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Salt Tolerance of Irrigated Guayule

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Summary. The salt tolerance of guayule (*Parthenium argentatum* Gray cv. N565-II) was tested in small field plots (silty clay soil) in the Imperial Valley of California. Seedlings were transplanted in October 1981. Differential salination was begun in March 1982 and continued for 4 years by irrigating with waters salinized with NaCl and $CaCl_2$ (1:1 by wt.) to obtain electrical conductivities of 0.8, 1.4, 3, 6, 9, and 12 dS/m. Dry matter, rubber, and resin yields were determined from pollarded plants in February 1984 and uprooted plants in February 1985 and 1986. Rubber concentrations in the woody branches in 1984 and 1985 averaged 6.1 and 7.3%, respectively on a dry weight basis and were not significantly affected by soil salinity. Resin concentrations averaged 8.6% and 7.3% for the two years. In 1986, both rubber and resin concentrations decreased with increased salinity. Rubber and resin concentrations in the root crowns were approximately one percentage point less than those of the shoot. Dry matter and resin yields were not affected by salinity until the time- and depth-averaged electrical conductivity of the saturated-soil extracts ($\overline{\overline{EC}}_e$) taken from the rootzone (0–90 cm) exceeded 8.7 dS/m. Above 8.7 dS/m, both yields decreased 11.6% per dS/m increase in $\overline{\overline{EC}}_e$. Rubber yields decreased 10.8% per dS/m above a threshold of 7.8 dS/m. Plant mortality rather than growth reduction at high levels of salinity appears to be the limiting factor for rubber production from irrigated guayule.

Guayule (*Parthenium argentatum* Gray) is a perennial desert shrub that has the potential of becoming a commercial rubber-producing crop on 5 million acres in Arizona, California, New Mexico, and Texas (National Academy of Science 1977). While these areas are climatically suitable for guayule, the soils often are saline or are likely to become saline if irrigated. Limited data obtained during the Emergency Rubber project indicated that guayule was relatively sensitive to soil salinity. Wadleigh et al. (1946) found that sodium salts increased the rubber concentration of guayule grown in potted soil cultures but the concommitant decrease in vegetative growth generally decreased rubber production. In earlier sand culture experiments, Wadleigh and Gauch (1944) reported that at iso-osmotic concentrations, guayule was much more tolerant to $CaCl_2$ than to NaCl which suggests that the tolerance of guayule to mixed

Na and Ca salts might be higher than indicated by single-salt treatments. Retzer and Mogen (1946) attempted to correlate the variable growth of guayule with percent salt in the soil of irrigated fields. They reported that guayule grew well in soils with concentrations of up to 0.3% salt but growth was increasingly reduced at concentrations between 0.3% and 0.6% in the upper 60 cm of soil. Above 0.6% salt, most plants died. However, salt concentrations expressed as percent salt in the soil are difficult to interpret.

Because little data relating plant growth or rubber production to soil salinity existed in 1981, this field plot study was undertaken to determine yield responses for rubber, resin, and dry matter produced as a function of the electrical conductivity of saturated-soil extracts taken from the rootzone. Preliminary results of this study were reported at the Fourth International Conference on Guayule Research and Development (Maas et al. 1986).

Experimental Procedure

Guayule (cv. N565-II) was tested for salt tolerance in field plots at the USDA-ARS Irrigated Desert Research Station in Brawley, CA. The soil was a Holtville silty clay (Typic Torrifluvents, clay over loamy, montmorillonitic (calcareous) hyperthermic). The initial electrical conductivity of saturated-soil extracts (EC_e) taken from the 0 to 90 cm depth averaged 2.8 dS/m. Three-month-old seedlings, cv. N565-II, purchased from a commercial nursery, were transplanted into 18 plots each 6 × 6 m, on October 20, 1981. Each plot contained five flat-top beds that were 15 cm high, 50 cm wide, and spaced on 100 cm centers. Plants were placed in two rows near the edges of each bed at a spacing of 35 cm to obtain a plant population equivalent to 28,600 plants per hectare. All plots were irrigated with Colorado River water (electrical conductivity, EC_i = 1.4 dS/m) subsequent to planting. Differential salination was begun in March 1982 by adding equal parts by weight of NaCl and $CaCl_2$ to the Colorado River irrigation water.

The experiment consisted of six treatments replicated three times in a randomized block design. A nonsaline control treatment was irrigated with well water from Ocotillo, CA (EC_i = 0.8 dS/m). Five saline treatments were irrigated with Colorado River water which was salinized to obtain EC_i's of 1.4, 3, 6, 9, and 12 dS/m. Average concentrations in mol/m^3 for the major constituent ions in the well and river waters were Ca = 0.9 and 2.0, Mg = 0.03 and 1.2, K = 0.15 and 0.1, Na = 5.9 and 5.8, HCO_3 = 3.5 and 2.1, Cl = 2.1 and 3.3, and SO_4 = 0.4 and 3.4, respectively. The four most saline treatments were irrigated with waters having one-half their designated EC_i in the first irrigation. Beginning with the second irrigation on April 9, 1982 all irrigation waters were at the designated treatment concentrations. Because similar soil salinities resulted from irrigation waters having an EC_i of 0.8 and 1.4 dS/m, the well water was replaced with Colorado River water beginning in March 1985. All plots were irrigated on the same schedule but the depth of water applied was adjusted depending upon soil water depletion. Irrigations were applied to keep soil matric potentials in the two lowest salt treatments above −85 J/kg in the 15 to 30 cm soil depth as measured by tensiometers. The depths of water applied for each treatment are given in Table 1. Soil salinity was determined in April and September 1983, January and June 1984 and 1985 and February 1986 by measuring the EC_e of three soil samples taken within each of five depth increments, 0−15, 15−30, 30−60, 60−90, and 90−120 cm in the plant rows.

In February 1984, plants in one-half of each plot were clipped (pollarded) about 10 cm above the surface of the bed. Approximately 18 plants from the center three rows (land area = 6.3 m^2) were used to determine yield. In February 1985, plants in the remaining half of each plot were harvested by cutting the shoots at the soil surface and the roots about 15 cm below the soil surface. The term "root crown" is used herein to refer to that part of the root between the two cuts. In February 1986, plants that had been pollarded in 1984 were harvested with the same procedure as used in 1985. Fresh weights were obtained at harvest and dry weights of defoliated shoots and root crowns were determined after air drying 21 days. Oven-dried subsamples

Table 1. Annual number of irrigations and depth of water applied and rainfall for each salinity treatment

Year	Number of Irrigations	Depth of irrigation water applied (mm)						Rain (mm)
		EC of irrigation water (dS/m)						
		0.8	1.4	3	6	9	12	
1982	17	1,170	1,150	1,130	1,090	1,050	1,020	93
1983	15	910	870	820	770	720	680	190
1984[a]	13	760	730	660	540	460	390	83
1985	13	820	900	700	580	440	–[b]	78

[a] Plots received less water in 1984 because half of each plot was pollarded and required less water

[b] Not irrigated

indicated that the average water contents of air-dried shoots and root crowns were between 11% and 12%. The defoliated shoots and root crowns were chipped and subsampled for rubber and resin analysis. Rubber and resin concentrations were determined by near-infrared spectroscopy (Black and Hamerstrand 1985).

Bulk leaf samples were removed from random living plants in each plot in November 1982 and in February 1986 for mineral analyses. Samples were washed, dried, and ground with a Wiley mill. Ca, Mg, K, and Na were determined by atomic absorption spectrophotometry and P by molybdo-vanadate colorimetry on nitric-perchloric acid digests of leaf powder (Kitson and Mellon 1944). Cl was determined by coulometric-amperometric titration of nitric-acetic acid extracts of the leaf powder (Cotlove 1963).

Results

Soil Salinity

The mean salinity levels ($\overline{EC_e}$) in the rootzone (0–90 cm deep) for each salinity treatment during the experiment are shown in Fig. 1. Soil salinity increased rapidly from the initial level when salination began until about September 1983. The $\overline{EC_e}$ for treatments irrigated with 3 and 6 dS/m waters continued to increase but at a lower rate during the next two years; whereas that for the two lowest and two highest salinity treatments tended to level out. The continued increase in salinity of the 3 and 6 dS/m treatments indicated that insufficient water was applied to accomplish the leaching required to obtain the steady-state salinity profiles that are desired in salt tolerance experiments. Including rainfall, the mean depth of water applied during the years 1982 and 1983 ranged from 1180 mm in the control plots to 990 mm in the most saline plot (Table 1). As soil salinity increased, the amount of water applied was reduced in response to decreased water use. Less water was applied in 1984 because only half of each plot contained full-sized plants; the other half were pollarded plants which consumed less water.

Soil salinity profiles as a function of depth just prior to the three harvests are shown in Fig. 2. Salt concentrations tended to increase with depth to 60 cm in all

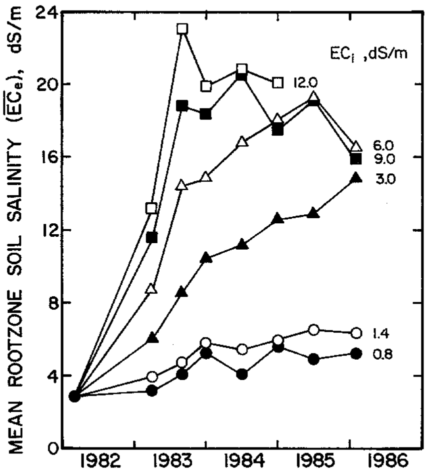

Fig. 1. Soil salinity trends for the six salinity treatments during the course of the experiment. Values are means of three replications and four soil sampling depths from 0 to 90 cm

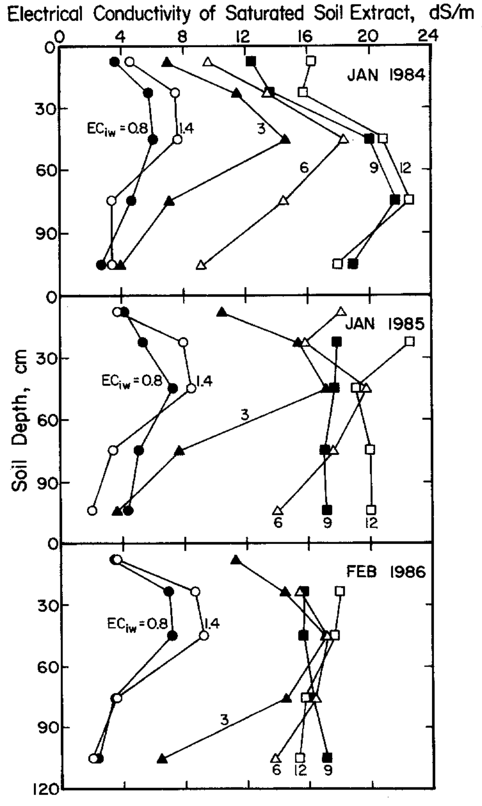

Fig. 2. Soil salinity profiles of the six salinity treatments just prior to the 1984, 1985, and 1986 harvests. Values are means of three replications

treatments and either increased or maintained high concentrations to 90 cm in the two highest salinity treatments. Salt concentrations in the 90 to 120 cm zone generally were similar to those in the upper 15 cm zone. EC_e's in the upper 15 cm zone for the 9 and 12 dS/m treatments are not given for 1985 and 1986 because many or all plants had died and salt accumulated to very high levels on the surface of the soil. From the salt distribution in the soil profiles, it appears that most of the roots were in the upper 60 cm and few, if any, extended below 90 cm. Consequently, it is reasonable to assume that the plants responded primarily to the salt concentrations in the upper 90 cm of the profile.

To obtain yield response curves as a function of soil salinity, yields were plotted against $\overline{\overline{EC}}_e$, i.e. the $\overline{EC}_e$ data in Fig. 1 integrated over time from March 1982 until each respective harvest. The mean $\overline{\overline{EC}}_e$'s for each treatment were 3.4, 4.0, 5.8, 9.7, 11.2, and 12.6 dS/m preceding the 1984 harvest; 4.0, 4.7, 7.8, 12.4, 14.3, and 15.3 dS/m preceding the 1985 harvest; and 4.3, 5.1, 9.4, 14.1, 15.1, and 16.2 dS/m preceding the 1986 harvest, respectively.

Plant Mortality

Plant establishment and survival the first year were excellent. A plant count on April 26, 1983 indicated an average survival rate of over 99%. By the Fall of 1983, however, a significant number of plants irrigated with 12 dS/m water were dying.

The number of live and dead plants per unit area for all treatments for the three harvests is given in Table 2. The initial plant population was 2.86 plants/m^2; therefore, where the sum of live and dead plants are less than 2.86, the difference includes plants that died very young and pollarded plants that produced little regrowth and died. The dead plants listed in Table 2 were generally full-size plants and were included in determining dry matter, rubber, and resin yields. At the first harvest in February 1984, 36% of the plants harvested in the 12 dS/m treatment were dead while 98% or more of the plants in the other treatments were living. Recovery and regrowth of pollarded plants was significantly affected by soil salinity. Four months after pollarding, 97% to 100% of the plants in the three lowest salt treatments survived, but the mean survival rates for treatments irrigated with 6, 9, and 12 dS/m waters were 83%, 43%, and 22%, respectively. Plant mortality of both pollarded and unpollarded plants continued to

Table 2. Number of live and dead plants harvested per unit area in 1984, 1985, and 1986[a]

EC_i (dS/m)	Harvest 1984 (plants/m^2)		Harvest 1985 (plants/m^2)		Harvest 1986 (plants/m^2)	
	Live	Dead	Live	Dead	Live	Dead
0.8	2.86	0	2.64	0	2.33	0.48
1.4	2.86	0	2.59	0	2.59	0
3.0	2.86	0	2.80	0	2.11	0.42
6.0	2.75	0	2.01	0.63	0.37	1.59
9.0	2.75	0.05	0.21	2.43	0.32	0.79
12.0	1.59	0.90	0	2.54	0.05	0.26

[a] The initial population was 2.86 plants/m^2

increase through the summer of 1984 and by harvest in February 1985 most of the plants irrigated with 9 dS/m water and all with 12 dS/m water were dead. At the final harvest in 1986, most of the plants irrigated with 6 dS/m water had also succumbed.

Rubber and Resin Content

Rubber and resin percentages in the woody shoot material were not significantly affected by soil salinity in 1984 or 1985 (Tables 3, 4). In 1984, rubber and resin in the shoot averaged 6.1% and 8.6%, respectively. In 1985, both averaged 7.3% in the shoot, indicating an increase in rubber concentration with age and a decrease in resin concentration. Mean rubber and resin percentages in the root crowns were 5.0% and 6.2%, respectively. Only the resin concentration in the root was significantly affected by salinity. In 1986, concentrations of both rubber and resin (Table 5) decreased with increased soil salinity. The greatest decrease was measured on the 6 and 9 dS/m treated plants which represented the few plants in these treatments that survived the severe salt stress.

Leaf Mineral Composition

Analyses of leaves sampled in November 1982 (8 months after salination began) revealed no nutritional problems as a result of salt stress (Table 6). Nitrogen and P concentrations decreased 20% to 25% with increased salinity while those of K and Mg followed no obvious trends. Of the ions contributing to soil salinity, Ca and Cl increased with increased salinity; whereas Na was effectively excluded from the leaves. At the end of the experiment, leaf analysis indicated Na was accumulating in leaves but only in plants irrigated with 6 and 9 dS/m waters. These same treatments had significantly lower K concentrations. Ca and Cl again increased with increased salinity, while Mg and P were little affected.

Table 3. Dry matter, rubber, and resin yields of defoliated shoots of 31-month-old pollarded guayule plants grown at six salinity levels[a, b]

EC_i (dS/m)	Dry matter (Mg/ha)	Rubber concn (%)	Rubber yield (kg/ha)	Resin concn (%)	Resin yield (kg/ha)
0.8	10.9	5.9	588	8.2	820
1.4	12.5	6.1	692	8.2	927
3.0	11.3	6.4	653	8.3	848
6.0	11.7	6.2	654	9.0	953
9.0	8.9	6.0	482	8.8	711
12.0	5.7	5.8	312	9.2	466
Analysis of variance					
Source	$Pr > F$[c]				
Rep	0.692	0.012	0.542	0.302	0.520
Salinity	0.0006	0.296	0.0005	0.112	0.0001

[a] Yields expressed on an air-dry basis. Shoots include all woody branches 10 cm or more above the soil surface

[b] Rubber and resin concentrations expressed on an oven-dry wt basis

[c] Probability that an F value would occur by chance

Table 4. Dry matter, rubber, and resin yields of 43-month-old guayule plants grown at six salinity levels[a, b]

EC_i	Shoot					Root crown				
(dS/m)	Dry matter (Mg/ha)	Rubber concn (%)	Rubber yield (kg/ha)	Resin concn (%)	Resin yield (kg/ha)	Dry matter (Mg/ha)	Rubber concn (%)	Rubber yield (kg/ha)	Resin concn (%)	Resin yield (kg/ha)
0.8	17.8	7.8	1,257	7.0	1,142	3.31	4.5	136	6.9	205
1.4	20.7	7.3	1,361	7.0	1,307	3.32	4.8	147	7.0	208
3.0	18.5	7.4	1,245	6.9	1,166	3.46	5.3	172	6.2	195
6.0	17.5	6.9	1,035	7.1	1,093	3.22	4.8	158	6.4	180
9.0[c]	9.4	7.7	654	7.4	644	1.68	5.6	92	5.0	79
12.0[c]	6.3	6.7	387	8.4	481	1.30	5.3	63	5.8	68
Analysis of variance										
Source	Pr > F[d]									
Rep	0.019	0.348	0.032	0.392	0.009	0.0060	0.522	0.025	0.689	0.076
Salinity	0.0001	0.352	0.0001	0.196	0.0001	0.0001	0.200	0.0001	0.0008	0.0001

[a] Yields expressed on an air-dry basis; shoots include all woody branches above the soil surface, the root crown included the woody root from the soil surface to a depth of 15 cm

[b] Rubber and resin concentrations expressed on an oven-dry wt basis

[c] Data for the 9 and 12 dS/m treatments were obtained from dead plants

[d] Probability that F value would occur by chance

Table 5. Dry matter, rubber, and resin yields of 55-month-old guayule plants grown at six salinity levels and pollarded at 31 months[a, b]

EC_i	Shoot					Root crown				
(dS/m)	Dry matter (Mg/ha)	Rubber[c] concn (%)	Rubber yield (kg/ha)	Resin[d] concn (%)	Resin yield (kg/ha)	Dry matter (Mg/ha)	Rubber[c] concn (%)	Rubber yield (kg/ha)	Resin[d] concn (%)	Resin yield (kg/ha)
0.8	6.20	7.5	459	6.1	375	2.29	4.8	105	5.3	118
1.4	8.98	7.4	667	5.7	513	3.35	4.3	145	5.2	175
3.0	6.35	7.1	438	5.4	349	2.72	4.1	105	4.9	130
6.0	2.78	5.5	125	5.2	159	1.02	2.8	13	4.6	40
9.0	1.35	5.7	67	5.8	82	0.62	3.2	11	5.0	27
12.0	0.38		17		23	0.19		4		10
Analyis of variance										
Source	Pr > F[e]									
Rep	0.274	0.0001	0.290	0.0004	0.098	0.176	0.211	0.304	0.172	0.117
Salinity	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.004	0.0001

[a] Yields expressed on an air-dry basis; shoots include all woody branches above the soil surface, the root crown includes the woody root from the soil surface to a depth of 15 cm

[b] Rubber and resin concentrations expressed on an oven-dry wt basis

[c] Data for live plants. Mean rubber concentrations of shoots and roots harvested from dead plants were 4.0% and 0.74%, respectively

[d] Data for live plants. Mean resin concentrations of shoots and roots harvested from dead plants were 6.1% and 4.0%, respectively

[e] Probability that an F value would occur by chance

Table 6. Mineral composition of leaves sampled in November 1982 and February 1986

EC_i	Ion concentrations						
	N (g/kg)	P (g/kg)	K (mmol/kg)[b]	Ca (mmol/kg)[b]	Mg (mmol/kg)[b]	Na (mmol/kg)[b]	Cl (mmol/kg)[b]
1982							
0.8	32.2	44.0	1,169	972	294	11	583
1.4	29.6	36.5	1,017	1,027	267	9	592
3	29.4	38.0	1,149	1,033	251	5	703
6	28.7	38.3	1,221	1,014	249	8	824
9	28.7	33.0	1,213	1,178	262	5	935
12	25.5	34.1	1,043	1,259	282	12	983
1986							
0.8	–[a]	49.1	1,021	765	268	1	469
1.4	–	48.6	975	802	283	2	553
3	–	47.0	1,011	800	261	27	711
6	–	45.2	655	1,142	284	104	865
9	–	47.2	529	1,163	305	199	902

[a] Not determined
[b] dry wt

Plant Growth and Yield

Plant heights measured approximately one year after treatments were imposed (22 months old), decreased linearly from about 54 cm in plots irrigated with 0.8 and 1.4 dS/m water to 45 cm in plots irrigated with 12 dS/m water. The yield of dry matter, rubber, and resin of air-dried, defoliated shoots of plants pollarded in February 1984 (Table 3) was not affected by salinity until the irrigation water salinity exceeded 6 dS/m ($\overline{EC}_e = 9.7$ dS/m). Above an EC_i of 6 dS/m, dry matter, rubber and resin production were all significantly decreased. Dry matter, rubber, and resin yields of 43-month-old plants harvested in February 1985 (Table 4) were considerably higher than those obtained from 31-month-old plants, indicating significant growth during the third growing season. The response to salinity, however, was similar (Table 4). Irrigation water salinity above 6 dS/m significantly decreased the dry weights of both shoots and root crowns, as well as the yields of rubber and resin, primarily because of the high mortality at these salinities. Although 40% of the plants irrigated with 6 dS/m water had also died, yields per unit area which included dead plants, were not yet affected. By 1986, the yield of 55-month-old plants (Table 5) was significantly reduced in the 6 dS/m treatments, a result that reflected the effect of the increased soil salinity. Because salinity also reduced rubber and resin concentrations, their yields were decreased even more than dry matter production. Regrowth of the pollarded plants produced less dry matter than the shoots harvested at 31 months at all salinity levels. Interestingly, dry matter, rubber, and resin yields of plants irrigated with 1.4 dS/m Colorado River water were greater at every harvest than those irrigated with 0.8 dS/m well water. It should be noted, however, that the 0.8 dS/m treatment was

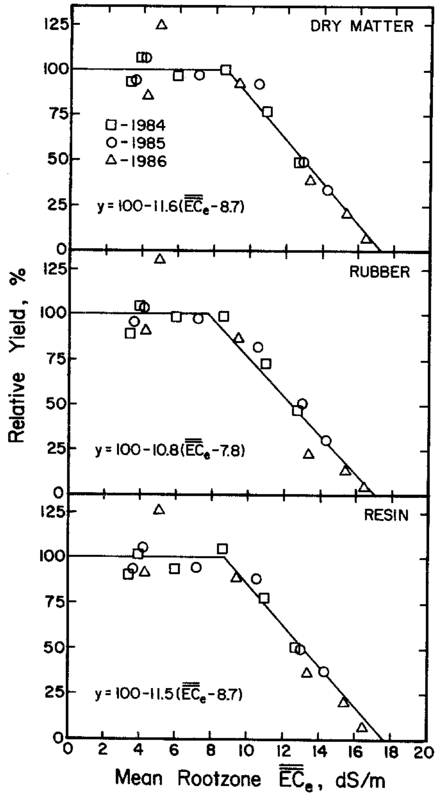

Fig. 3. Relative dry matter, rubber, and resin yield of guayule shoots (1984) and shoots and root crowns (1985, 1986) as a function of increasing soil salinity

irrigated with 1.4 dS/m water the last year. Mean separation by Duncan's multiple range test indicated that this increase was significant ($\alpha = 0.05$) in 1986 but only for shoot dry weights in 1985. The difference between the two waters was not statistically significant in 1984.

Yield response functions for dry matter, rubber and resin (Fig. 3) were obtained by analyzing the data with the nonlinear least-squares inversion method of van Genuchten and Hoffman (1984). The normalized data were analyzed with NOPT 5 which fits the data from all three harvests to a single curve even though the absolute yields varied from year to year. The threshold $\overline{\overline{EC}}_e$ values for these three yield components were 8.7, 7.8, and 8.7 dS/m, respectively. At soil salinities above the threshold, dry matter, rubber, and resin yields decreased 11.6%, 10.8%, and 11.5% per dS/m, respectively.

Discussion

The results of this study show that after plants become established, guayule is a highly salt tolerant crop. Dry matter yields were not significantly affected by salinity until the $\overline{\overline{EC}}_e$ exceeded 8.7 dS/m for all three harvests; i.e. 1) pollarding after nearly two years of salt treatment, 2) harvesting shoots and root crowns after three years salt treatment, and 3) harvesting shoots and root crowns after four years (two years after pollarding).

This threshold is significantly lower than that reported previously (Maas et al. 1986) where yield was correlated with mean EC_e's integrated for only one year preceding the harvest. In this paper, yields are plotted as a function of $\overline{\overline{EC}}_e$, i.e. the mean rootzone EC_e integrated from the time salination began until harvest. Nevertheless, these results place guayule among the more salt tolerant crops (Maas 1986), although it is much more susceptible than other commercial crops to high plant mortality at salinities above the threshold. Above 8.7 dS/m, dry matter yield decreased at the rate of 11.6% for each 1.0 dS/m increase in $\overline{\overline{EC}}_e$. This rate is somewhat greater than that found in the adjoining plant population study (Hoffman et al 1988). One explanation for this difference is that this study included higher salinity treatments and substantially more data on low yields that help to establish the slope of the yield response curve.

Although our data are based on one cultivar, an adjacent study comparing the growth and rubber production among 30 USDA cultivars and experimental lines indicated that the salt tolerance of N565-II was representative of that of the other cultivars (M. C. Shannon, pers. comm.).

Since soil salinity up to 8.0 dS/m had no appreciable effect on rubber and resin concentrations of the plant material, the salt tolerance parameters for rubber and resin yields were similar to those for dry matter yield. This finding does not rule out the possibility that salinity increases rubber concentration in one- and two-year-old plants as found by Wadleigh et al. (1946) and Miyamoto et al. (1984a). Though not statistically significant, our results and those of Hoffman et al. (1988) also indicated that rubber concentration in 31-month-old shoots tended to increase with moderate increases in soil salinity.

The most significant effect of salinity seemed to be on plant mortality. After two years salination, over one-third of the plants irrigated with 12 dS/m water had died; one year later nearly all plants irrigated with 9 dS/m water had died and 40% of those irrigated with 6 dS/m water. These results indicate that survival rather than growth reduction at high levels of salinity will be the limiting factor for rubber production. It is also important to recognize that the plants in this study were well established before saline irrigations were imposed. While this was done deliberately to ensure a good stand for salt tolerance testing to maturity, it is known that plant stands could be severely reduced if plant establishment is attempted under saline conditions. Miyamoto et al. (1984a) found that the average mortality of several cultivars transplanted in the spring and summer was 21% and 81%, respectively in loamy sand soils with a mean EC_e of 4.8 dS/m. This reduction in plant stand could further reduce yields of salt-stunted plants. Miyamoto et al. (1984a) reported that shoot dry weights of two-year-old plants irrigated with 4.6 and 7.2 dS/m waters beginning at transplanting were reduced 15% and 51%, respectively, based on a full stand. Their results indicate that plants stressed at transplanting would yield less than that predicted from the salt tolerance parameters obtained in this study.

Salinity is also a problem in direct seeding. Although guayule, like many other crops, is very tolerant at germination [Miyamoto et al. (1985) reported that guayule germinated well up to 23 dS/m], the seedlings are especially sensitive to salts that accumulate at the soil surface. Miyamoto et al. (1984b) reported that emergence of several cultivars planted in May ranged from 19% to 47% when irrigated with 0.8 dS/m water but decreased to 2% to 8% when 4.5 dS/m water was used.

The small but significant increase in yield when plants were irrigated with the 1.4 dS/m Colorado river water as compared to 0.8 dS/m well water indicated that low levels of salinity may be beneficial for guayule production. This did not appear to be related to nutritional factors because plants in both treatments had similar nutrient concentrations in the leaves.

Results of the Emergency Rubber Project indicated that guayule grows best on well-drained, sandy loam soils (National Academy of Science 1977). However, comparing the yields of this study with those at other locations indicates that guayule can be grown successfully on a heavier silty clay soil. Shoot yields of N565-II plants irrigated with Colorado water (Table 3) were comparable to the average dry matter and rubber yields of seven cultivars grown in loamy sand in El Paso, Texas, (Miyamoto et al. 1984 a) and to those of three cultivars grown on Superstition sand in Yuma, Arizona, with optimum water and nitrogen (Bucks et al. 1985, treatment T5). Dry matter yields at the three locations were 12.5, 10.1, and 11.9 Mg/ha, respectively. Rubber yield was highest in Yuma because of higher rubber contents in the shoot. Dry matter yield of 43-month-old plants (shoot plus root) was 24 Mg/ha which compared favorably with the 25 Mg/ha yields of three cultivars grown at Mesa, Arizona (D. A. Bucks, pers. comm.).

A comparison of the combined yields of pollarding at $2\frac{1}{2}$ years and whole plant harvesting at $4\frac{1}{2}$ years versus a single, whole plant harvest at $3\frac{1}{2}$ years indicated that the latter was more productive on a yield/ha/year basis. The mean yield of the 0.8, 1.4, and 3 dS/m treatments was about 30% higher for the single whole plant harvest at $3\frac{1}{2}$ years than it was for the combined harvests of pollarded plants and whole plants at $2\frac{1}{2}$ and $4\frac{1}{2}$ years. Furthermore a single whole plant harvest eliminates the cost of pollarding and the handling of two rather than one batch of plant material. The same but variable benefit was also observed in the three saline treatments that produced lower yields.

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