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Effect of plant density on yield, rubber and resin accumulation in guayule in central-western New South Wales

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Abstract

The potential of guayule to produce natural rubber and resin was assessed in a trial conducted at Hillston, New South Wales between 1983 and 1987. Three cultivars of Guayule (11591, N565 and 11619) were evaluated under dryland conditions and with limited irrigation on a sandy soil site. Plants were grown at densities of 9.2, 18.6, 36.7 and 52.6 thousand plants/ha under dryland conditions and with all but the lowest density under irrigation for the two cultivars (11591 and N565). Plant establishment and survival of guayule was excellent for all treatments. However, plant production was universally poor (<8.4 t total DM/ha) compared with irrigated production from U.S. research. Production is largely driven by the availability of water and in the Hillston environment, guayule, due to its low water-use efficiency, is never likely to be highly productive. The effect of plant density on rubber and resin content of guayule as well as total production from original and ratooned plants was also monitored. Rubber yields of 254 kg/ha were obtained from the tops (defoliated branches) of the highest density dryland plots after 3.8 years growth with a further 250 kg/ha coming from the roots and stump. Three years ratooned growth of tops only produced 90 kg/ha of rubber. The irrigated plots with a slightly higher water regime produced 600 kg/ha from the branches after 3.6 years. Resin production was slightly lower than rubber production for all treatments.

Keywords: Guayule; Rubber production; Resin production; Ratoon crop; Plant density

1. Introduction

Guayule (*Parthenium argentatum* Gray) a compact, branchy perennial shrub, native to the arid north-central regions of Mexico and south-western Texas U.S.A., produces high-quality rubber in its bark. It also produces slightly greater amounts of resin than rubber (Gilliland and van Staden, 1986; Gathman et al., 1992). Specialised techniques are required to extract the rubber which is stored in individual cells (Nurthen et al., 1986), but the quality of the rubber is almost identical with that of the rubber tree (*Hevea brasiliensis*) (Bonner, 1991). The resin has some commercial application, but is less valuable (Wright et al., 1991).

Several studies assessing the potential of producing natural rubber under dryland conditions in Australia have predicted encouraging results (Siddiqui and Locktov, 1981; Alcorn et al., 1982; Stewart, 1986), but they depended on extrapolations

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from limited overseas data rather than from local production data. The only recent local production data have come from small plots of guayule grown over a wide environmental range of N.S.W. (Milthorpe, 1983, 1986). Practically all overseas research has been conducted where irrigation is either required, because of low rainfall, or is an integral part of crop management. Guayule has nominally been planted at densities of about 25,000 plants/ha, but for some irrigation research higher planting densities (54,000 plants/ha) have been used (Bucks et al., 1985a; Miyamoto and Bucks, 1985). American research data suggests that the water-use efficiency of guayule is low (5–8 kg DM/mm ha), irrespective of water supply, compared to other crops (Miyamoto et al., 1984; Bucks et al., 1985b).

To obtain more detailed data on the potential productivity of guayule, especially under dryland conditions, cooperative studies, conducted by NSW Agriculture and CSIRO, were established at Hillston, N.S.W., and Kingaroy, Qld. These sites were selected because they represented different extremes in the probable environmental range for commercial dryland production of guayule, as assessed by earlier production studies (Siddiqui and Locktov, 1981). A wide range of planting densities were incorporated into the design of the trials to assess optimum plant density. Consideration of previous research data as well as the limitation caused by the need to use seedling transplants for stand establishment under dryland conditions was given when setting planting densities. This paper reports on the Hillston trials, which were established to gather production data from the dry end of the environmental range of guayule. The results of the Kingaroy trial is reported elsewhere (Ferraris, 1993).

2. Materials and methods

Two trials, (dryland and irrigated), were established near Hillston (33°12′S, 145°54′E, alt. 145 m) on a loamy sand soil. The long term annual average rainfall is 351 mm (60 years). Rainfall has no seasonal pattern, but monthly means for February, April and September are slightly lower than the other months. The site had a northerly aspect with a 1% slope. Some soil characteristics of the site are listed in Table 1. The land was cultivated and fertilised (12.N : 23.P : 0.K fertiliser, 100 kg/ha) in July 1983 and hilled for planting in early September 1983.

Table 1
Soil characteristics of the guayule trial site, Hillston, N.S.W.

Depth (cm)	pH	Bulk density	Particle size analysis (%)				$CaCO_3$ nodules (%)
			clay	silt	coarse sand	fine sand	
0–25	5.8	1.5–1.7	17.0	5.3	50.4	27.3	0.0
25–50	6.9	1.4–1.5	21.3	4.8	50.6	23.3	1.0
55–100	7.6	1.3–1.5	29.9	5.9	42.5	21.7	3.3
100–140	7.6	1.3–1.5	36.0	5.5	38.5	20.0	5.5

2.1. Dryland trial

The split-block design of this experiment allowed machine planting of the seedlings. The blocks of 3 cultivars were randomised for each of the 4 replicates as were the 4 density plantings (plots) within each block. The 3 cultivars used, 11591, N565, and 11619, were selected as representative of 7 lines recommended by U.S. authorities.

The size of each plot varied in length depending on planting density, but was either 22.5, 45 or 90 m long. Each plot consisted of 4 rows of plants, spaced 0.83 m apart, of which only the centre 2 rows were harvested. Outside plots had an extra guard row of plants planted at the same densities as the adjacent treatments while end plots were extended by at least 2 m to ensure adequate buffering. The plots had sufficient plants to allow for 15 four-plants harvests. A total of 10 harvests were made, between May 1984 and May 1987. They were made 3 times yearly: at the onset of each winter dormancy (harvests 1,4, 7 and 10); at the onset of each spring (harvests 2, 5 and 8) and at the end of each spring flush (harvests 3, 6 and 9).

Pre-emergent herbicide was applied after hilling and immediately prior to planting using 2 + 2 kg [a.i.]/ha of oxyfluorfen (Goal) and oryzalin (Surflan) in mid-September 1983. Seedlings were planted into hilled rows 0.83 m apart, and running directly downhill. They were not watered in.

Following planting, weed growth occurred along the planting furrows necessitating a further directed spray treatment of oxyfluorfen (0.5 kg [a.i.]/ha) along the rows. Weeds were subsequently suppressed by hoeing or spot spraying with glyphosate as required.

Soil moistures were monitored using a neutron moisture meter, with regular monitoring commenced in August 1984 until the final harvest in 1987. Readings were taken monthly, except for the spring of 1985 (between harvests 5 and 6), when readings were taken fortnightly to monitor soil moisture depletion through a period of active growth. Soil moisture data was also collected in October 1983, soon after planting and in May 1984.

At the initial harvest, plants were randomly selected within each plot but for the successive harvests, plants were taken serially along the plot to allow subsequent monitoring. At each harvest, 4 plants from the central 2 rows of the plot were clipped 7.5–10 cm above ground level. A buffer of 4 plants was allowed between each harvest set. Prior to each harvest, plant height and diameter was measured, together with survival of previously harvested plants after the first harvest and diameter of regrowth from previously harvested plants were recorded. Survival was monitored by either counting the plants in the buffer rows to avoid confusion with plants previously harvested, as well as the live stumps from previously harvested plants.

After each harvest, the tops of the four plants of each plot were dried in a forced air dehydrator, defoliated and weighed (to obtain branch weight), then chipped. A sub-sample of chips was then milled and freeze-dried. Further sub-samples of milled and freeze-dried material was taken for resin and rubber analysis. The modified soxhlet method of solvent extraction, developed by Nurthen et al. (1986), was used to determine resin and rubber contents (% resin or rubber on a dry weight basis). Resin and rubber production could then be calculated using this data with branch and root production data.

Ratooned harvests were made in August 1987, on all previously harvested dryland plots. The plants were re-sampled by digging and then partitioning into roots or tops. The cut stump was included as a component of the roots at this harvest. Samples for two cultivars (N565 and 11591) were then prepared for resin and rubber analysis in the same manner as the initial harvests.

2.2. Irrigated trial

Insufficient seedlings delayed the planting of this trial until April 1984. The preparation, design, planting and harvesting were similar to the dryland trial except that only 2 cultivars (N565 and 11591) and 3 planting densities were used. Following planting, the seedlings were drip irrigated. Periodic irrigations were made during each summer so that plants received about twice the annual average rainfall. No attempt was made to fully satisfy evapotranspiration demands with irrigation. Eight harvests were made between May 1985 and December 1987. No ratoon harvests were taken from the irrigated plots.

3. Statistical analysis

Results for individual harvests were analysed. Variance–covariance matrices of residuals from each harvest were calculated. These showed independence of harvest plots. Error mean squares were compared using Barlett's test of homogeneity. When significant differences occurred standard errors for each harvest time are shown. Where possible, a split-split-plot analysis was done to compare harvest times. Level of significance is $P < 0.05$ unless otherwise stated. The error bars shown on graphs are least significant differences (LSD), $P = 0.05$.

4. Results

4.1. Plant survival

Dryland plots. Although seedlings were not watered at planting, excellent plant establishment was achieved due to high soil moisture levels. Death rates were low and only 3.5% of seedlings died at planting. At the first harvest, 95% of plants were alive with 90% remaining in July 1986. Few plants died from then to the end of the trial. Plant survival was not significantly affected by planting density or cultivar.

Irrigated plots. Plant survival was excellent throughout the trial, irrespective of planting density or cultivar.

Ratooned plants. Plant survival was significantly affected by time of initial harvest ($P < 0.001$), planting density ($P < 0.01$) and cultivar. A definite pattern of plant survival emerged with time (Fig. 1). Overall there was a trend for lower survival at higher planting densities for all harvest times and there were significantly more deaths at the higher 2 planting densities compared to the lower 2 densities. Of the 3 cultivars, N565 was the poorest survivor, being 9% lower than 11591 and 11619.

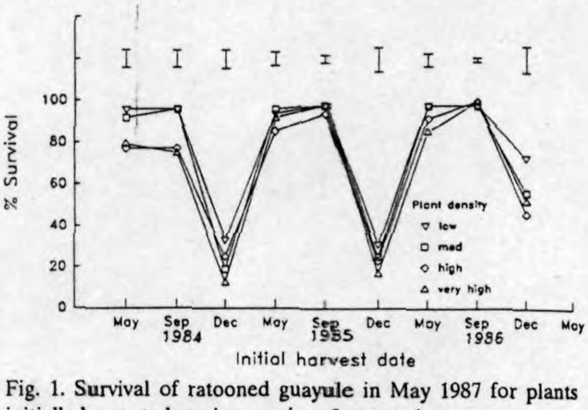

Fig. 1. Survival of ratooned guayule in May 1987 for plants initially harvested at nine previous harvest times.

4.2. Branch production from initial harvests

Dryland plots. Branch production (defoliated stems) increased with time and with increasing planting density (Fig. 2a). There was no significant difference in production between the 3 cultivars (averaged over planting density) or with time. Increasing planting density increased branch production by 0.11 t/ha for every 10,000 additional

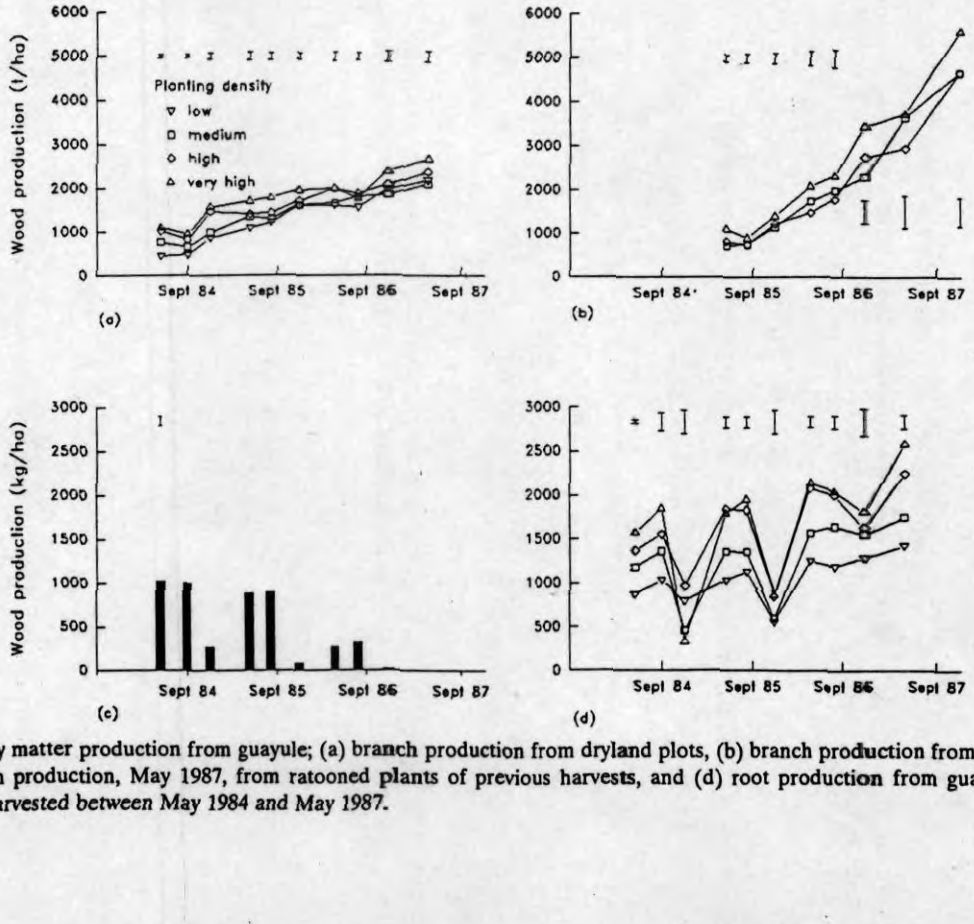

Fig. 2. Dry matter production from guayule; (a) branch production from dryland plots, (b) branch production from irrigated plots, (c) branch production, May 1987, from ratooned plants of previous harvests, and (d) root production from guayule for plants initially harvested between May 1984 and May 1987.

plants over the planting density range tested. The cumulative dry matter production for the 3 spring periods was 1.12 t/ha or 74.2% of total branch production. A decrease in production was recorded in 2 of the 3 winter periods and the combined production during the winter was −8.8%, while the summer production was 34.5% of the total.

Irrigated plots. Production increased with time and increasing planting density (Fig. 2b), but there was no significant difference between the cultivars. Increasing planting density increased production by 0.13 t/ha for every 10,000 additional plants over the planting density range tested, but this increase was not significant. Over the 2 year period, May 1985–May 1987, winter production was 7.0% of the total; spring production 48.9%, and summer/autumn production 44.1%. At the final harvest, in December 1987 after of 3.6 years growth, accumulated branch production had reached 5 t/ha.

4.3. Branch production from ratooned plants

Plant tops. Total branch production was affected by time of initial plant harvest and by length of growth period from initial harvest to ratoon harvest. There was no significant effect due to planting density or cultivar. December harvested plants had very low production due to low plant survival following initial harvest. There was little difference in production between plots harvested in May and August of the same year (Fig. 2c). Production for the 3 year ratoon period of about 1 t/ha was recorded from all plots initially harvested in May or September, 1984.

Roots. Total root production generally increased with time to initial harvest, but plots initially harvested in December 1984 and December 1985 had less total root production than other harvest times because of low plant survival (Fig. 2d). At the final harvest there was a significant effect of planting density on root production, increasing from 1.43 t/ha to 2.60 t/ha for the low to very high planting densities. There was no difference in root production between cultivars.

4.4. Leaf production.

A distinct and repetitive pattern of leaf growth was observed for guayule grown at this site. New leaves were produced in spring each year and continued to form until water stress caused a cessation of growth. Data for the December harvests, when leaf production for dryland plots was near maximum following the spring flush, indicated that total leaf weight was about 40% that of the branches. By the May harvest, significant leaf senescence was observed on all plants, the oldest leaves usually dying first. Live leaf material in May was only about 20% of the branch weight. This reduction was attributed to leaf death and fall as well as to increased branch growth over the summer. By early the following spring all leaf from the previous year had senesced.

4.5. Total guayule production

Total accumulated production of guayule for dryland plots was estimated for each treatment by summing leaf production data from the May 1984 and each December harvest, branch production data from the May 1987 harvest and root production data from the ratooned plants harvested in May 1987 (Table 2). Total dry matter production at May 1987, increased from planting at a linear rate of 60 kg/ha for each additional 1000 plants, irrespective of variety. The addition of a quadratic term was found to be non-significant. The relative proportions of root and branch in the total biomass was affected by increasing planting density, but the differences are probably attributable to sampling technique. The leaf component of total biomass was 42% ± 1%.

4.6. Resin production

Dryland plots. Percent resin fluctuated with time. Significant differences between cultivars (Fig. 3a), density and harvest time (Fig. 3b) were recorded. This usually fluctuated between 8 and 10%. Cultivar N565 always had a greater percent resin than the other two cultivars, which were similar to each other. There was similar production between the three cultivars until harvest 5, after which cultivar

Table 2
Total dry matter production (kg/ha) for three cultivars of dryland guayule grown between September 1983 and May 1987, a
Hillston using four planting densities

Cultivar		Planting densities (×1000)				
		L 9.2	M 18.6	H 36.7	VH 52.6	s.e.m.
N565	Roots	1481	1902	2501	2498	207
	Branch	2201	2515	2708	2419	282
	Leaf	2773	3072	3999	3994	192
	Total	6455	7364[a]	9208	8942[a]	455
11591	Roots	1287	1795	2278	2811	207
	Branch	1914	2069	2398	3136	282
	Leaf	2551	2613	3459	3972	192
	Total	5979[a]	6477	8446[a]	8024[a]	455
11619	Roots	1534	1580	1979	2496	207
	Branch	2461	1721	2050	2471	282
	Leaf	1817	2872	3124	3350	192
	Total	5443[a]	6173	7153	8317	455
Mean Cult.	Roots	1434	1759	2252	2602	110
	Branch	2192	2102	2385	2675	162
	Leaf	2380	2853	3551	3541	93
	Total	5959[a]	6672[a]	8269[a]	8428[a]	211
	% Leaf	40	43	43	42	

[a] Discrepancy due to missing value being estimated for components and total production.

N565 produced significantly more resin than the other two, similar cultivars (Fig. 3d). Resin production increased sharply between planting and harvest 3 and again after harvest 8 (Fig. 3e). Resin production after 3.8 years for the very high planting density was 234 kg/ha.

Irrigated plots. Percent resin peaked at harvest 2 (11.0%) and then fell to maintain more moderate levels of between 8.6 and 9.6% (Fig. 3c). This was consistently higher than for the dryland plots. There was a significant difference between cultivars at each harvest with N565 having a higher content than 11591 (10.4% cf. 8.4 ± 0.3%).

There was no difference in production due to increasing planting density, although there was an interaction between planting density and harvest time (Fig. 3f). Resin production was higher than for the dryland plots but followed a different pattern to dry matter production. Only 34.4% of resin was produced during the spring period, while 52% was produced during summer and autumn. Winter resin production was low, at 13.7%. Resin production after 3.6 years for the very high planting density was 559 kg/ha.

4.7. Ratooned plants

Tops. There was a general decrease in percen resin with time from initial harvest to ratoon harvest. This was also affected by increasing planting density (Fig. 4a). Plants from harvest 3 were exceptional and had the highest resin contents. The difference due to increasing planting densities diminished for successive harvests. There was no difference in percent resin or total resin production attributable to cultivar. Total resin production had a similar trend to branch production, rapidly decreasing at successive harvests (Fig. 4b).

Roots. There was significant variation in the percent resin of the ratooned roots over time and due to planting density (Fig. 4c). Generally, the lower the planting density the higher the resin content. Resin production from the roots increased with time reaching a maximum of 212 kg/ha for the

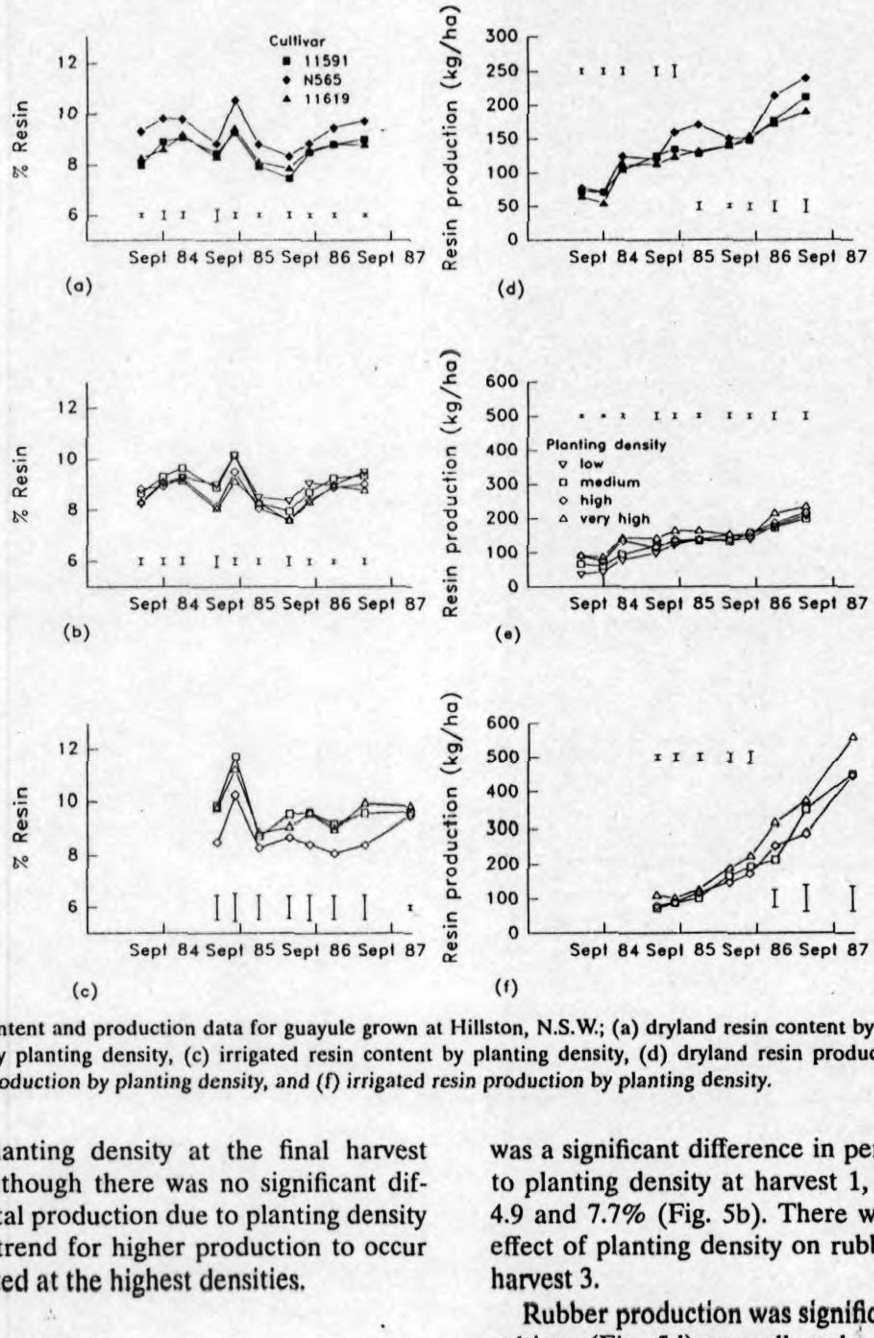

Fig. 3. Resin content and production data for guayule grown at Hillston, N.S.W.; (a) dryland resin content by cultivar, (b) dryland resin content by planting density, (c) irrigated resin content by planting density, (d) dryland resin production by cultivar, (e) dryland resin production by planting density, and (f) irrigated resin production by planting density.

very high planting density at the final harvest (Fig. 4d). Although there was no significant difference in total production due to planting density there was a trend for higher production to occur in plots planted at the highest densities.

4.8. Rubber production

Dryland plots. Rubber content (%) differed between cultivars with cultivar N565 having a significantly higher rubber content than the other two cultivars after harvest 4 (May 1985; Fig. 5a). There was a significant difference in percent rubber due to planting density at harvest 1, varying between 4.9 and 7.7% (Fig. 5b). There was no significant effect of planting density on rubber content after harvest 3.

Rubber production was significantly affected by cultivar (Fig. 5d) as well as by planting density (Fig. 5e). After harvest 5, cultivar N565 produced significantly more rubber than the other two cultivars. Almost 55% of the cumulative rubber production occurred during the springs, 22% during the summer/autumn periods and 23% during the

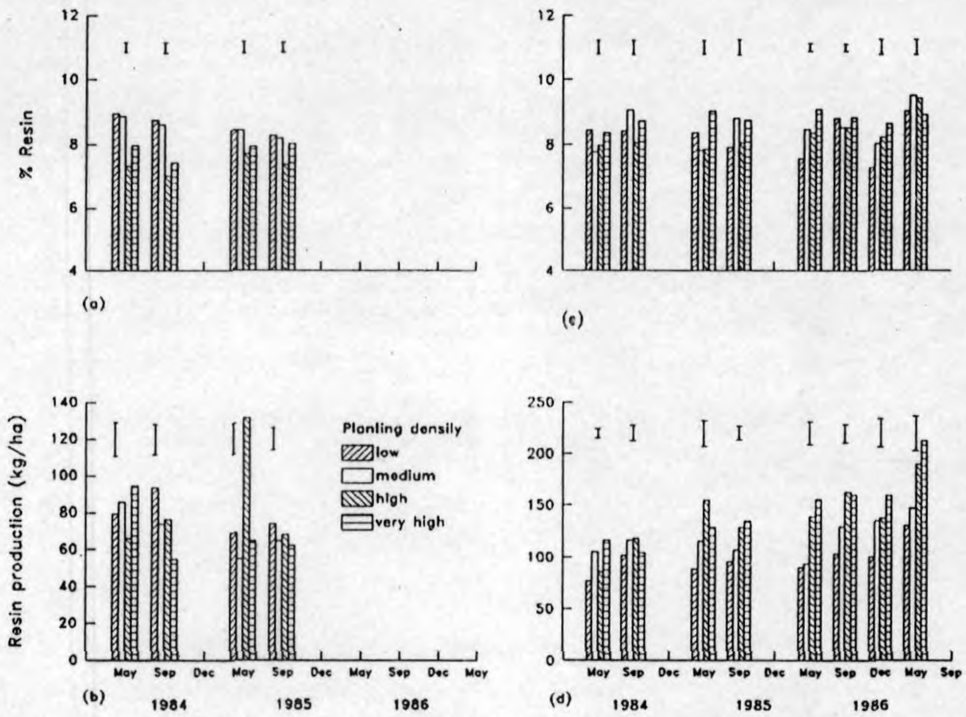

Fig. 4. Resin data at May 1987 taken from ratooned guayule initially harvested at various dates; (a) resin content of tops by planting density, (b) dryland resin production from tops, (c) resin content of roots by planting density and (d) dryland resin production from roots by planting density.

winters. Total rubber production after 3.8 years for the very high planting density was 254 kg/ha.

Irrigated plots. The rubber content of plants at the highest planting density was greatest at harvest 1, but not significantly different from the other two planting densities. The rubber content for all planting densities increased significantly to 12% by harvest 2, but then fell and maintained values of between 10 to 10.8% until the last harvest when it rose again to 11.9% (Fig. 5c).

Total rubber production increased with time throughout the trial, but most rubber accumulated during the spring periods (48.7%). There was no significant difference in production due to planting density (Fig. 5f), but production from the very high density plantings after 3.6 years was 660 kg/ha, considerably higher than from the dryland plantings. Cultivar N565 produced significantly more rubber (691 kg/ha) after 3.6 years compared to 11591 (504 kg/ha).

4.9. Ratooned plants

Tops. There was considerable variation in rubber content of plant tops due to initial harvest time and planting density (Fig. 6a). Overall there was a trend of reduced rubber content with time of initial harvest, and with the lower planting densities having the highest rubber contents. There was no difference between the two cultivars tested. Total rubber production from declined, with decreasing time between initial harvest and ratoon harvest (Fig. 6b). Total rubber production from the tops of ratooned plants after 3 years growth was 90 kg/ha.

Roots. Rubber content of the roots was lower than for the tops and tended to be less variable, but still fluctuated for different harvest times (Fig. 6c). Rubber content of the roots was usually between 7.8 and 9.4%. Rubber production from the roots increased with time as well as with increasing

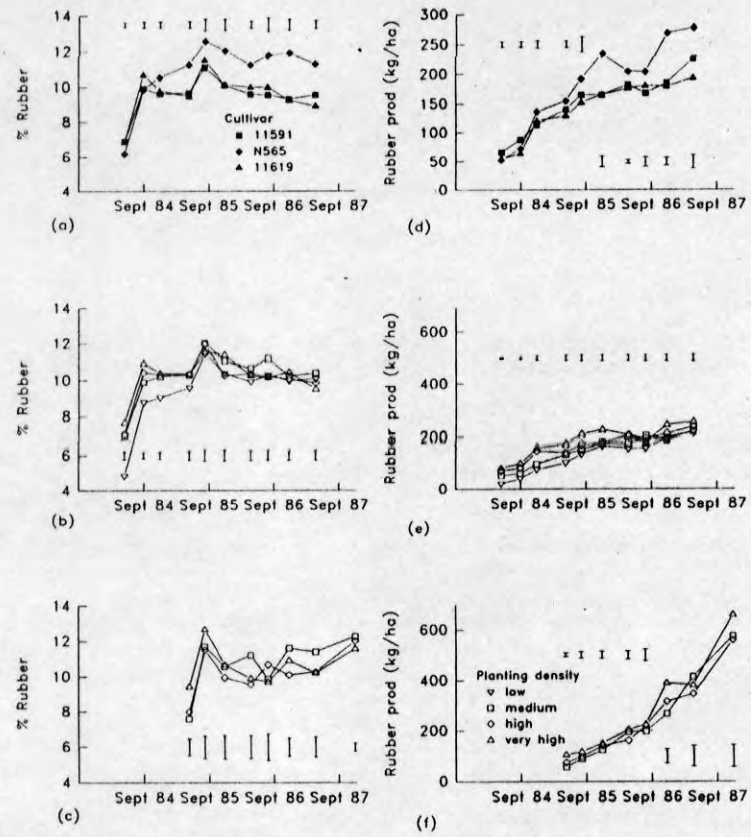

Fig. 5. Rubber content and production data for guayule grown at Hillston, N.S.W.; (a) dryland rubber content by cultivar, (b) dryland rubber content by planting density, (c) irrigated rubber content by planting density, (d) dryland rubber production by cultivar, (e) dryland rubber production by planting density, and (f) irrigated rubber production by planting density.

planting density (Fig. 6d), but there was no difference in production between the two cultivars. Total rubber production from the roots of the highest planting density plots was 250 kg/ha after 3.8 years.

4.10. Soil moisture and water-use

Dryland plots. The soil moisture content (stored water) of all dryland plots sampled in October 1983 was similar, indicating that at the beginning of the trial all plants had access to the same level of subsoil moisture. However, by May 1984 (harvest 1), there was considerable variation between treatments with the low density plots having the greatest soil moisture content. This was reflected by the relative moisture status of the plants in the field as plants in all but the lowest planting density plots showed mid-day incipient wilt at the first harvest. When regular soil monitoring began in September 1984 (harvest 2), the differences between treatments that existed in May, were still evident, but all soils had been recharged from rainfall by between 20 and 30 mm of water during this inactive growth period. Stored water continued to be depleted during the following spring (between harvests 2 and 3), but during this period there was greater soil moisture loss from the low and medium planting density plots compared to the higher planting densities. From December 1984 (harvest 3) to May 1985 (harvest 4) the water-use from the low planting density plots was greater than the other three treatments which were similar to each other. The rate of soil mois-

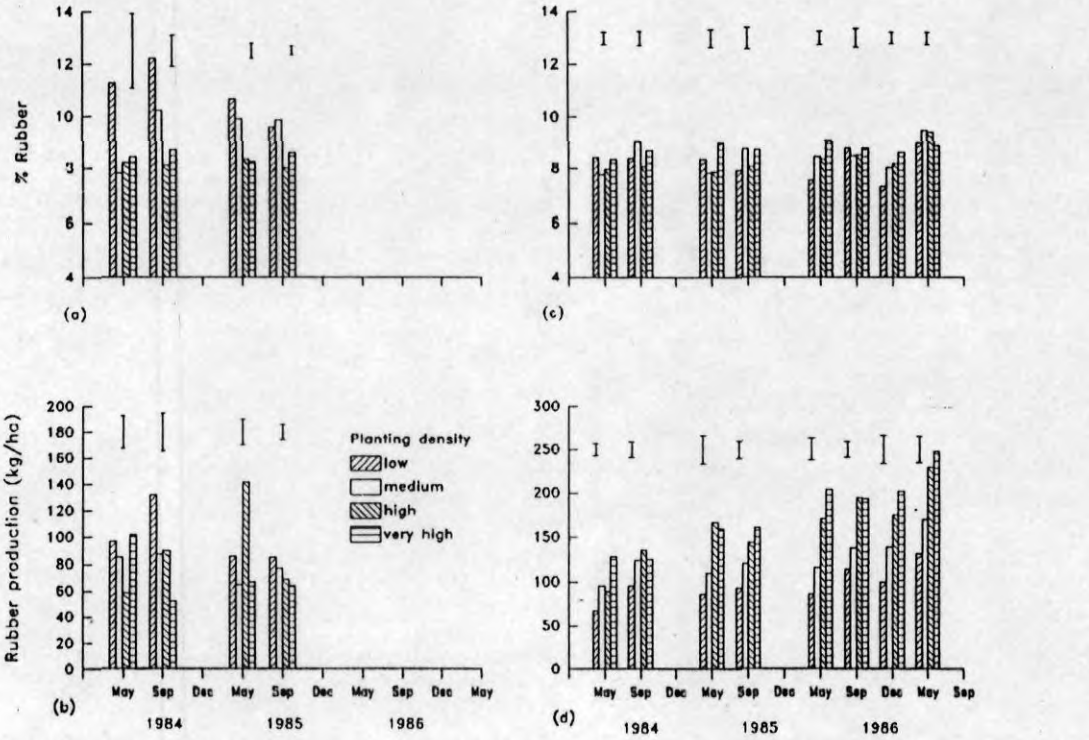

Fig. 6. Rubber data at May 1987 taken from ratooned guayule initially harvested at various dates; (a) rubber content of tops planting density, (b) dryland rubber production from tops, (c) rubber content of roots by planting density and (d) dryland rubb production from roots by planting density.

ture usage for all treatments was then similar for the remainder of the trial (Fig. 7).

Each year, there was a general pattern of depletion in stored water during spring and summer, followed by recharge in winter or early spring. During April 1986, which was at the height of a drought, stored water for all treatments reached its lowest level. Total water turnover (evapotranspiration), for the 4 planting densities, during the trial (3.8 years) was calculated to be between 1769 and 1787 mm, assuming the soil was at field capacity at planting. Loss of water as runoff from the trial would have been very small, occurring only after heavy rainfall.

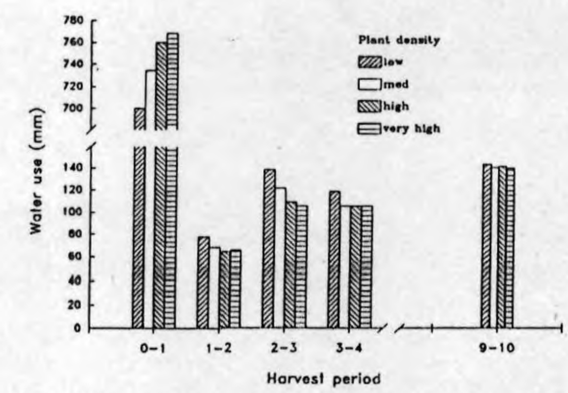

Fig. 7. Water use by time for guayule growing at four plantii densities.

Irrigated plots. The soil was near field capacity at planting (April 1984) as this area was kept fallowed from September 1983 and the seedlings were watered immediately following planting. There was no significant difference in measured water-use between planting densities, suggestin that at these spacings all plants utilised moistu in a similar manner. Evapotranspiration durin the 3 year trial was between 2314 and 2341 mm.

Table 3
Water use efficiency (kg DM/mm ha) for dryland and irrigated guayule grown at Hillston using four planting densities

	Planting densities (×1000)			
	L	M	H	VH
	9.2	18.6	36.7	52.6
Dryland plots				
Total water use (mm)	1775	1769	1783	1787
WUE (whole plant)	3.32	3.77	4.60	5.07
WUE (branch)	1.24	1.19	1.34	1.50
Irrigated plots				
Total water use (mm)	–	2314	2341	2330
WUE (whole plant)	–	4.66	4.91	6.04
WUE (branch)	–	2.03	2.00	2.41

4.11. Water-use efficiency

Dryland plots. Water-use efficiency (WUE), measured as kg DM/mm ha, on a whole plant basis was low for all planting densities, but increased with increasing plant density. At the lowest density WUE was 3.02, increasing to 4.45 at 52,600 plants/ha. The WUE for branch production was much lower, ranging from 1.19 to 1.50 (Table 3).

Irrigated plots. WUE was higher for these plots than the dryland plots, reflecting a greater continuity of growth due to a more abundant water supply. On a whole plant basis the WUE ranged between 4.66 and 6.04, while for branch production the range was 2.00 to 2.41 (Table 3).

5. Discussion

The survival of ratooning plants followed established patterns (Milthorpe, 1983; Foster et al., 1986). Plants harvested in May or September had excellent survival, but survival was poor from December harvested plants and usually about one quarter that of the cool season harvests. This has implications in commercial plantations as initial harvests of plants would need to be undertaken in the cooler months of the year to ensure high survival of the ratooned crop.

Branch production varied from very low in the initial harvests to abysmal from the ratooned plants. For example, the May and September 1984 initial harvested plots produced 0.4 to 1.1 t/ha followed by 1.0 t/ha from the ratoon growth up to May 1987 (a total of 1.4 to 2.1 t/ha) whereas plants cut for the first time in May 1987 produced 1.9 to 2.6 t/ha (an additional 0.5/ha). This difference could partly be attributed to loss of leaf at harvest and possibly due to competition from adjacent uncut buffer plants. In a commercial situation plants would not receive an initial cut for at least three years from planting and then be allowed to ratoon.

A measured decrease in branch production for two of the three winter periods from dryland plots and one for the periods from the irrigated plots is worthy of comment. It is unlikely that this decrease is an artifact of sampling or field variation as the measured decrease in the first year of dryland plots occurred across all cultivars and all densities. Also the coefficient of variation of samples within replicates was low at 2.5%. It may be explained by the need for the guayule plants to call upon stored reserves for survival metabolism during the winter, or by the conversion of stored photosynthate into rubber, a process which uses energy.

Increasing planting density only increased branch production during the first year of growth at the rate of 0.11 and 0.13 t/ha for dryland and irrigated stands respectively for each additional 10,000 seedlings/ha over the range of planting densities tested. On this basis, the estimates of production up to 30 t shrub/ha after 6 years extrapolated from U.S. data by Stewart (1986) for plant densities of up to 500,000/ha appear unachievable as benefit could only be gained during prolonged extremely wet periods.

Guayule performed here according to the documented behavioural patterns, with plants reacting to cold and moisture stress stimuli to increase the deposition of rubber. Most other data, where the plants have been grown with abundant irrigation, show a resin to rubber content ratio greater than unity (Gilliland and van Staden, 1986; Gathman et al., 1992). However, in Australia, and particulary for dryland production, the resin to rubber ratio is mostly less than unity. This was the case here for both the dryland and irrigated trials for all but the first harvest, highlighting the impact of stress in enhancing rubber production. Despite relatively high rubber contents, compared to other data, the rubber yields from all plots were disappointingly low, even when the ratooned components are included.

The WUE of guayule in these trials is similar to recent data obtained from irrigated trials conducted in the U.S.A. Our WUE values of 3.0–4.45 kg DM/mm ha for dryland and 4.7–6.0 kg DM/mm ha for irrigation were only slightly lower than the 5–8 kg DM/mm ha achieved in the U.S.A. (Miyamoto et al., 1984; Bucks et al., 1985a, b). However, in the U.S. studies the much greater water supply (up to 3,000 mm/yr) restricted periods of water stress and cessation of plant growth compared to that experienced here. The lower WUE obtained in these trials is attributed to periods of water stress during most summers which prevented continuous growth of guayule. If WUEs comparable with those obtained in the U.S. studies were achieved in these trials, then about twice the measured dry matter production could be expected. Even with these projected figures the potential yields claimed by Stewart (1986) are not supported.

6. Conclusion

The results of these studies are also in general agreement with that of other work in N.S.W. (Milthorpe, 1983, 1985) and suggest that the yield predictions made by Siddiqui and Locktov (1981) and Stewart (1986) have been grossly overestimated. As the WUE of guayule is relatively constant over a wide range of watering regimes it is unlikely that the production of rubber can be significantly altered by changing existing management practices and that the yield potential of the crop is directly related to water use.

The regular field measurement of guayule growth over 3.8 years in this trial has provided a sound basis for the assessment of guayule production. There is now the need to reassess the viability of a commercial natural rubber industry in Australia, based on current knowledge. Such an assessment should not only consider production figures, including ratooned harvest data; but also the need to use seedling transplants and expensive herbicides for crop establishment. It would appear that there is little hope that guayule production could be economically viable unless there is a major upward shift in the price of natural rubber and other co-products.

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