relative performance in two diverse environments- (i) Optimum growing conditions, wherein the recommended inputs were provided and (ii) Stress conditions, wherein all inputs including irrigation were withdrawn. The test genotypes were subjected to different stress conditions like soil moisture stress, alkalinity and salinity along with control genotypes K-2 and V-1 maintained at pH 7.0, with recommended dosage of NPK and irrigation. Significant variability was recorded among the genotypes in respect of leaf yield response index [LYRI], stress resistance index [SRI] and varietal score [VS].

MATERIALS AND METHODS

The study was carried out under controlled conditions using pot culture technique. Six hybrids short-listed for their superior performance under stress and non-stress environments were considered for the study along with K-2, a variety popular in semi-irrigated conditions and V-1, a variety popular under optimum growing conditions, as checks. Well-rooted saplings of the genotypes were planted in pots lined with polyethylene sheets to provide full effect of the treatments under simulated conditions to study the plasticity of genotypes under different conditions. The different conditions were treated as environments.

The genotypes were put under soil moisture stress (irrigation once in 3 & 7 days), salinity stress (Ec- 4.0 & 7.0 mmho-cm) and alkalinity stress (pH 8.5 & 10.0). The controls were maintained with recommended dosage of fertilizers i.e., N:P:K @ 300:120:120 kg/ha/yr in 5 equal splits, pH 7.00 and Ec 0.8 mmho-cm

Seven different conditions comprising of optimal and six different conditions were simulated (Table 1). The stress levels were induced by adopting different frequencies of irrigation; adding sodium carbonate and calcium carbonate to induce alkalinity; adding sodium chloride and sodium carbonate to induce salinity. Soil samples were collected periodically from each pot, where different salinity and alkalinity levels were induced and analyzed after each harvest. The data indicated slight increase in pH and exchangeable sodium percentage (ESP) and sodium adsorption Ratio (SAR). However, pH, ESP and SAR were within normal range of variation and did not affect the actual stress conditions induced. The experiment was conducted in randomized design with three replications, considering individual pots as replications. Each ordered replicate was arranged compactly with a guard row around each replication. Pots were shifted at regular intervals and data recorded each time during harvest.

The experiment was conducted for one year after establishment of saplings in pots. Leaves were harvested at intervals of 70 days and the data of five leaf harvests were recorded. Average leaf yield was considered for further analysis.

Plastic response of genotypes was measured by one-way and two-way ANOVA. Tolerance indices for different stress environments were determined following Rana (1986) and Maloo (1993) with slight modifications:

Leaf yield response index [LYRI]

$$\text{LYRI} = \frac{\text{Leaf yield of a variety (average of all stress environments)}}{\text{Mean yield of all varieties under stress environments}}$$

Stress resistance index [SRI]

$$\text{SRI} = \frac{\text{Leaf yield of a variety (average of all stress environments)}}{\text{Leaf yield of the variety under non-stress environment}}$$

Varietal score [VS] = LYRI x SRI

RESULTS AND DISCUSSION

The mean values for leaf yield at different growth environments are presented in Table 2. Significant reduction was recorded in leaf yield of all genotypes in response to different stress factors and also in the yield among the genotypes under a particular environment. Although the leaf yield of the test genotypes significantly reduced in all the treatments (E2 to E7) compared to the control (E1), the reduction in leaf yield was not similar in all the genotypes.

Under moderate stress conditions [E2], the leaf yield was found to vary from 56.65% in G-3 to 82.28% in G-6, in comparison to the yield in E1. The test genotype G-6 showed least reduction under E2 and the mean leaf yield was almost equal to the superior check V-1. Under severe soil moisture stress [E3], the leaf yield was found to vary from 38.86% in V-1 to 60.10% in G-4, in comparison to the yield in E1. The test genotype G-4 showed least reduction under E3, but was outyielded by G-6 and G-2.

Under moderate stress conditions [E4], the leaf yield was found to vary from 46.21% in V-1 to 77.27% in G-6, in comparison to the yield in E1. The test genotype G-6 showed least reduction under E4 and the mean leaf yield was also highest in the genotype. Under severe alkalinity stress [E5], the leaf yield was found to vary from 28.46% in V-1 to 47.60% in G-4, in comparison to the yield in E1. The test genotype G-4 showed least reduction under E5, followed by G-6, which out yielded all the test genotypes and both the checks.

Under moderate stress conditions [E6], the leaf yield was found to vary from 63.29% in G-3 to 86.69% in K-2, in comparison to the yield in E1. The check genotype K-2 showed least reduction under E6 and the mean leaf yield was highest in the check genotype V-1, followed by G6, which did not show any significant difference in mean leaf yield with the check variety V-1. Under severe salinity stress [E7], the leaf yield was found to vary from 47.99% in G-4 to 70.63% in G-6, in comparison to the yield in E1. The test genotype G-6 showed least reduction under E7, which out yielded all the test genotypes and both the checks.

In all the treatments G-6, among the test genotypes, was found superior to K-2 in respect of leaf yield, with the largest positive yield variance in case of mild soil moisture stress (87.60%), followed by mild alkalinity (51.87%) and severe salinity (50.24%). The variance was 47.96% in case of control maintained under non-stress conditions. However, the test genotype G-6 showed positive yield variance against the superior check V-1 only in four of the six environments. The highest positive variance of 52.28% was recorded under mild alkalinity stress followed by severe alkalinity stress [41.15%].

It is reported that due to effect of plasticity, not only a genotype behaves differently in different environments but also; the different genotypes behave similarly in a particular environment (Bradshaw, 1965). In the present study, the maximum yield was obtained in the genotype V-1 under optimal conditions and the minimum in K-2 under similar conditions. The yield of genotype K-2 (95.16 g/plant) was only 61.50% of the yield of V-1 (154.80 g/plant) under optimal conditions, the yield difference being highly significant. But it is interesting to note that the leaf yield of K-2 and V-1 was nearly similar in both alkaline stress treatments E4 and E5. Under severe soil moisture stress treatment [E3], the yield difference was not significant.

The leaf yield was dependent on both genotype and environments. Genotype x environment interaction was also found to be significant. Both environment and G x E terms were found to be significant indicating the plastic response of the genotypes and differences in their response. Schlichting (1986) stated that comparing a large number of genotypes for plasticity couldn't provide sufficient information for the plastic response of a pair of genotypes. Hence the pair wise comparison was made through two-way ANOVA. The result indicated how the genotypes varied in their plastic response when compared with the other selected genotypes (Table-3). The genotype pairs viz., G-1 Vs G-2, G-1 Vs G-6 did not differ significantly in respect of plasticity for yield. Similarly, G-2 Vs G-6, G-5 and G-3 did not differ significantly in respect of plastic response to yield. All other pairs were found to be highly significant.

The tolerance indices measured by using leaf yield under stress and control conditions indicated clear differences between the genotypes (Table 4). The test genotype G-6 recorded highest values of the two indices, Leaf yield response index (LYRI) and Varietal score (VS) in all the treatments. The genotype G-6 ranked a very close second in respect of Stress resistance Index (SRI). Rana (1986) and Singh (1991) critically analyzed the selection criteria for salt tolerance in crop plants and concluded that the tolerant genotype shows higher rankings for leaf yield response, stress resistance indices and varietal scores.

The results indicated a high degree of plasticity in G-6 that would assure sustained leaf production in alkaline and semi-irrigated tracts. The genotype could be recommended for cultivation by the marginal and small farmers in semi-arid and alkali-affected tracts for economic utilization of the soils through sericulture. This will not only increase the silk production but also will improve the economy of the poor farmers in those areas.

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Tables

Table 1. Details on different experiments and their treatment information.

Sl. No.	Experiment No.	Treatment details
1	E-1	Optimal- water daily (7/7), full dose of fertilizers (F)
2	E-2	Water once in 3 days (1/3), full dose of fertilizers
3	E-3	Water once a week (1/7), full dose of fertilizers
4	E-4	Water daily, full dose of fertilizers, pH 8.50
5	E-5	Water daily, full dose of fertilizers, pH 10.0
6	E-6	Water daily, full dose of fertilizers, Ec 4.0 mmho-cm
7	E-7	Water daily, full dose of fertilizers, Ec 7.0 mmho-cm

Table 2. Mean values for leaf yield (g/plant) under different growing environments*

Sl. No	Environment	Mulberry genotype							
		G-1	G-2	G-3	G-4	G-5	G-6	K-2	V-1
1	E1- Non- stress	125.73	134.50	135.09	107.73	126.06	140.80	95.16	154.80
	Index	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	100.00
2	Fertilizer stress								
	E2- Mild (50% dose)	86.73	88.03	73.09	62.26	80.89	100.90	75.96	108.09
	Index	*68.98*	*65.44*	*54.10*	*57.79*	*64.16*	*71.66*	*79.82*	*69.82*
	E3- Severe (25% dose)	72.83	74.33	57.43	51.96	65.10	89.26	65.26	97.73
3	*Index*	*57.92*	*55.26*	*42.51*	*48.23*	*51.64*	*63.39*	*68.57*	*63.16*
	Soil moisture stress								
	E4- Mild (once in 3 days)	93.47	94.16	76.53	76.93	72.75	115.86	61.76	117.56
	Index	*74.34*	*70.00*	*56.65*	*71.41*	*57.71*	*82.28*	*64.90*	*75.94*
	E5- Severe (once in 7 days)	67.45	68.49	55.90	64.75	52.96	67.96	50.40	60.16
4	*Index*	*53.64*	*50.92*	*41.37*	*60.10*	*42.01*	*48.26*	*52.96*	*38.86*
	Alkalinity stress								
	E6- Mild (pH- 8.5)	86.42	93.29	76.82	67.16	97.51	108.94	71.73	71.54
	Index	*68.73*	*69.36*	*56.86*	*62.34*	*77.35*	*77.37*	*75.37*	*46.21*
	E7- Severe (pH-10)	47.16	58.38	50.71	51.36	55.10	62.19	41.91	44.06
	Index	*37.50*	*43.40*	*37.53*	*47.60*	*43.70*	*44.16*	*44.04*	28.46
5	Salinity stress								
	E8- Mild (Ec-4.0 mmho-cm)	94.30	92.00	85.50	83.73	87.63	111.23	82.50	124.80
	Index	*75.00*	*68.40*	*63.29*	*77.72*	*69.51*	*78.99*	*86.69*	*80.62*
	E9- Severe (Ec-7.0 mmho-cm)	70.13	86.60	72.23	51.70	72.66	99.46	66.20	94.00
	Index	*55.77*	*64.38*	*53.46*	*47.99*	*57.63*	*70.63*	*69.56*	*60.72*
	C. D. at 5%	14.90	10.95	08.96	10.97	12.08	14.44	10.32	14.82

* Results of one-way ANOVA

Table 3. Significance between genotype pair grown in different environments as calculated by two-way ANOVA (Mean square)

Genotype	Source of variation	Genotype G-2	G-4	G-6	G-5	G-3	G-1	V-1
G-1	G	6.67*	52.06**	56.65**	3.11 NS	12.87**	59.38**	38.99**
	E	53.67**	45.87**	45.70**	43.36**	66.55**	41.59**	64.46**
	G X E	1.09 NS	2.54**	1.37 NS	2.63*	2.75*	3.10**	6.51**
G-2	G	-	134.11**	35.35**	22.75**	56.32**	150.66**	20.45**
	E	-	60.85**	56.92**	62.38**	95.46**	56.52**	77.93**
	G X E	-	4.66**	1.48 NS	1.85 NS	1.66 NS	4.44**	10.10**
G-4	G	-	-	243.43**	31.89**	21.81**	0.21 NS	195.23**
	E	-	-	46.16**	51.19**	82.15**	44.86**	67.64**
	G X E	-	-	6.16**	5.95**	5.75**	6.85**	14.83**
G-6	G	-	-	-	92.53**	151.67**		1.31 NS
	E	-	-	-	50.58**	68.82**	262.37**	67.39**
	G X E	-	-	-	2.70*	3.83**	44.62**	5.84**
G-5	G	-	-	-	-	2.97 NS	4.23**	67.81**
	E	-	-	-	-	79.09 NS	37.85**	66.42**
	G X E	-	-	-	-	2.64*	49.33**	12.79**
G-3	G	-	-	-	-	-	3.87**	114.41**
	E	-	-	-	-	-	27.69**	92.91**
	G X E	-	-	-	-	-	75.05**	10.91**
K-2	G	-	-	-	-	-	8.77**	211.11**
	E	-	-	-	-	-	-	66.79**
	G X E	-	-	-	-	-	-	13.16**

G- Genotype; E-Environment (treatment); *- significant at 5% level;
**- significant at 1% level; NS- Non-significant.

Table 4. Indices for measuring tolerance in mulberry genotypes under different stress conditions

STRESS	INDEX	G-1	G-2	G-3	G-4	G-5	G-6	K-2	V-1
Soil Moisture stress	LYRI	1.08	1.09	0.89	0.95	0.84	1.23	0.75	1.19
	SRI	0.64	0.60	0.49	0.66	0.50	0.65	0.59	0.57
	VS	0.69	0.66	0.43	0.62	0.42	0.80	0.44	0.68
Alkalinity stress	LYRI	0.99	1.12	0.94	0.87	1.13	1.26	0.84	0.85
	SRI	0.53	0.56	0.47	0.55	0.61	0.61	0.60	0.37
	VS	0.52	0.63	0.44	0.48	0.68	0.77	0.50	0.32
Salinity stress	LYRI	0.97	1.05	0.93	0.80	0.95	1.24	0.88	1.17
	SRI	0.65	0.66	0.58	0.63	0.64	0.75	0.78	0.64
	VS	0.63	0.70	0.54	0.50	0.60	0.93	0.69	0.75

LYRI – Leaf yield response index; SRI -Stress resistance index; VS – varietal score.