Irrigation strategies for guayule grown in the U.S. desert

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A perennial shrub

Guayule (*Parthenium argentatum,* A. Gray) is a perennial shrub, native to the desert of northcentral Mexico and southwestern Texas, which produces high quality natural rubber that is suitable for use in passenger and commercial-grade tires (Eranki et al., 2018). The plant produces latex that is hypoallergenic, particularly desirable in the medical device market (Rasutis et al., 2015), and resin that can be used in a variety of industrial products such as adhesives and coatings (Nakayama et al., 2001; Thames and Kaleem 1991). The primary parts of the guayule plant of economic interest are in the parenchyma tissues of the stems and roots where the majority of the rubber particles accumulate (Kajiura et al., 2018). However, stems and roots only constitute about 6 and 9% of the total plant dry weight, respectively (Kuruvadi et al., 1997).

Planting (direct seeded)

Seeds are planted in 40”-rows using a planter pulled behind a power train tractor. Seeding should be in dry raised beds, 0.25-m wide and 0.15-0.20 m high. Of the six registered AZ cultivars, the AZ2 and AZ6 were shown to have the highest RY after two years of growth in the trial plots (Ray et al., 1999). The AZ2 line is an interspecific hybrid with good seedling vigor and high biomass production (Ilut et al., 2017). AZ6 has less biomass than AZ2 but it can produce higher rubber content than AZ2 (Ray et al., 1999).

Germination

Flood, solid-set sprinkler, and gravity drip irrigation methods have been used for germination. Soil surface should be kept wet for about 5-10 days after planting for seedling germination, as recommended by Dissanayake et al. (2008). After germination, guayule seedlings should be kept well-watered by irrigating several times during the next seven weeks using level furrow irrigation (Martin and Gilley, 1993), a common surface irrigation method used in the area. Irrigation treatments were initiated in mid-July 2020 using the level furrow irrigation method.

Nitrogen and water use and tolerance to drought

Guayule is a drought tolerant crop and can survive extreme dehydration in the desert where it remains in a semi-dormant state until irrigation is resumed. Its ability to survive long periods of drought comes from the capability of its roots to extract moisture from the lower depths of the soil profile (Bucks et al., 1985a). Previous research indicated that even though guayule can withstand long periods of drought, well-watered guayule grown from transplants can have cumulative crop evapotranspiration (ET_c) of over 1500 mm during its first year of growth, and over 2000 mm during its second year (Bucks et al., 1985a, 1985b; Hunsaker and Elshikha, 2017; Hunsaker et al., 2019). In these studies, TWA levels that either matched or exceeded ET_c requirements, combined with moderate nitrogen applications (65 to 100 kg N/ha per year), gave the highest biomass production.

Guayule growers in the U.S. Southwest will likely not have an irrigation delivery close to that needed to meet 100% of ET_c (1300 to 1500 mm per year). For guayule grown on lighter soils, some literature indicates an irrigation deficit of 20-25% for full ET_c would not reduce RY

significantly (Bucks et al., 1985a and b; Hunsaker and Elshikha, 2017; Elshikha et al., 2021). However, on heavier soils there appears to be a greater opportunity to reduce irrigation water use, even much more than 25%. A field study on a heavier soil type in central Arizona, Elshikha et al., 2022, indicated that exposing direct-seeded guayule to a pre-determined soil water deficit periods over a 22.5 month-long growing season did not reduce the yield significantly from fully irrigated guayule.

The amount of water required for germination of direct seeded guayule may range from 6-15 inches, depending on weather and the irrigation method (lower rates under drip and sprinkler and higher rates under flood irrigation). An example of the irrigation amounts, and number of events are given in Table 1. The table indicates small difference in water use (6.3”-6.8”) during germination when sprinkler and gravity drip are used with similar plant stand at the end of germination period. However, germination under flood required more than double (15”) the water use under drip and sprinkler. After germination flood irrigation can be used at a rate of 4”-5.8” per event. There are two irrigation events per season, during spring, summer and fall of the first year of growth. In the second fall, one of the two irrigations can be skipped. No water is applied during winter due to plant dormancy.

The annual water requirement under flood irrigation is approximately 2.4 ft/year with the irrigation schedule in Table 1, which is within the probable annual water allocation depth for many Central Arizona farmers. Table 1 represents the I_4 treatment in our recent deficit irrigation study (https://doi.org/10.1016/j.agwat.2022.108093). In this treatment, irrigation took place approximately every six weeks in summer, which was half of the normal rate that was previously recommended in the clay soil. Little decrease in rubber production was observed in this treatment. This implies that cycles of wetting and drying are advantageous for rubber production.

Table 1. Irrigation (water use, inches) for guayule grown in Arizona (two-year growing season)

Years of growth		Flood	Drip	Sprinkler	No. of events			Month
		(F)	(D)	(S)	F	D	S	
	Germination	15	6.3	6.8	3	8	8	
		F	D		F	D		
1st year	Spring	5.1	0.51		2	20		May
	Summer	4	0.40		2	40		June-Aug.
	Fall	5.5	0.55		2	40		Oct.-Nov.
	Winter							
2nd year	Spring	5.8	0.58		2	40		Mar.-May
	Summer	5.1	0.51		2	40		June-Aug.
	Fall	5.4	0.54		1	10		Oct
	Winter							
	Total (in.)	71.3	62.6					

Our deficit irrigation study showed that guayule survived with no detrimental effect other than decreased growth during the hottest and driest summer on record with no irrigation between June and September. Under water shortage conditions and the uncertainty of water supply in some areas, growers may be forced to cut irrigations for several months. Our research shows that the guayule will be fine and will start to grow again when water is applied.

References

Bucks, D.B., Nakayama, F.S., French, O.F., Legard, W.W., Alexander, W.L., 1985a. Irrigated guayule-evapotranspiration and plant water stress. Agric. Water Manag. 10, 61-79.

Bucks, D.B., Nakayama, F.S., French, O.F., Rasnick, B.A., Alexander, W. L., 1985b. Irrigated guayule-plant growth and production. Agric. Water Manag. 10, 81-93.

Dissanayake, P., George, D.L., Gupta, M.L., 2008. Direct seeding as an alternative to transplanting for guayule in southeast Queensland. Industrial Crops and Products 27, 393-399.

Elshikha, D. M., G. Wang, P. M. Waller, D. J., Hunsaker, D. Dierig, K. R. Thorp, A. L. Thompson, M. E. Katterman, M. T. Herritt, E. Bautista, D. T. Ray, G. W. Wall, 2022.

Guayule growth and yield responses to deficit irrigation strategies in the U. S. desert. Agric. Water Manag. 277, 108093.

Eranki, P.L., El-Shikha, D., Hunsaker, J., Bronson, K.F., Landis, A.E., 2018. A comparative life cycle assessment of flood and drip irrigation for guayule rubber production using experimental field data. Ind. Crops Prod. 99, 97–108.

Hunsaker, D.J., Elshikha, D.M., 2017. Surface irrigation management for guayule rubber production in the US desert Southwest. Agric Water Manag. 185, 43-57.

Hunsaker, D.J., Elshikha, D.M., Bronson, K.F., 2019. High guayule rubber production with subsurface drip irrigation in the US desert Southwest. Agric Water Manag. 220, 1-12.

Ilut, D.C., Sanchez, P.L., Coffelt, T.A., Dyer, J.M., Jenks, M.A., Gore, M.A., 2017. A century of guayule: Comprehensive genetic characterization of the US national guayule (Parthenium argentatum A. Gray) germplasm collection. Ind. Crops Prod. 109, 300–309.

Kajiura, H., Suzuki, N., Mouri, H., Watanabe, N. & Nakazawa, Y., 2018. Elucidation of rubber biosynthesis and accumulation in the rubber producing shrub, guayule (Parthenium argentatum Gray). Planta 247, 513-526.

Kuruvadi, S., Jasso Cantu, D., Angulo-Sanchez, J.L., 1997. Rubber content in different plant parts and tissues of Mexican guayule shrubs. Ind. Crops Prod. 7, 19-25.

Martin, D.L., Gilley, J.R., 1993. Irrigation Water Requirements. Part 623, Nat. Eng. Handbook. USDA-SCS, Washington, D.C, Chapter 2.

Nakayama, F.S., Vinyard, S.H., Chow, P., Bajwa, D.S., Youngquist, J.A., Muehl, J.H., Krzysik, A.M., 2001. Guayule as a wood preservative. Ind. Crops. Prod. 14, 105-111.

Rasutis, D., Soratana, K., McMahan, K., Landis, A.E., 2015. A sustainability review of domestic rubber from the guayule plant. Ind. Crops Prod. 70, 383–394.

Ray, D.T., Dierig, D.A., A.E. Thompson, and Coffelt, T.A., 1999. Registration of six guayule germplasm with high yield ability. Crop Sci 39, 300.

Thames, S.F., Kaleem, K., 1991. Guayule resin in amine-epoxy strippable coatings. Bioresource Technology 35, 185-190.