

Morpho-physiological evaluation of some mulberry genotypes under high moisture stress condition

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Received: 23.01.2012, Revised: 05.04.2012, Accepted : 26.04.2012

Key words: Abscisic acid, flood tolerant mulberry, NRA

Availability of optimum moisture in the soil is important for normal growth and development of plants. Most of the tropical lowlands are humid and marshy due to high rainfall and poor drainage system and face the problem of excessive moisture in the soil. Stagnation of water in the low lying areas not only reduces soil aeration but also causes number of adverse effects on plants like (a) impairs the root respiration by slowing down nutrients and water uptake, (b) limits growth of the root system, (c) stimulates toxic metabolism, (d) disturbs hormone metabolism, and (e) prevents the normal functioning of essential biological, chemical and physical processes associated with fertile and productive soils. The renewal of soil air is not only important from the point of maintenance of an optimum level of O₂ and CO₂ but also for exclusion of byproducts of anaerobic decomposition, such as hydrogen sulphide, methane, hydrogen, etc., and the stresses produced by ethylene which accumulates in the soil. In addition, high temperature further aggravates the problem as more O₂ is required to produce a given growth response than at lower temperature. This is partly due to the lower solubility of O₂ in water, and partly due to the increased rate of O₂ consumption by roots and soil microorganisms. Microorganisms affect the distribution of O₂, influence the supply of nutrients (e.g., nitrate) and under anaerobic condition produce compounds which are extremely toxic to plants (such as sulphide and butyric acid). To cope up with the situation an attempt was made to screen twelve mulberry genotypes along with three checks to study the extent of their flood tolerance. Data on growth, leaf yield, root anatomy and different stress related parameters were recorded for three years (2002-2004) for screening and selection of excess moisture condition tolerant mulberry genotype.

In Eastern India mulberry is distributed from the hills to plains around sea level, covering very wide range of situations, viz., rainfed, flood prone, acidic and saline soils, hill terrains, etc. but the highest production comes from the irrigated Gangetic plains only. Due to horizontal expansion of mulberry in traditional and non-traditional areas of eastern India, it has also become necessary to develop high yielding

genotypes specific to a particular agro-climatic zone. Raw silk production greatly depends on productivity and quality of mulberry leaf. The systematic leaf productivity and quality improvement research conducted on mulberry at Central Sericultural Research and Training Institute (CSR&TI), Berhampore, West Bengal led to develop a series of high yielding varieties.

The total mulberry acreage in Eastern and North-Eastern India is 34,472 ha. Out of the total raw silk production of the region more than 86.39% (1865 mt.) is produced in the state of West Bengal. The Gangetic plains which comprise the majority of the region's mulberry area in West Bengal presently cover over 65% under the high yielding varieties S-1 and S-1635. A total of 12 mulberry genotypes viz., S-1755, S-1718, C-2010, C-2011, C-2028, C-2014, C-1690, C-1990, JD-1, C-1991, C-2016 and C-1907 along with two commercially ruling varieties S-1 and S-1635 and 3 local checks (Malda local, Kolitha-3 and Jatinuni) were planted in RBD with 3 replications during February month of 2004 in the low lying areas of the State Govt. Sericulture farm at Akherighata in Murshidabad district of West Bengal where every year river waters enter in the mulberry garden, inundates once in a year and create natural flood condition. During August-September silkworm commercial rearing season the plants in the experimental plots remained inundated for a period of about 30 days up to depth of 30 cm. For recording of root data plants were raised and maintained in polythene tube, inundated in the same condition of the experimental field and by sacrificing the plants data recorded after 90 days of planting in the polythene tube containing soil media. Membrane Stability Index of the treated mulberry leaf tissues was measured according to the method of Deshmukh *et al.* (1991). Nitrate reductase activity was estimated following the methods described by Paliwal and Ilangovan (1990). Ethylene production was measured as per method of Bufler *et al.* (1980). Abscisic acid content of flood affected mulberry leaves was estimated through Radio Immuno Assay technique (Quarrie *et al.*, 1988). The pooled data were analyzed statistically to estimate critical difference and CV% (Gomez and Gomez,

1983). Growth and leaf yield data were recorded 5 times in a year and a total of 15 times in 3 years.

Root morphology and anatomy

Data recorded on root morphology (Table 1) revealed that number of primary root and its length were highest in C-2028. Among the root anatomical characters, thickness of cortex, main medullary rays and cork were found significantly higher over check and most the test varieties. Information available on the root anatomical parameters in flooded conditions

Table 1: Morphological and anatomical characters of root of different mulberry genotypes

Mulberry genotype	No. of roots	Length of root (cm)	Thickness (μ) of		
			Cortex	Main medullary ray	Cork
C-2014	19.13	40.07	357.13	45.61	50.20
C-2010	19.93	47.00	427.07	57.09	61.73
C-1991	23.93	40.80	453.07	58.31	42.67
S-1	22.60	55.60	391.80	45.53	61.33
S-1755	21.00	46.33	282.40	36.08	61.47
C-1907	20.93	40.60	472.13	58.33	82.87
S-1718	20.20	36.67	428.67	45.68	69.80
C-2028	26.40	64.27	362.67	57.10	82.00
S-1635	18.73	41.87	369.47	46.75	50.47
C-1990	25.20	50.53	360.00	60.35	76.67
C-2011	21.73	39.07	391.80	45.77	45.80
C-2016	21.67	36.33	347.47	45.06	44.33
C-1690	21.00	40.47	359.00	45.93	50.67
JD-1	18.07	28.47	426.07	58.15	49.47
ML (check-1)	20.87	41.67	336.73	51.99	38.07
KL-3(check-2)	18.40	44.13	384.20	58.81	39.33
JT(check-3)	13.53	41.07	336.93	56.72	50.80
LSD (0.05)	0.88	1.52	1.32	0.43	1.03
CV(%)	5.88	4.89	0.48	1.17	2.55

indicates that the thick cortex protects the vascular bundles, thick medullary rays help in radial translocation of solutes and thick cork provides mechanical support to the plant. It was also observed that flooding suppressed the formation of root hairs and branching of roots. Adventitious roots are not physiologically adapted to excessive moisture conditions but help the plant to recover when the excess water is drained.

Physio-biochemical parameters

Photosynthesis was recorded from most expanded 5th leaf from the top of a branch of 17 flood affected mulberry genotypes *in situ* condition. Results indicated that C-2028 registered superiority in net photosynthetic rate (Table 2).

Nitrate reductase activity (NRA) for screening and selection

Sethiya *et al.* (1986) used nitrate reductase as a selection criterion for water stress tolerance in sugarcane. They evaluated tolerant, susceptible and fairly tolerant cultivars of sugarcane for nitrate reductase content. In the tolerant cultivars nitrate reductase activity declined to zero in 20-30 days after the initiations of water-logging whereas in susceptible cultivars this decline took only 10 days. On return to normal condition, the nitrate reductase activity resumed in tolerant cultivars but not in susceptible cultivars. Similar fluctuation in NRA content in response to flooding was observed in C-2028. Before

flooding it was $7.49 \mu \text{mol h}^{-1} \text{g}^{-1} \text{fw.}$, on 30th day under flooding it declined to $1.89 \mu \text{mol h}^{-1} \text{g}^{-1} \text{fw.}$ but within 10 days after ending of water-logging it resumed the level of $9.41 \mu \text{mol h}^{-1} \text{g}^{-1} \text{fw.}$

Nutrient availability and uptake

Low oxygen levels affected aerobic respiration and that ultimately reduced the rates of energy dependent active uptake of minerals. Low O_2 and high CO_2 in flooded soils modify the properties of cell protoplasm which leads to decrease permeability and reduce ion uptake. Nitrogen mineralization under anaerobic soil conditions can not proceed fast after the ammonium stage because of the absence of O_2 necessary for the micro-organisms concerned in converting NH_3 to NO_2^- . The breakdown of organic matter leading to the release of ammonium ions also proceeds at a slower rate. Nitrogen from a waterlogged soil is lost through denitrification, ammonia volatilization, leaching of nitrate and ammonia and run-off.

Table 2: Leaf characters of different mulberry genotypes under water logged condition

Mulberry genotype	NPR $\mu\text{ mol CO}_2\text{ m}^{-2}\text{ s}^{-1}$	Leaf yield ($\text{mtha}^{-1}\text{ year}^{-1}$)	Leaf fall rate (%)
C-2014	6.76	39.11	33.49
C-2010	6.03	33.87	29.15
C-1991	9.00	33.18	24.13
S-1	7.44	28.12	22.24
S-1755	8.08	36.17	29.98
C-1907	7.52	34.23	32.54
S-1718	4.95	33.15	29.30
C-2028	9.39	36.29	17.83
S-1635	6.76	41.62	36.33
C-1990	6.56	34.27	35.63
C-2011	4.92	34.87	28.14
C-2016	8.14	37.17	32.21
C-1690	6.99	40.15	31.99
JD-1	9.28	29.09	32.33
ML (check-1)	3.42	30.45	26.62
KL-3(check-2)	7.20	32.59	27.95
JT(check-3)	7.78	-	29.42
LSD (0.05)	0.90	-	1.48
CV(%)	-	-	3.03

Table 3: Bio-chemical performance of different mulberry genotypes under water logged condition

Mulberry genotype	NRA ($\mu\text{ mol NO}_2\text{ h}^{-1}\text{ g}^{-1}$ fresh wt)	Abscisic acid ($\mu\text{ mol g}^{-1}\text{ fresh wt}$)	Ethylene content ($\mu\text{ mol h}^{-1}\text{ g}^{-1}$ dry wt)	Membrane stability (%)
C-2014	10.03	5.70	5.84	77.20
C-2010	8.88	17.70	3.64	74.60
C-1991	8.18	20.50	4.42	79.96
S-1	9.29	43.20	2.46	80.10
S-1755	7.34	9.50	4.25	67.00
C-1907	9.22	11.00	4.59	67.70
S-1718	8.57	2.30	3.24	63.90
C-2028	9.41	56.90	2.60	87.10
S-1635	8.61	16.80	5.16	67.90
C-1990	8.66	14.10	4.28	81.00
C-2011	8.57	32.80	4.02	61.80
C-2016	7.36	49.00	4.91	62.80
C-1690	9.55	3.70	3.90	77.70
JD-1	9.20	13.10	4.62	74.70
ML(check-1)	9.38	6.80	5.06	78.10
KL-3(check-2)	7.34	51.50	4.65	69.70
JT(check-3)	7.24	7.60	4.97	59.00
LSD (0.05)	0.68	0.57	0.26	4.21
CV(%)	-	1.63	3.68	5.78

Hormonal study

Among the genotypes screened, contents of abscisic acid ($56.90\ \mu\text{ mol g}^{-1}\text{ fw}$) found higher in C-2028 with lower level of ethylene ($2.60\ \text{ n mol h}^{-1}\text{ g}^{-1}\text{ dw}$) (Table 3). Information on the physiological aspects of plants due to flood condition reveal that production or transport of both of the hormones like auxin are affected by flooding. The anaerobic environment due to water-logging inhibits auxin

transport in plants. On the other hand, IAA-oxidase activity is also restricted due to lack of O_2 or accumulation of a phenolic inhibitor of IAA-oxidase in the plants. Besides, ethylene originating from the root tissue or from activities of soil micro-organisms may interfere with various auxin controlled processes, which was found minimum in C-2028.

Thus, the water logging-resistant mulberry variety should have a mechanism to restrict the rise in ethylene concentration which is in agreement with the

findings of Dodds *et al.* (1984) in *Vicia faba* where highest water logging resistant variety exhibited rapid conversion of ethylene to ethylene oxide. Flooding also markedly reduced gibberellins levels in the xylem sap of tomato plants (Reid *et al.*, 1969). Gibberellin level in plant system falls after one or two days of flooding and the exogenous application of gibberellic acid stimulates stem growth of the waterlogged plants (Reid and Crozier, 1971). The quantity of root-produced gibberellins, which moves to the shoot, is reduced, thus resulting in growth depression of waterlogged plants.

From the results it emanates that C-2028 possessed better adaptation to water logged condition in comparison to other varieties tested and recorded a considerable higher leaf yield (36.29 t ha⁻¹ year⁻¹) and low leaf fall (17.83 %). Further, high membrane stability, higher abscisic acid accumulation during stress condition and low ethylene content under water logged condition suggested that C-2028 mulberry variety is suitable for water logged condition and may be exploited in the field commercially through authorization study.

ACKNOWLEDGEMENT

The authors thank Dr. V. R. Sashidar Prof. and Head, Dept. of Crop Physiology, GKVK, Bangalore for rendering help in estimating the Abscisic acid content of mulberry leaves. We are also indebted to Prof. K.C. Saha, Soil Chemistry Laboratory, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia (West Bengal) for providing help in ethylene estimation by Gas Liquid Chromatograph equipment.

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