Growth and Leaf Gas Exchange of Well-Watered and Water-Stressed *Tamarindus indica* Seedlings under NaCl Salinity

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Abstract

Four-month-old *Tamarindus indica* seedlings were irrigated with nutrient solutions containing NaCl at 0 (control), 60 (low salt) or 120 (high salt) mM. Half of each group was either well-watered (≈-0.03 MPa) and the other was water-stressed (≈-0.7 MPa). Well-watered seedlings in general grew rapidly during the course of the experiment, whereas growth of water-stressed plants was greatly inhibited. In well watering treatment, growth was only slightly affected by low salt, but was significantly reduced by high salt. On the other hand, under water stress condition salt level had no effect on seedling growth. A large reduction in photosynthetic capacity occurred in all water-stressed plants, irrespective of salt treatment.

Keywords: Tamarind, salinity, water stress, growth, gas exchange.

Introduction

Tamarind, *Tamarindus indica* L., is an important woody perennial fruit species that is found throughout the tropics for its beauty as an ornamental, adaptability to variable climatic and edaphic conditions and fruit production (El-Siddig, 1999). The international survey of unexploited tropical and subtropical perennials revealed that tamarind is cultivated on an orchard basis (10 or more trees) in the Caribean, Central America, South America, South-Central Asia and South-East Asia (Sedgely and Gardner (1989). Although little research has been conducted on tamarind, there exists a few reports to provide potential growers with general information on cultural practices, post-harvest handling and pests and diseases (Chapman, 1984).

Drought and salinity are the major agricultural problems in arid and semiarid areas, where tamarind is commonly grown. In these areas, low soil moisture affects plant growth through an interaction between a lowered matric component of the soil water and an increased salt concentration in the soil solution (Zerbi et al., 1990). Most of the previous studies have focused on either salt or water stress but essentially ignored the joint effects of these two stresses. This is particularly significant in arid climates when salts accumulate gradually as soils dry up. Therefore, when studying the plant responses in saline environment, the inclusion of water stress concurrent with salt stress should be considered (Hao and Jong, 1988; Yanez et al., 1992). This paper described changes in growth and leaf gas exchange of well-watered and water-stressed tamarind seedlings subjected to different levels of NaCl salinity.

Materials and methods

Four-month-old tamarind seedlings (*Tamarindus indica* L) were cultured under greenhouse conditions with a mean day/night temperatures 25/18°C and a mean relative humidity of ca 60%. The plants were grown in 5-l pots filled with quartz sand (0.6-1.2 mm). Nutrient solution was applied daily by hand at 50 ml per pot until initiation of treatments. The nutrient solution was made with tap water to which 1.0 $g.liter^{-1}$ Manna Lina Spezial (Wilhem Haug GmbH & Co. KG) was added. The complete nutrient solution was based on 8 mM N (NH_4NO_3), 3 mM K^+, 3.5 mM Ca^{2+}, 1.7 mM Mg^{2+}, 2.5 mM Na^+, 2 mM SO_4^{-2}, 0.5 mM PO_4^{2-}, 2 mM Cl^-. This solution had a pH of ≈ 6.7 and an EC of ≈1.3.

Treatments were applied beginning on 10 Sep. 1999, when height of the plants was 20.1 ± 3.5 cm and the number of leaflets was 136 ± 10 (mean ± SD). 36 plants were divided into three groups of 12 plants each. Plants of each group were irrigated with a nutrient solution to which either 0 (control, C), 60 (low salt, LS) or 120 (high salt, HS) mM NaCl was added. Each group was further subdivided into two sets. One set was watered daily to near field capacity by application of 50 ml of solution per pot (well watering, WW). In the other set, water was withheld until one plant had symptoms of drought stress and then rewatered with 50 ml per pot (water stress, WS). The soil water potential of WW was ≈-0.03 and that of WS was ≈-0.7 MPa as determined by tensiometers inserted for each treatment at a depth of 20 cm.

Leaf gas exchange was determined during midday with an open photosynthesis system (CI-310PS, CID Inc., USA) 2, 4 and 6 weeks after treatment initiation. Two most recently expanded leaves per seedling were selected for measurement. The instrument provides data on CO_2-assimilation rate (A, µmol.m^{-2}.s-1), transpiration rate (E, mmol.m^{-2}.s^{-1}) and stomatal conductance (g_s, mmol.m^{-2}.s^{-1}). Light was supplied from a 400-W Osram Power Star lamp which delivered 1000 µmol.m^{-2}.s^{-1} photosynthetic photon flux (PPF) at the leaf surface.

Growth measurements were taken at the end of the experiment (19 Nov.). The height of each seedling was measured and leaf number counted. Seedlings were then harvested and separated into their individual parts. Leaf area was determined by using LI-COR Model L13000 area meter (Linkoln, Nebraska, USA).
Data were analysed by analysis of variance, and differences among treatment means were determined by least significance difference (LSD).

Results and Discussions

The combined effects of water (WW and WS) and salt (C, LS and HS) treatments on the growth of tamarind seedlings are shown in Table 1. In general, WW seedlings grew rapidly during the course of the experiment (10 weeks); their height, leaf number and leaf area increased about 2 times from the initial values at the start of the experiment. On the other hand, growth of WS seedlings was greatly inhibited; their height, leaf number and leaf area were only 70%, 71% and 65%, respectively, of the WW seedlings. Under WW condition, seedling growth was only slightly affected by LS, but was greatly reduced by HS treatment. These results are consistent with our previous findings that tamarind seedlings can tolerate salinity level of up to 80 mM NaCl, but are sensitive to an excessive high salinity level of 120 mM (Gebauer et al., 2000). Under

WS condition, variation in salt level had little effect on seedling growth. Hence, any negative effect of salt stress on the growth of WS plants could well be outweighed by inhibiting effects of water stress.

Table 1. Combined effects of water and salinity stresses on vegetative growth of greenhouse-grown tamarind seedlings.

Treatment	Plant height (cm plant^{-1})	Leaf number (No. Plant^{-1})	Leaf area (cm plant^{-1})
At the start	20.1±3.5	136±10	159±14
AW-C	47.3	302	354
AW-LS	39.7	257	299
AW-HS	28.7	197	231
IW-C	29.4	201	226
IW-LS	27.3	170	177
IW.HS	25.4	165	172
$LSD_{0.05}$	7.3	55	68

For well-watered unsalinized seedlings (WW-C), leaf stomatal conductance (g_s) was maximum and remained nearly constant, in the range of 98 to 102 mmol.m^{-2}.s^{-1}, during the span of the experiment (Tab. 2). Expectedly, the time courses of leaf net assimilation rate (A) and leaf transpiration rate (E) were very similar to that of g_s. Addition of low salt caused a slight decrease in A throughout the duration of the study. However, with high salt treatment, A declined from 7.9 to 6.2 µmol.m^{-2}.s^{-1} three weeks from initiating treatments, then stabilized with no further reduction. In leaves subjected to water stress alone or to simultaneous water and salt stresses, A and E were minimum and decreased as a function of time (Tab. 1). This decrease coincided with a significant decline in g_s, suggesting that stomatal closure played a significant role in the limitation of A in those leaves. No large differences occurred in inhibition of A, E and g_s between LS and HS treatments.

Table 2. Combined effects of water and salinity stresses on photosynthetic rate (A_{CO2},), transpiration rate (E), stomatal conductance (gs) and water use efficiency (WUE) of greenhouse-grown tamarind seedlings

Treatment	Leaf gas exchange characteristics											
	A_{CO2} (mol CO_2 m^{-2} S^{-1})			E (mmol H_2O m^{-2} S^{-1})			g_s (mmol m^{-2} S^{-1})			WUE (mol CO_2/mmol H_2O		
	Weeks from treatment initiation											
	2	4	6	2	4	6	2	4	6	2	4	6
AW-C	8.2	8.5	7.8	2.4	2.2	2.0	98	101	102	3.4	3.9	3.9
AW-LS	7.6	7.1	6.9	2.3	1.9	1.7	100	94	82	3.3	3.7	4.0
AW-HS	7.9	6.2	6.3	2.3	1.8	1.7	95	70	64	3.4	3.4	3.7
IW-C	4.9	3.2	1.4	1.6	1.0	0.5	42	25	15	3.1	3.2	2.8
IW-LS	4.7	2.2	1.0	1.6	1.1	0.4	38	26	14	2.9	2.0	2.5
IW-HS	4.2	1.8	0.7	1.4	0.8	0.3	41	18	10	3.0	2.3	2.3
$LSD_{0.05}$	1.7	0.9	0.5	0.5	0.3	0.2	8	9	5	0.4	0.6	0.3

Water use efficiency (WUE) is an important aspect in tolerance to water stress and salt stress (Marler and Zozar, 1996). In the present study, the higher WUE of well-watered seedlings resulted from an enhanced net assimilation rate and a decreased transpiration rate. In the high salt treatment, assimilation rate was reduced more than transpiration, thereby reducing WUE relative to low salt treatment. Similar responses were reported in tomato (Zerbi et al., 1990) and sugar apple (Marler and Zozor (1996). In others studies WUE increased or remained unaffected by salinity (Hoffmann and phene, 1971; Downton et al., 1985)

In summary, we found that water stress reduced growth of tamarind seedling much more severely than salt stress. Growth of well-watered plants were only inhibited when high salt level (120 mM NaCl) was imposed, while plant growth continued at concentration of 60 mM NaCl..

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