Genotypic and environmental effects on guayule 
(*Parthenium argentatum*) latex and growth

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Abstract

Guayule (*Parthenium argentatum* Gray) is the best potential source of hypoallergenic latex to replace latex products from the Hevea (*Hevea brasiliensis*) plant that cause Type I allergies. However, information is not available on environmental effects on latex content and growth of newly released germplasm lines. This knowledge is needed to enhance guayule breeding efforts. The objectives of this study were to evaluate the genotype, environment, and genotype \times environment effects on latex content and plant growth of guayule. Four lines were planted in the field at Maricopa, Arizona, USA on 6 April 1995 and 6 March 1996 and at Marana, Arizona, USA on 11 April 1995 and 12 June 1996. Plant height and width measurements were made in the spring of 1997 and latex content and biomass determined in the spring of 1997 and 1998. The main factors that included location, line, and plant age were significant and the interactions not significant for all traits measured. Environment accounted for over 50% of the variability observed in all traits, followed by plant age (16%) and line (10%). These results point to the tremendous impact that environment has on guayule plant growth, biomass, and latex content. We could not determine from these tests whether temperature, soil type, moisture, fertility, or a combination of these or other environmental factors were responsible for this response. Some of the non-significant interactions may have been significant if a larger or wider germplasm base could have been evaluated. Additional studies are needed to determine the environmental factor(s) responsible for the large environmental response we observed.

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1. Introduction

Hevea (*Hevea brasiliensis*) latex allergies in the United States have become a serious health problem in certain population groups, especially health care workers and patients who undergo multiple surgeries (Ownby et al., 1994). Guayule (*Parthenium argentatum* -
Gray) has been demonstrated to be a source of hypoallergenic latex to replace Hevea latex (Siler and Cornish, 1994). Guayule latex has been shown to prevent virus and other pathogen transmission, making it suitable for use in medical products, gloves, and condoms (Cornish et al., 1996). In addition, guayule can be grown in the United States to provide a domestic source of natural latex (Thompson and Ray, 1988). Currently, the United States imports more than one million metric tons of natural rubber at a cost of about one billion US dollars (Mooibroek and Cornish, 2000).

Several improved guayule germplasm lines have been released for use in breeding programs and cultivar development (Estilai, 1986; Ray et al., 1999). However, previous breeding programs have focused on screening germplasm and developing improved lines with higher rubber and/or resin contents with a goal of harvesting in 3–5 years after planting. For guayule to be used in the hypoallergenic latex market, lines with high latex contents that can be harvested in less than 3 years are needed. Thus, high yielding, fast growing, and easily establishable germplasm lines are needed for guayule to succeed commercially as a new crop. Recent research results have also indicated that maximum benefits for genetic improvement can be obtained when the selection for desired traits in a breeding program is done when plants are 1–2 years old instead of 3–5 years old (Dierig et al., 2001). The recent germplasm releases (Ray et al., 1999) have not been fully evaluated for latex content or for the effects of environment on latex content and plant growth. This knowledge is needed to enhance the guayule breeding efforts. The objectives of this study were to evaluate the genotype, environment, and genotype × environment effects on latex content and plant growth of guayule.

2. Materials and methods

2.1. Plot design and germplasm

Three recently released germplasm lines AZ-1, AZ-2, and AZ-3 and a closely related advanced breeding line G7-14 were transplanted in a field at Maricopa, Arizona, USA (33.07°N, 111.98°W) on 6 April 1995 and 6 March 1996, and at Marana, Arizona, USA (32.25°N, 111.13°W) on 11 April 1995 and 12 June 1996. The four lines were developed from plant selections in the USDA-ARS/University of Arizona guayule breeding program (Ray et al., 1999). The Maricopa field site is about 350 m and the Marana field site about 600 m above sea level. The soil was a variable Mohall sandy loam (fine-loamy, mixed hyperthermic, Typic Hapludalf) at Maricopa and a Pima clay loam (fine-silty, mixed, thermic, Typic Hapludult) at Marana. Mean maximum temperatures are 30.4 °C at Maricopa and 29.5 °C at Marana. Mean minimum temperatures are 11.5 °C at Maricopa and 11.6 °C at Marana. Mean annual rainfall is 190 mm at Maricopa and 248 mm at Marana. The years of this study were similar to these long-term means for precipitation and temperatures. Plots consisted of two rows, each 6 m long and spaced 1 m apart. Transplants were spaced 0.36 m apart within the row. A completely randomized design with four replications was used at each location. Plants of the same age surrounded each plot to reduce border effects from plants of different ages. Plots were irrigated immediately after transplanting and the soil kept moist with frequent irrigations until the plants were established. Plants were maintained each year during the active growing season with irrigations every 2 weeks from May to September, and irrigations once a month February to April, and October to November.

2.2. Measurements and evaluations

Plant height and width were determined in 1997. Plant height was measured from the ground surface to the tallest point of the plant, excluding floral structures. Plant width was determined by averaging the measurements of two plant diameters for each plant, one perpendicular to the row and one parallel with the row center. Ten plants in each plot were measured for height and width and the means for each replicate were used for statistical analyses.

Two representative plants from each plot were selected in 1997 and 1998 for determining latex content per plant and plant biomass. Plots were harvested by replicate over a 4-week period to insure that samples could be processed in the laboratory immediately following harvest to prevent latex degradation differences among the samples. All lines within a replicate at a location were harvested at the same time and harvests were alternated between locations to minimize the interaction between the time of harvest and location. Plants
were clipped at the soil surface, chipped into a solution containing the antioxidant sodium sulfite (0.1%), and latex content determined by the method described by Cornish et al. (1999). Plant weights were taken before chipping to obtain fresh plant biomass. Latex content and biomass are reported on a dry weight basis. Samples for determining moisture were taken at harvest following chipping and oven-dried to obtain plant moisture content.

Data were analyzed using the Proc GLM procedure in SAS statistical package version 8 (SAS Institute, 1987). Locations were considered fixed effects, whereas lines and plant ages were considered random effects. Significance of main factors (location, age, line) and the two and three way interactions among these main factors was determined by analyses of variance and LSD at the $P = 0.05$ level.

3. Results and discussion

Differences between the two environments were significant and accounted for over 50% of the variability for all traits studied (Tables 1–3). Plants at the Marana location were over 54% taller and almost 93% wider than those at Maricopa after 1 and 2 years of growth (Table 1). Differences between the two environments for latex content (Table 2) and plant biomass (Table 3) were even greater than those for plant height and width (Table 1). Strong within-field environmental factors were noted earlier by Dierig et al. (2001), but this is the first report of environmental effects between locations on latex. This relationship was expected, because previous reports have also shown environmental effects on the agronomic and rubber traits in guayule (Thompson and Ray, 1988). We could not determine from these tests whether temperature, soil type, moisture, fertility, or a combination of these or other environmental factors were responsible for this response. Because, these environmental factors were similar at both locations (Section 2.1), additional studies are needed to determine the environmental factor(s) responsible for the large environmental response observed in this study.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Identity</th>
<th>Height 1997 (mm)</th>
<th>Width 1997 (mm)</th>
<th>Height 1998 (mm)</th>
<th>Width 1998 (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment</td>
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<td>394 b</td>
<td>339 b</td>
<td>0.60 b</td>
<td>0.85 b</td>
</tr>
<tr>
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<td>420 c</td>
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<td>1.59 a</td>
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<td>AZ-2</td>
<td>505 b</td>
<td>524 ab</td>
<td>1.13 b</td>
<td>1.27 ab</td>
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</tr>
<tr>
<td>AZ-3</td>
<td>527 ab</td>
<td>491 b</td>
<td>1.07 b</td>
<td>1.28 ab</td>
<td></td>
</tr>
<tr>
<td>G7-14</td>
<td>553 a</td>
<td>553 a</td>
<td>0.94 b</td>
<td>1.13 b</td>
<td></td>
</tr>
<tr>
<td>Age</td>
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<td>428 b</td>
<td>422 b</td>
<td>0.93 b</td>
<td>1.06 b</td>
</tr>
<tr>
<td>2 Years</td>
<td>574 a</td>
<td>574 a</td>
<td>1.46 a</td>
<td>1.57 a</td>
<td></td>
</tr>
</tbody>
</table>

* Means followed by the same letter within a column and main effect are not significantly different according to LSD at the $P = 0.05$ level.
Smaller effects were due to differences among the four lines studied (Tables 1–3). Generally, the AZ-1 plants were smaller in size, but with greater latex content than the other lines, especially in 1997, when the plants were younger. The results for younger plants (1997) are similar to previous results (Ray et al., 1999) reporting AZ-1 higher in rubber content than AZ-2 and AZ-3, and AZ-2 and AZ-3 higher in plant biomass than AZ-1. However, these differences were not evident in the older plants (1998).

Significant differences in 1997 were noted between the 1- and 2-year-old plants for plant height, width, latex content, and plant biomass (Tables 1–3). Older plants were larger and had higher latex content than the younger plants. Similar differences were found between 2- and 3-year-old plants in 1998 for latex content (Table 2), but not for plant biomass (Table 3). This indicates that plants of the lines used in this study may reach maximum size in 2 years, but they continue to accumulate additional latex. More studies are needed to determine whether this additional gain in latex is worth the additional inputs necessary for the extra year of growth. Studies are also needed to determine the plant age when the latex accumulation reaches a maximum and begins to decline or remain constant. While this would be the optimum harvest time biologically, it may not be the optimum time economically.

It is also interesting to note that significant differences existed between 2-year-old plants in 1997 and 2-year-old plants in 1998, for their latex content and plant biomass (data not shown). This shows a strong environmental difference between 1997 and 1998. Two-year-old plants in 1997 had a greater latex content, but less biomass than those in 1998. These results expand those of Dierig et al. (2001) who found strong within field variability to show that there may be even more variability among fields and years that could further complicate effective breeding selection.

The only interaction of significance was the location x age interaction for latex content in 1997 ($P = 0.01$). This was because the differences between the 1- and 2-year-old plants were significant at Marana, but not at Maricopa. This interaction was not significant in 1998 ($P = 0.86$) when the plants were 1 year older. The generally non-significant interactions may have been significant if a larger or wider germplasm base could have been evaluated. The lines used in this study were from a relatively narrow genetic base. If lines from a wider genetic base were used, they would increase the chances of finding significant genotype by environment interactions. However, limitations on the number of samples that could be analyzed for latex content prevented more lines from being evaluated in this study. The generally non-significant interactions are important both from a breeding and agronomic standpoint because results from one location or set of lines or plant age should be expected to be representative of their relative performance under other conditions.

Results from this study, provide the first latex data on three of the newly released germplasm lines. Latex content for these lines was similar in relative amounts to that reported for total rubber content of the same lines in an earlier study (Ray et al., 1999). This suggests that possibly past studies on rubber content may be valid for latex content also. However, more studies that compare both latex and rubber content in the same experiment are needed to verify this theory. Growth rates of the lines are also similar to those reported previously, with AZ-1 slower growing and smaller than AZ-2 and AZ-3 as well as the advanced breeding line G7-14. The lines in this study should provide a good beginning for developing guayule cultivars for use by industry in the development of a cost-effective hypoallergenic latex. The large environmental effects show that testing over multiple environments may be necessary to identify those areas where maximum production will occur.

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References


