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STUDIES ON HANDLING AND TRANSPLANTING GUAYULE NURSERY STOCK
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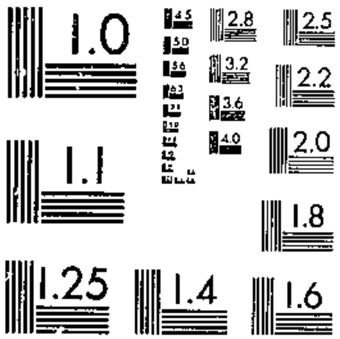

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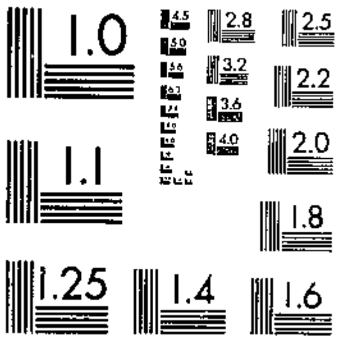

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Studies on Handling and Transplanting Guayule Nursery Stock[1]

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INTRODUCTION

Transplanting in a broad sense, covers all the cultural practices and operations involved in getting the plant from the seedbed into the field. The success or the necessity of any operation is, of course, measured by the subsequent performance of the plant in the field. The transplanting of guayule is complicated by the large-scale packing, storage, and shipping operations. Furthermore, because of residual effects, a study of transplanting requires the consideration of factors which condition the plants prior to the time of digging in the nursery.

It is the purpose of this bulletin to present the results of such studies on transplanting guayule. Some of the changes in stock brought about by hardening, watering, topping, undercutting, packing, shipping, storage, and time of transplanting are considered in various ways.

All the experiments were conducted on nursery stock grown in nurseries of the Emergency Rubber Project at Salinas, San Clemente, and Indio, Calif.

[1] Submitted for publication April 22, 1946.

MATERIALS AND METHODS

Description of Nursery Stock

Stock for transplanting in guayule plantations is usually grown in nurseries for one season (*16*).[2] At Salinas nursery sowings were made in the spring or early summer for stock to be transplanted the following fall, winter, and spring. To obtain plants of the desired size 3 or 4 months of growth is generally required. Such a period does not include the intervening winter months when the plants are practically dormant or the period of hardening required after the desired size has been attained.

Plants for field plantings by the Emergency Rubber Project ranged from 2.4 to 12.7 mm. (3/32 to 1/2 inch) in root-crown diameter, with a trend toward increasing the minimum diameter to 4.0 mm. (5/32 inch). Plants of this size range are readily accommodated by the machines used (e. g., the Holland celery planter and the Kindorf planter). The number of suitable plants obtained per square foot in the nursery depends a great deal on the density of stand. Guayule nursery stock was grown in beds 4 feet wide with 7 bands of seed per bed. Thus, 1 square foot would be equivalent to 21 lineal inches of seed band. Figure 1 shows the size distribution of plants in densities of 15 to 40 per square foot 4 months after sowing.[3] On this basis a density of 25 to 30 plants is considered desirable at Salinas when the minimum-size standard is 5/32 of an inch.

The height of the stems of nursery stock is variable, ranging from 1 to 18 inches. The average height of all stock grown at the Salinas nurseries was about 5 inches, whereas that at the Indio nurseries was about 10 inches. Some of the stock at Indio reached a height of 15 to 18 inches in 1943, but the great density (about 40 plants per square foot) prevented excessive growth in diameter during the long growing period. The density of the nursery stock has important effects on the plant besides those on diameter. Regardless of the care exercised in obtaining a stand of seedlings there are bound to be great local variations in density. For example, isolated plants tend to be short and have numerous spreading branches (fig. 2). If 2 or 3 plants occur in groups, they are taller and their branches are less spreading. Near the optimum density (25 plants per square foot) the living branches are fewer and rather closely appressed. Excessive local densities (35 or more per square foot) usually result in large numbers of spindly plants. The coarseness of lateral roots seems to vary inversely with the density of stand (fig. 2).

During the rapid growth of well-watered guayule nursery seedlings of average density the leaves become large and succulent (fig. 3, *b*). By winter most of the large leaves die and the stems retain only the terminal groups of leaves (fig. 4, *b*). On the other hand, nursery plants which grow slowly (fig. 4, *a*) or in a sparse stand (fig. 2, *a* and *b*) remain more leafy throughout the winter.

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[2] Italic numbers in parentheses refer to Literature Cited, p. 57.

[3] Unpublished data of W. A. Campbell, pathologist, Special Guayule Research Project.

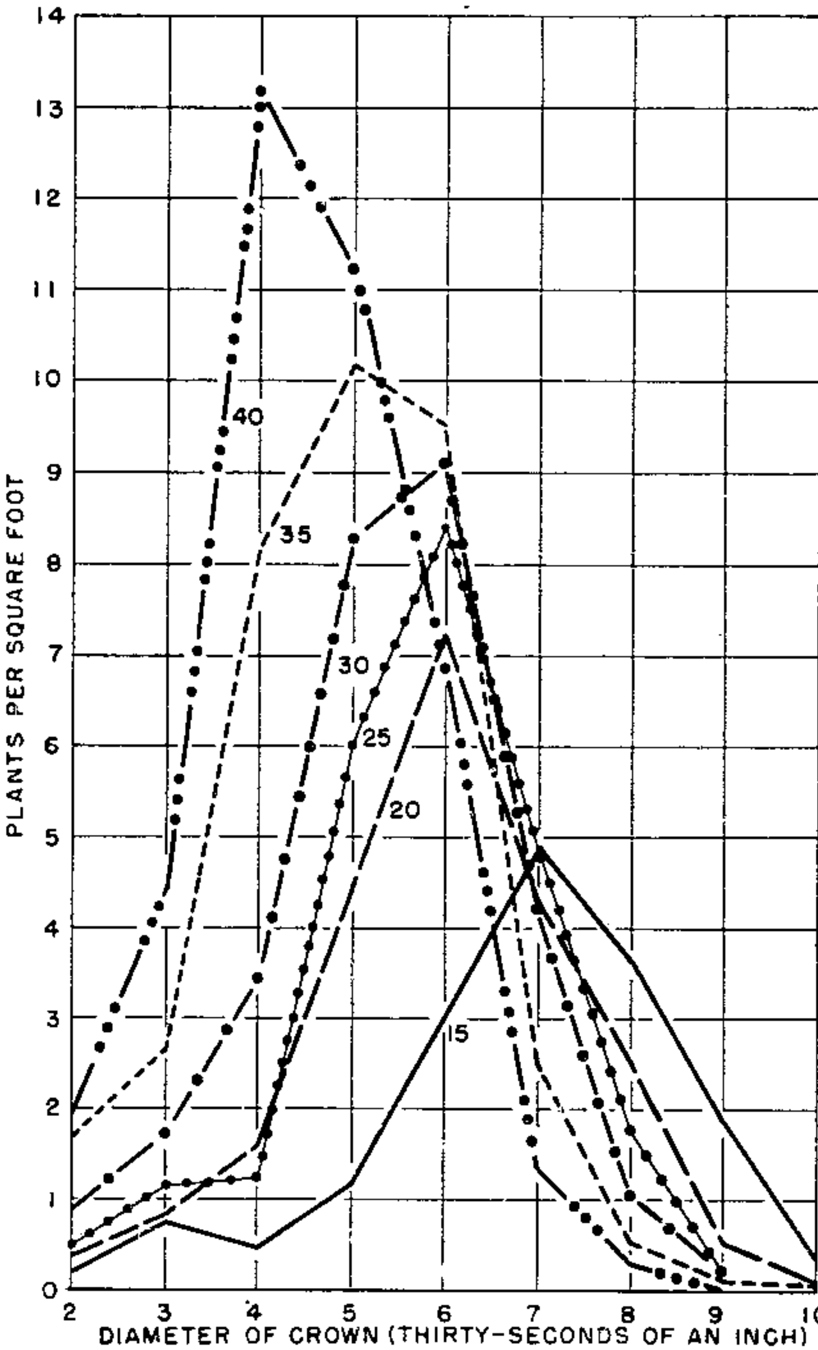

FIGURE 1.—Size distribution of 4-month-old guayule plants per square foot in the nursery when density of stand ranged from 15 to 40 plants per square foot. (The numbers on the graphs indicate the density of stand.)

FIGURE 2.—Guayule plants 7 months old (January 1945) from a single location, showing differences in development due to extreme variation in density of stand: *a*, Isolated plant; *b*, plant from a group of 2 to 4 plants; *c*, plant from a normal stand (15 to 30 plants per square foot); *d*, plant from an excessively dense stand (35 or more plants per square foot).

The age of the nursery stock used in the experiments herein reported ranged from 4 to 17 months. The root-crown diameter, however, was constantly maintained at 4.8 to 9.5 mm. (3/16 to 3/8 inch) by selection, except when otherwise stated. Stem heights varied between 4 and 12 inches for different experiments but not by more than 2 or 3 inches for any experiment. Unless otherwise indicated the taproots were cut back to 5 or 6 inches and the number and lengths of lateral roots were those which were normally retained in pulling the undercut plants.

STATISTICAL TREATMENT

Statistical analyses of the data were made by using the analysis-of-variance method (*25*); in some cases the amount required for significance between means (*10*) is presented. In the discussions odds of 19 to 1 were considered significant and odds of 99 to 1 highly significant. Where the variability of the mean is indicated by the ± sign the value presented is the standard error. Percentage data were transformed to degrees percentage ($p = \sin^2 \theta$) before analysis of variance was made (*10*).

FIGURE 3.—Guayule nursery stock 4 months old, September 1: *a*, Plants grown without irrigation after they were 2 months old; *b*, plants that were irrigated continually.

FIGURE 4.—Guayule nursery stock of the type shown in figure 3, when 8 months old: *a*, Plants grown without irrigation after they were 2 months old; *b*, plants that had received little irrigation after they were 4 months old.

PREPARATION OF NURSERY STOCK FOR TRANSPLANTING

Successful transplanting of guayule depends on more than the proper digging, storage, and handling of plants in the nursery and field. Adequate conditioning of the plants in the nursery is necessary to overcome certain inadequacies inherently present in the form and composition of rapidly growing guayule nursery plants.

Guayule has a taproot, and when the plants are dug in the nursery very few of the weakly developed lateral roots are retained. Unhardened plants do not survive well even if topped. The presence of leaves on the untopped plants retards or prevents recovery (*7, 22*); and if the plants are topped, there is probably an insufficiency of growth factors and carbohydrates for regeneration of roots and leaves. During establishment of a transplant there is a considerable decrease in the dry weight of the stem and root.[4]

HARDENING

From a practical standpoint, hardening is a necessary step in preparing guayule for transplanting. No single criterion adequately describes hardiness of plants, but it has been variously associated with many factors such as unfreezable water (*26*), water content (*26*), rehydration (*9*), pentosans (*11, 21*), and carbohydrates (*15*). Dexter (*5*) found that conditions favorable for hardening were also favorable for accumulation of food. Although methods for hardening plants have been in common use for a long time, the changes occurring in the process have not been adequately evaluated. Probably many plants have been hardened for transplanting as a matter of routine without investigation as to whether the practice was beneficial. Recently Babb (*1*) found that hardening was of no discernible benefit in transplanting several vegetables and in some instances it even had deleterious residual effects on earliness of maturity and yield. Kelley, Hunter, and Hobbs (*12*) demonstrated that for transplanting guayule by the usual procedures it was very necessary to harden the plants for a considerable period prior to this operation. Associated with the hardening of guayule was an increase in levulin content.[5] Auxin, however, was much lower in hardened than in unhardened guayule (*24*).

HARDENING BY DROUGHT AND COLD

For the purpose of obtaining information on the changes that would occur and in the hope that such knowledge would lead to a better understanding of the physiological processes involved in the recovery of transplants, an experiment on hardening nursery stock was undertaken. The plants used for the experiment were from a sowing made on May 9, 1944; they were watered frequently and

[4] Unpublished data of H. P. Traub, principal physiologist, Special Guayule Research Project.

[5] Unpublished data of H. P. Traub, M. C. Slattery, and W. McRary, principal, assistant, and associate physiologists, respectively, Special Guayule Research Project.

with increasing amounts so that readily available moisture was present to within about 1 inch of the soil surface. After the stems of the plants were about 1 inch tall, they were irrigated at the rate of 1 inch per week in two applications until the end of August. Thereafter, only three waterings were given to prevent severe drying (0.25 inch, September 18; 0.20 inch, September 23; and 0.05 inch, October 3). At the time the regular watering was discontinued the plants were flowering freely but were barely at the minimum size limit for transplanting.

Beginning August 31, at intervals 6 harvests were made to determine various changes in the plants during hardening. Three replicates of 25 to 75 plants were obtained from 5 random locations in the experimental plot, which was 5 nursery beds wide and 150 feet long, for dry weights, rehydration, and carbohydrate analysis.[6] Total fructosans were based on hot-water extraction and levulins on cold-water extraction. The difference between the products obtained in hot and cold extractions was designated "inulin." The rehydration values were determined by a method modified from the one used by Greathouse and Stuart (*9*). Root samples previously dried at 65° to 70° C. were ground to pass a 40-mesh screen in a Wiley micromill. Duplicate samples of approximately 1 gm. each were placed in weighing bottles and dried to a constant weight at 80° and a 3- to 4-cm. pressure. The weighed samples were placed in a desiccator over sulfuric acid having a specific gravity of 1.228 (relative humidity of approximately 75 percent at 30°). A bottle containing 1 ml. of formalin was also placed in the desiccator to prevent the growth of molds. The desiccator was placed in an incubator oven with temperature controlled at 30° and at atmospheric pressure for 3 weeks. At the end of this time weighings were made and the rehydration percentages were calculated. All determinations presented were made during one run and with one desiccator.

Turgorized values for roots were obtained from 10 determinations on 20 additional plants. The procedure was to take the upper 4 inches of taproots devoid of laterals and place them in water until they were turgid (48 hours), as indicated by constant weight.

After surface moisture was removed by blotting and the weights were recorded, the roots were dried at 100° C. and the water contents were determined.

Each survival value is based on 160 plants in 8 replications. The plants were topped to 1½ inches above the crown, and the roots were cut to 6 inches. All laterals were removed to make the stock uniform for each transplanting. Crown diameters and heights of stems are based on five 1-lineal-foot samples of all the plants present. In all determinations (table 1) except those of diameter and height the plants were selected for a minimum root-crown diameter of 5/32 of an inch.

Hardening was effected by drying until October 31, when the first rain occurred. After that date the soil remained moist but the temperature dropped and further changes may be ascribed to low temperatures (fig. 5).

During the hardening process the most noticeable change in the plants was a loss of the lower leaves. The dry weight of living leaves

[6] Thanks are due to M. C. Slattery of the Guayule Project carbohydrate laboratory for the carbohydrate analyses. (Unpublished data of H. P. Traub and M. C. Slattery.)

decreased very rapidly during the drought, whereas the dry weights of stems and roots increased (table 1). Growth in height and in diameter were sharply retarded, indicating that a large part of the increased dry weights was a reflection of the accumulation of reserve substances. This accumulation was also reflected by the decreasing moisture contents in turgorized roots. Carbohydrate analyses indicated that reducing sugars, pentosans, and inulin varied only slightly during the hardening process, but that levulins increased in large quantities; this increase indicated that levulins were the main carbohydrate reserve. Traub, Slattery, and McRary[7] found a similar increase of levulins in the guayule plants they studied; a high correlation was found between the reserve carbohydrates and the survival of transplants in the fall and early winter but not in the late winter and spring. Loomis *(15)* noted sudden increases of carbohydrates in vegetables as a result of wilting and determined that hardening periods of 10 days resulted in more roots forming on transplants. In guayule, however, the sudden slight increase in carbohydrates seemed to have little beneficial effect on survival of transplants (table 1).

A change commonly found in the plants during hardening is the increase in hydrophilic substances *(11, 21)*, which results in increased values for rehydration. Loomis *(15, p. 35)*, using a method of imbibition, concluded that decreases in imbibition in some hardened vegetables ". . . indicate the accumulation of substances which have a lower absorbing power than the normal cell constituents." In the case of guayule, however, the rehydration values showed no consistent trends which could be positively correlated with hydrophilic substances or negatively correlated with hydrophobic ones.

The water content of roots of young unhardened guayule plants is above 80 percent (table 1), whereas in the hardened plants it is usually about 60 percent or slightly less in second-year nursery stock *(7)*. During hardening by drought the water content of roots normally drops sharply because of wilting (table 4), but turgorized roots during hardening show intermediate values which may be con-

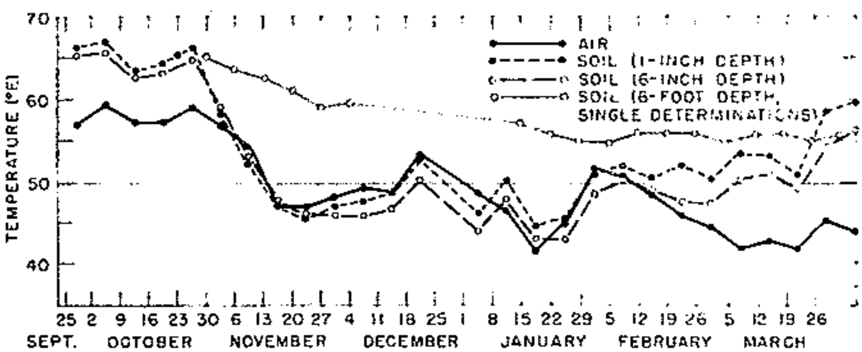

Figure 5.—Weekly mean temperatures for air and soil at Salinas, Calif., during the winter of 1944–45. The rapid drop in temperature accompanied the rainy period at the end of October.

[7] See footnote 5, p. 7.

TABLE 1.—*Changes accompanying the hardening of guayule nursery stock*

Date	Period after beginning of test	Water in—				Rehydration of roots	Root content			
		Leaves	Stems	Roots	Turgorized roots		Inulin	Levulins	Pentosans	Reducing sugars
	Days	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
August 31	0	86.1±1.6	86.1±1.2	85.4±0.6	85.4+	25.3±1.1	0.09±0.05	4.72±0.95	1.12±0.08	0.37±0.04
September 9	9	80.5± .3	74.6±1.8	69.7± .8	.....	26.8±1.7	.15± .03	7.54± .59	1.10± .05	.71± .05
September 19	19	66.5± .9	64.2± .5	75.3± .4	75.3+	25.2± .8	.50± .13	7.67± .49	1.02± .06	.63± .04
September 29	29	57.1±1.2	47.0±2.0	60.8± .6	70.0±0.4	29.0±2.3	.13± .13	9.43± .27	.93± .06	.93± .05
October 20	50	53.8±1.2	47.4± .7	59.6± .3	66.5± .9	23.6± .4	.45± .26	13.6 ± .73	1.3 ± .17	.86± .07
March 9	190	72.9± .2	59.4± .9	60.8± .7	63.7± .5	24.3±1.8	1.95± .37	14.54± .53	1.50± .01	.78± .01

Date	Period after beginning of test	Transplants sprouting [1]	Mean dry weight			Mean diameter of crown	Mean height of stem
			Leaves	Stems	Roots		
	Days	*Percent*	*Grams*	*Gram*	*Gram*	*Millimeters*	*Centimeters*
August 31	0	27.5±3.4	1.44±0.01	0.41±0.04	0.32±0.01	3.9±0.1	9.0±0.3
September 9	9	27.5±5.7	1.26± .09	.49± .03	.37± .03	.....	.....
September 19	19	23.1±4.9	.68± .03	.56± .04	.41± .01	.....	.....
September 29	29	.....	.49± .02	.67± .02	.52± .03	.....	.....
October 20	50	70.3±4.6	.37± .02	.84± .05	.60± .02	.....	.....
March 9	190	93.1±2.1	.09± .01	.92± .05	.61± .02	4.5± .2	11.1± .5

[1] Based on plants without lateral roots.

sidered an index of the degree of hardening. In previous experiments with other plants low moisture content was also correlated with hardiness (*17, 21, 26*).

The survival values obtained for the transplants, as indicated, are based on plants without lateral roots; therefore the differences between unhardened and hardened plants are greater and more truly depict the greatly improved regenerative powers of the hardened plants.

HARDENING BY COLD

At the time the drought treatment was begun on the plants of the previous experiment, other plants in the same beds continued to receive semiweekly irrigations until the rainy season began at the end of October. With the advent of the rainy season the mean air and soil temperatures dropped rapidly (fig. 5) and remained below 50° F. during the greater part of the winter. Thus, changes occurring in the plants were principally due to low temperatures and to whatever drought effects the low temperatures may indirectly have had in decreasing the water absorption by the roots. It was observed that the low temperatures (thirties) in November resulted in yellowing and finally dying of most of the large, succulent leaves produced at the height of the summer's growth. The plants did not at once become as leafless as those undergoing drought treatment, but by March 9 there was very little difference in leafiness between these cold-hardened plants and those of the previous experiment which in addition were subjected to drought.

The data in table 2 indicate that the survival of transplants was the same whether they were only cold-hardened or were also subjected to drought. Carbohydrate analyses revealed that plants of both treatments had accumulated large amounts of levulins and smaller amounts of inulin and other carbohydrates. While the drought- and cold-hardened plants had slightly higher reserve carbohydrate contents than those cold-hardened only, this was probably a result of the longer period of hardening. On the other hand, the cold-hardened plants were larger, a result of the longer initial period of growth.

TABLE 2.—*Comparison of drought- plus cold-hardened guayule stock with cold-hardened stock, March 9, 1945*

Item	Value for plants		
	In initial condition	Drought- + cold-hardened (2 months + 4 months)	Cold-hardened (4 months)
Water content of turgorized roots..percent..	85.4 ±	63.7 ±0.5	63.5 ±0.4
Rehydration of roots..............percent..	25.3 ±1.1	24.3 ±1.8	25.4 ±1.4
Inulin in roots....................percent..	.09± .05	1.95± .37	1.08± .18
Levulins in roots..................percent..	4.72± .95	14.54± .53	11.41± .33
Pentosans in roots.................percent..	1.12± .08	1.50± .01	1.50± .01
Reducing sugars in roots.........percent..	.37± .04	.78± .01	.66± .02
Mean dry weight per plant:			
Leaves ....grams..	1.44± .01	.09± .01	.44± .01
Stem ....grams..	.41± .04	.92± .05	1.36± .06
Root ....gram..	.32± .01	.61± .02	.94± .01
Transplants sprouting ....percent [1]..	47.5 ±4.9	98.1 ±1.3	98.1 ±1.3

[1] Based on plants with lateral roots.

Watering Before Digging

In the fall, when stock is to be dug after it has been hardened, the soil is frequently dry and in many cases very hard so that it becomes necessary to water prior to digging. If the temperature is favorable for growth, the hardened stock breaks its dormancy and evidence of new leaf growth may be found within 1 or 2 weeks. An experiment was designed for the purpose of determining whether survival of transplants was materially altered by keeping the soil in the nursery bed moist for various periods prior to digging when the temperatures were still favorable for growth in the fall. The periods used were 2, 4, 8, 14, and 20 days before digging for stock which was growing in the San Mateo nursery near San Clemente in 1943. After the first of August regular nursery irrigation was decreased to 0.25 inch every 2 weeks to permit the nursery stock to harden. Experimental watering before digging began on October 7, and the watering schedule was so arranged that plants of all treatments were ready for digging on the same day, October 27. Topping was done at an average height of 2 inches above the root crowns, and undercutting at a 7-inch depth followed.

Samples of 200 plants for each treatment were taken at random for the initial planting (2 days after digging) and wrapped with moist shingletow (132 percent water on dry-weight basis) in waxed paper. The remaining plants were crated with shingletow having a moisture content of 132±5.3 percent in crates having waxed-paper lining on 4 sides. Four-crate replicates of each treatment were held in common storage for each of 2 periods, 7 and 14 days. At the end of these periods the second and third plantings were made. The plants of each treatment were divided into 10 replicates and randomized in the planting, but for the 3 plantings time was confounded with position. Final counts of the plants were made at the end of April 1944 (table 3). These counts showed that when the soil was kept moist for various periods up to 20 days before digging during temperature conditions favorable for growth there was a gradual but statistically highly significant decline in survival. Similarly, delaying the planting 1 and

Table 3.—*Effect of watering before digging on survival (percentage of plants sprouted) of guayule transplants 6 months after planting*

Period in moist soil before digging	Plants surviving when in common storage before planting for—			Mean [1]
	2 days	7 days	14 days	
	Percent	*Percent*	*Percent*	*Percent*
2 days	97.5	96.5	90.5	94.8
4 days	98.0	93.5	85.5	92.3
8 days	95.0	89.5	91.0	91.8
14 days	95.5	90.5	81.0	89.0
20 days	76.5	85.5	81.0	81.0
Mean [2]	92.5	91.1	85.8	89.8

[1] Observed F value=9.06; F value required at 1-percent level=4.78; observed t value (linear regression)=10.14; t value required at 1-percent level=5.84.
[2] Observed F value=14.96; F value required at 1-percent level=3.47.

2 weeks after digging reduced the survivals gradually, but season of planting and position confounded the net effects of storage in this experiment.

TOPPING

Previous work (*22*) demonstrated that topping is necessary for the successful transplanting of guayule nursery stock. One of the important considerations in topping is the time at which it is done. In practice it is desirable to know what effects might result from topping when the plants cannot be dug shortly afterward. It has been observed that after topping, new bud growth is evident in 5 to 7 days under favorable conditions of temperature and moisture or in somewhat longer periods when one or both of these factors are limiting.

Experiments were undertaken to determine the effects of pretopping on survival of the transplants. The first of these trials was made in June 1943 with unhardened stock grown in a nursery near San Clemente. One-half or three-fourths of the top was removed at each of the following times: 0, 3, 6, 11, and 18 days before digging. One hundred and eighty plants per treatment were transplanted in 9 randomized blocks. The experiment was repeated in October 1943 with hardened plants. In a third experiment carried on at Salinas, topping was done at 4 levels: topped to crown, seven-eighths-topped, three-fourths-topped, and half-topped, 0, 3, 9, and 25 days before digging. In this case 100 plants per treatment were transplanted in 10 randomized blocks on November 4.

The results of these experiments showed that when plants were topped many days in advance of digging the recovery was poor (table 4). In all three experiments larger numbers of the plants with half the top removed recovered when topping was done 3 days before digging; but when it was done more than 3 days before digging (6 days in one case) there was a decrease in the number of plants recovering. As the severity of topping increased, the time of topping became more important.

From a physiological standpoint the best time for topping nursery stock may not be the time of digging. In July 1944 three-fourths of the top was removed from 1-year-old, hardened nursery plants at 36, 12, and 0 hours before digging and 12, 24, 36, 48, and 96 hours after digging. Twenty plants from each time of topping were placed in water culture within an hour after digging. After 11 days the rooted plants and the new roots on the 6-inch taproot, from which the laterals had been removed at time of digging, were counted. Figure 6 presents the data graphically. The mean number of roots is based on the rooted plants. Analysis of variance for the root means gave significance at the 5-percent level.

Two points are worthy of mention in regard to the data of this experiment. The first is the tendency of plants to root better if they are topped a short time before digging rather than at the time of digging. There seemed to be also an indication that topping shortly before digging (3 days) was beneficial for field plantings (table 4). The second point is that placing plants in water for several hours before topping improved rooting. The latter response was obtained in another way when control plants were soaked in water in experiments designed for the purpose of determining the effects of hor-

TABLE 4.—*Relation of time and extent of topping of hardened and unhardened guayule transplants to percentage of plants growing after a minimum of 6 months*

Place and kind of stock	Date	Plants per treatment	Plants growing when topped the indicated time before digging						
			0 day	3 days	6 days	9 days	11 days	18 days	25 days
San Clemente, Calif.		*Number*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Unhardened plants:									
Three-fourths-topped	June 1943	180	18	37	28	.....	2	0	.....
Half-topped			25	43	31	.....	6	1	.....
Hardened plants:									
Three-fourths-topped	October 1943	180	96	97	88	.....	75	64	.....
Half-topped			83	86	86	.....	37	20	.....
Salinas, Calif.									
Hardened plants:									
Topped to crown	November 1943	100	83	64	.....	55	.....	.....	32
Seven-eighths-topped			90	84	.....	67	.....	.....	45
Three-fourths-topped			100	93	.....	96	.....	.....	88
Half-topped			90	97	.....	90	.....	.....	84

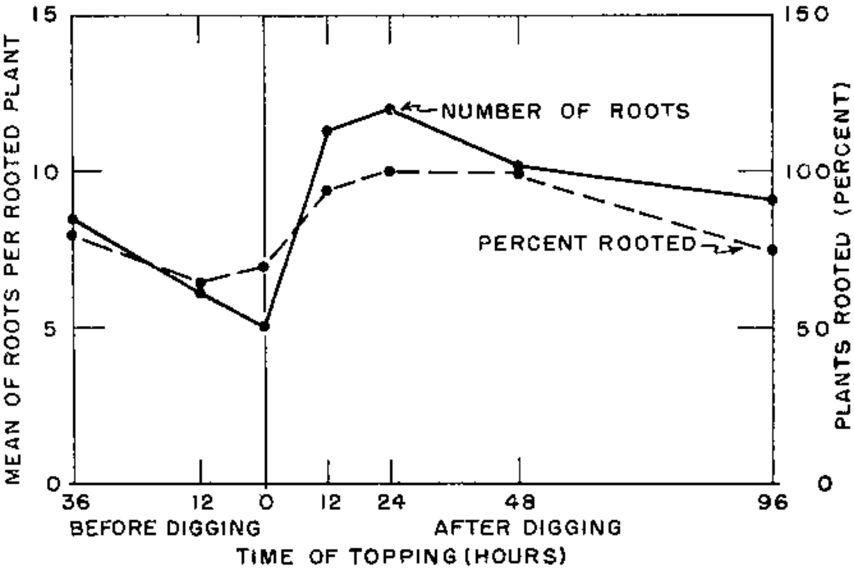

FIGURE 6.—Effect of time of topping on the initiation of roots by hardened guayule transplants in water culture. (Counts on 20 plants per treatment 11 days after digging.)

mones on rooting. In these experiments there was an increase in the number of plants growing when they were soaked in water before topping over those not soaked before topping; the plants in both groups were topped at the same time. This increase occurred whether the plants were grown in the field for many months or for a shorter time in the greenhouse in culture solution or sand culture. A possible explanation for the benefit of topping after digging is that root-forming substances accumulate in the severed taproot before their source, the top, is removed. If topping was postponed more than about 24 hours, it appeared that other factors, such as the lack of sufficient water in the tissues (*7*), delayed the formation of new roots.

The benefit of topping shortly before digging may have been due to various factors. One possibility was an increase in turgor in the taproot. As another possibility Went and Thimann (*27*) stated that the presence of a bud promotes root development, especially if the bud is rapidly developing. Where the plants were topped 3 days before digging there was probably already the beginning of lateral-bud growth, which would increase the supply of root-promoting substances over that of plants topped at the time of digging. When topping preceded digging by more than 3 to 6 days, however, the beneficial effects were lost. It is interesting to note that topping 3 days prior to digging seemed to be more beneficial to unhardened plants than to hardened ones (table 4).

UNDERCUTTING

Part of the procedure of digging nursery stock consists in passing a blade under the plants to sever the roots and loosen the soil. Nursery stock is generally undercut on the day it is pulled or the day before. Several experiments were performed in which undercutting in the nursery preceded topping by various lengths of time and in most cases with beneficial effects on rate of recovery and percentage of survival. The only topping trials in which improvements were not noted were those made in the winter or with stock which gave very high survival percentages regardless of time of undercutting.

The first experiment was conducted in July 1943 at San Clemente with March-sown stock which was large enough to be hardened and which had been permitted to wilt a few times prior to the beginning of the experiment. Undercutting was done 0, 4, 7, 14, and 21 days before digging. Overhead irrigations (about 0.2 inch) were made twice each week over all the plants and were arranged so as to follow shortly after each undercutting. One hundred and eighty plants of each treatment were three-fourths topped and transplanted July 28, 2 days after being dug. No leaves remained on any of the plants after they were topped.

Over 50 percent of the plants in two of the treatments (7 and 14 days) showed sprouting 5 days after the topping was done. Final survival counts (8½ months after planting) showed that of the plants undercut 0 day before digging, 71.7 percent survived; 4 days, 73.4 percent; 7 days, 86.1 percent; 14 days, 91.2 percent; and 21 days, 71.2 percent. The plants undercut 7 and 14 days before digging showed a highly significant increase in survival over the controls, while those undercut 21 days before were no better than the controls. It was observed at the time of digging that plants of the last category had reestablished themselves and were already showing new top growth.

In a second trial of undercutting in August 1943 two types of nursery stock were used—3-month-old unhardened plants and 6-month-old partly hardened plants—with a single time of undercutting (7 days before digging). Water was applied 2 days after undercutting. The three-fourths-topped 3-month-old plants gave only 33.9 percent survival when undercut 7 days before transplanting, but less than 3 percent of the check plants survived. The three-fourths-topped partially hardened plants about 6 months old responded as did plants of the first experiment; 86.6 percent of the undercut plants grew in contrast to only 30 percent in the controls. A comparison of topped and untopped plants showed that the preundercutting increased the

TABLE 5.—*Effect of 7-day preundercutting and of three-fourths topping on guayule transplants, August 1943*

[180 plants per treatment]

Age and condition of plants	Plants growing when— Preundercut 7 days: Three-fourths-topped	Plants growing when— Preundercut 7 days: Untopped	Plants growing when— Not preundercut: Three-fourths-topped	Plants growing when— Not preundercut: Untopped
	Percent	*Percent*	*Percent*	*Percent*
3-month-old unhardened plants	33.9	18.9	2.8	0
6-month-old partially hardened plants	86.6	71.1	30.0	11.1

survival of untopped plants (table 5) but not sufficiently to eliminate the need for topping. A treatment not presented in table 5 was one in which topping and undercutting of the 3-month-old plants were both done 7 days before digging. The survival was as poor as it was for the checks.

Preundercut plants are more difficult to top by mechanical means than are the intact nursery plants, but in two trials the operation was successfully accomplished—once in loam at San Clemente and once in sandy soil at Indio. A prerequisite for the mechanical topping of such stock is at least one good watering to firm the soil after undercutting. The watering is also necessary for the prevention of death of the root-pruned plants during warm weather.

Microscopic examination of the taproots was not made for the presence of root primordia at the time of transplanting preundercut plants; but since many new roots were found to emerge during the 1- to 2-week period after undercutting, it is not unreasonable to assume that when preundercut plants are transplanted the chances of having new roots in some stage of formation are very good. New roots already emerged are lost through drying, but those existing as primordia in the bark probably develop after the plant is set out.

This method of preconditioning the plant for transplanting is not as satisfactory as hardening by prolonged drought or cold, but in many cases it might be used to advantage as a supplementary treatment, because of the benefits to be obtained in a short time with partially hardened stock.

Trees are frequently root-pruned in nurseries to effect a change in the root habit or to increase the production of laterals (*6*). Relatively bushy root systems can also be developed on unhardened guayule nursery stock by undercutting the plants and allowing them to remain in the nursery for several weeks under irrigation. One hundred and sixty such plants were carefully bare-rooted in October 1944 and protected against drying until they could be planted the same day in the field at the edge of furrows already containing water. No topping was done, and about 97 percent grew. The new roots of guayule are very delicate, however, and any attempt to retain them during transplanting on a commercial scale would require unjustifiable precautions, especially in view of the great tolerance and regenerative ability of plants properly hardened by drought or cold. Very early root pruning might produce several sturdy laterals in the place of a taproot, but the type of planting machines now in use makes a spreading root system rather undesirable. Also, there is a tendency for lateral roots, when numerous, to become tangled and thus to reduce the efficiency of the workers who handle the plants.

PACKING, SHIPPING, AND STORAGE

Packing, shipping, and storage are important considerations in transplanting guayule on a large scale. Losses of plants resulting from delayed planting are largely due to excessive drying, sprouting, or attacks by fungi.

As the distance between the nursery and field increased, the amount of time that the plants were out of the ground also tended to increase. Local truck hauls in California by the Emergency Rubber Project required a day or two, while shipments by rail from California to

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Texas or Mexico required 10 days to 2 weeks. Rainy weather necessitated storage for several weeks before plants could be set out. Adequate precautions had, therefore, to be taken in packing the plants to cope with the difficulties which arose.

Types of Packing

Containers for guayule nursery stock have not been standardized. One commercial concern used redwood boxes 10 by 18 by 30 inches (inside measurements) for packing the nursery stock. The plants were placed upright in layers alternating with wet moss. Although these containers were durable, they were expensive and heavy (22.5 pounds) and their repeated use, especially in storage, tended to present disease hazards.

The container used by the Emergency Rubber Project was the lettuce crate (13½ by 17½ by 21½ inches inside, weighing 10 pounds with lid and waxed paper). Waxed paper was used to line the crates on four or six sides, and the plants were placed with the tops toward the sides of the crates and the roots toward the centers. Moist peat moss and shingletow in mixtures or shingletow alone was used as packing material. When packing material was not used, a narrower crate would have been advantageous in saving space and facilitating packing. Plants with 2- to 3-inch tops and 6- to 7-inch roots did not overlap sufficiently in the two halves of the lettuce crate to brace themselves or to occupy efficiently the volume of the crate. It was found that as many plants could be accommodated in crates 15½ or 13½ inches wide as in the standard one (17½ inches wide) and that about 90 percent as many plants could be packed in a crate 11½ inches wide.

A preliminary experiment on packing, shipping, and storage [8] indicated that the sprouting of plants was extensive when the moisture content of the packing material was from 200 to 300 percent (dry-weight basis). Lining only four sides of the experimental-size crates with waxed paper did not reduce water loss sufficiently to prevent lethal desiccation of the plants during a shipping period of 24 days in October 1942.

In another packing and shipping experiment [8] waxed paper was used to line all six sides of the crates. Crates of two sizes were used—experimental and standard—and a study of the effect of eliminating all packing material was made. Five replicate crates of each treatment were sent from Salinas to Indio and returned via railway express in January 1943. In the experimental crates the packing material lost most of its water content, but the plants lost very little from the standpoint of desiccation tolerance, regardless of whether packing material was present or absent (table 6). The plants in the crates without packing material did not lose more water from their tops than did those in the crates where packing material was present, but in the case of the roots there was a slight difference. The same response was found in the standard crates except that moisture con-

[8] Unpublished office report by H. P. Traub and L. Machlis, principal physiologist and formerly assistant physiologist, respectively, Special Guayule Research Project.

TABLE 6.—*Moisture contents of guayule nursery stock before and after shipment from Salinas to Indio, Calif., and return, January 1943, when packed with and without packing material and wrapped on 6 sides with waxed paper in crates of 2 sizes*

Kind of crate and layer	Water in— Packing material		Tops		Roots		Sprouting
	Initial	Final	Initial	Final	Initial	Final	
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	
Experimental crates:							
With packing material	107±0.3	34±0.9	60.8±0.3	58.2±0.7	54.8±1.1	54.8±1.1	Slight.
Without packing material	...	...		57.5±1.0		52.0± .4	Trace.
Standard crates:							
With packing material:							
Top layer		161±16		59.6± .1		58.5± .6	Extensive.
Next to top layer	151±7	67± 4	55.2± .3	55.8± .4	56.1± .6	56.4± .5	Slight.
Middle layer		60± 3		55.8± .7		55.6± .8	Do.
Without packing material:							
Top layer				...		...	Extensive.
Next to top layer	...	...	55.2± .3	54.8± .7	56.1± .6	53.9± .8	Trace.
Middle layer				55.9±1.2		54.7± .8	Do.

Adapted from unpublished data of H. P. Traub and L. Machlis.

densed under the cover, resulting in higher moisture contents and more sprouting of the uppermost plants. From this experiment it may be concluded that providing moisture by means of packing material is unnecessary if there is proper insulation against moisture loss. The undesirable features of moist packing material are that it promotes sprouting of the plants and spread of parasitic fungi when they are present.

Temperature and Storage

In an experiment on cold storage of guayule nursery stock experimental crates were used.[10] These were one-sixth the size of lettuce crates and were packed with 200 plants each; waxed paper on 6 sides and packing material of 113± 7.4 percent moisture content were used. Three temperature ranges (28° to 34°, 38° to 42°, and 40° to 60° F.) were employed. After 2-, 4-, and 6-week storage periods the plants of 5 crates from each temperature range were inspected, and half the plants were used for moisture contents and half for survival tests in the field.

The moisture content of the packing material changed greatly during the first 2 weeks and more slowly thereafter (table 7) but at the most rapid rate in the crates of highest temperature range, where the lowest relative humidity occurred. At the end of the first 2 weeks the plants, especially the tops, had increased in moisture content. Thereafter, after the packing material was drier, the moisture contents of the plants slowly decreased at all temperature ranges.

No plants were killed as a result of fungus attack, but parasitic fungi were probably absent. Superficial mold was present in large

Table 7.—*Effect of duration and temperature of storage on guayule nursery stock stored November 4, 1942*

Storage conditions	Water in—			Degree of sprouting	Plants growing (April 12, 1943)	Remarks
	Packing material	Plant tops	Plant tops			
	Percent	*Percent*	*Percent*		*Percent*	
Prestorage	113±7	56.1±0.2	55.5±0.4	None	....	
Stored at 28°-34° F.:						
2 weeks	78±2	59.0± .5	56.1± .4	do	91±1	
4 weeks	75±6	58.2± .4	56.2± .1	do	86±4	
6 weeks	75±4	57.7± .5	55.2± .6	do	96± .4	Leaves green.
Stored at 38°-42° F.:						
2 weeks	79±6	59.7± .9	57.5± .6	do	95±1	
4 weeks	63±4	58.8± .5	56.2± .4	do	91±3	
6 weeks	62±6	56.7± .4	55.5± .5	do	88±2	Slightly moldy; older leaves black.
Stored at 40°-60° F.:						
2 weeks	87±4	58.8± .5	56.3± .4	Trace	94±2	
4 weeks	56±2	57.3± .5	56.2±1.0	Slight	93±2	
6 weeks	49±2	56.8± .4	55.5± .6	Moderate	95±3	Strong moldy odor; leaves black.

Adapted from unpublished data of L. Machlis.

[10] Unpublished office report by L. Machlis.

amounts after 6 weeks at 40° to 60° F., and the leaves were black. At 38° to 42° the older leaves were black, but mold was less abundant. At 28° to 34° the leaves remained green during the 6 weeks of storage and practically no mold was found. Sprouting of the plants in the crates occurred only at the highest temperature range; it was observed at the end of 2 weeks and increased gradually during the subsequent 4 weeks.

A count of plants growing was made in the field plots 4 months after the last planting. Although the length of time in the field was not equal for all plants, the sprouting was practically complete and all percentages were high (table 7). The 28° to 34° F. temperature condition appeared to have no deleterious effects on the plants within the limits of the storage.

A study was made of the activity of *Sclerotinia* in plants stored at the temperature ranges used in the previous experiment.[11] Three replicate crates of plants were kept at each temperature range for examination after 30 and 60 days in storage. Each crate was packed with 200 healthy plants and 10 plants infected with *Sclerotinia sclerotiorum*. After 30 days 4 percent of the healthy plants had become diseased at 28° to 34°, 20 percent at 38° to 42°, and 100 percent at 40° to 60° F. At the end of the 60 days 14 percent were diseased at 28° to 34°, and 60 percent at 38° to 42°. These results indicated that, when a fungus such as *Sclerotinia* is present in the nursery stock packed as in the experiment and if plants are to be stored several weeks, it is necessary to keep the temperature of the plants in storage near 32°.

Many times it is convenient or necessary to store plants without putting them in cold storage. When harmful fungi are not present in the stock the problem is one of preventing desiccation without providing enough moisture for sprouting. An experiment at Indio in January and February 1943 was designed to determine the rates of water loss from crates of plants packed in different ways and stored outside in the shade of a windbreak. The plants were dormant in the nursery at the time of digging. Regular nursery procedures were employed in digging the plants: tops were cut to within 2 to 3 inches of the crowns and undercutting was done at a 6- to 7-inch depth.

The methods of packing were as follows:

1. Waxed paper on six sides; no packing material.
2. Waxed paper on six sides; shingletow with 200 percent moisture.
3. Waxed paper on six sides and overlapping corners; no packing material.

At a later date regular nursery operations provided a fourth method of packing as follows:

4. Waxed paper on four sides; shingletow with 200 percent moisture.

In each treatment the four replicate crates were weighed at intervals during the 37-day storage, and air temperature and relative-humidity records were kept. At the end of the period of storage the crates were opened for inspection of the plants and to take samples of them and of the packing material for moisture determinations.

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[11] Unpublished office report by W. A. Campbell.

The rate of water loss was not equal for the crates of the different treatments (fig. 7). The crates with paper on six sides lost weight at a rate about a third of that for crates with paper on four sides, and overlapping the waxed paper made a reduction of about a third of the remainder. The wet packing material in the crates with paper on six sides did not appear to alter the rate of loss.

Moisture contents of the plants were determined separately for samples from the corners and the interior of crates wrapped on six sides. In the case of those wrapped on four sides only interior samples were taken.

In the crates wrapped on six sides and containing packing material, weight was lost principally from the packing material. A slight loss also occurred from the peripheral plants, especially those nearest the corners where the paper gaped, but the plants in the interior tended to be more turgid than at the start of the experiment. Sprouting was extensive in these crates, with an estimated 75 percent of the plants showing sprouting and new root growth.

The effect of omitting the shingletow from the crates wrapped on six sides has already been indicated as having resulted in no change in rate of water loss. The lower moisture contents of the plants thus treated indicate that drying occurred in the interior plants as well as in the peripheral ones. Practically no sprouting took place.

Overlapping the paper in the corners resulted in better insulation of the plants as indicated by the total change in weight and also in moisture contents of the plants thus treated. Only the peripheral

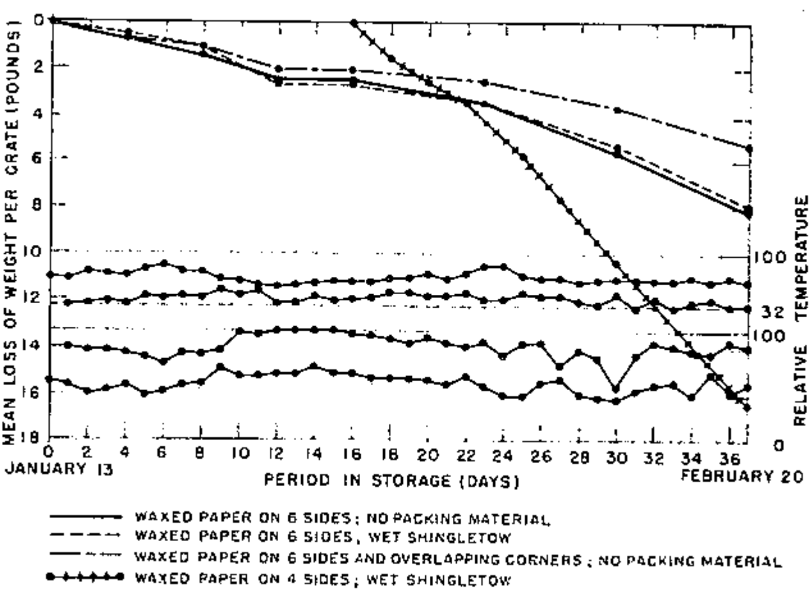

FIGURE 7.—Loss in weight by crates of guayule plants packed as described on page 21 and stored outdoors at Indio for 37 days in January and February 1943. The temperatures and relative humidities are daily maxima and minima. The initial mean weight of packed crates was 64.6 pounds.

plants decreased significantly in moisture content. The sprouting was practically absent.

The crates lined with waxed paper on four sides decreased in weight very rapidly because of loss of moisture from both packing material and plants. From the results of previous experiments it is perhaps safe to assume that most of the loss of moisture from the plants occurred after the packing material had dried considerably. In any event this type of packing is not satisfactory for storage outdoors where the relative humidity gets low daily and much air movement occurs. Sprouting was about as abundant as it was in the crates containing wet packing material and wrapped on six sides.

Desiccation Tolerance

Desiccation tolerance is a measure of the degree of drying which a plant can undergo and still recover readily when water is again made available. The test used in the present work has been that of recovery of the transplants in the field or in pots containing soil.

The procedure in all cases was essentially the same. Plants were randomized on a floor space and allowed to dry for various periods. At the end of each drying period samples were taken for determining moisture contents and planting.

Preliminary results[12] with partially hardened topped stock in October 1942 showed that drying for various periods up to 3 days resulted in a decrease in the number of plants sprouting after 7 to 23 days in pots kept outdoors. Moisture-content changes from the initial 61.3 percent to 55.2 percent did not significantly reduce the rate of recovery over that of the controls, but greater moisture changes markedly decreased the rate of recovery. Since the experiment was discontinued after 23 days, survival values were not obtained.

A study of desiccation tolerance[13] of plants of the same source 1 month later gave data which are essentially total recovery values for the first season in the field (table 8). A comparison was made of potted and field plants in this experiment, and the results showed that the percentage of recovery was not greatly different for the two types.

Table 8.—*Effect of desiccation on the growth of guayule nursery stock*

Drying period[1]	Moisture content		Potted plants sprouted (March 22, 1943)	Field plants sprouted (April 8, 1943)
	Tops	Roots		
	Percent	*Percent*	*Percent*	*Percent*
0 day	56.1 ± 0.5	54.4 ± 1.5	91 ± 2	95 ± 5
½ day	53.6 ± .2	49.8 ± .4	96 ± 2	96 ± 4
1 day	49.4 ± .1	45.8 ± .4	84 ± 5	94 ± 6
2 days	40.1 ± .4	37.4 ± .7	94 ± 4	82 ± 7
3 days	37.6 ± .3	32.9 ± 1.1	86 ± 6	76 ± 9
4 days	34.7 ± .6	31.7 ± .6	68 ± 11	62 ± 5
8 days	26.7 ± .6	26.4 ± .5	26 ± 13	12 ± 8

[1] The drying period began November 24, 1942, and ended December 2. During this time the temperature range was 35° to 60° F. and the relative humidity 81 to 91 percent.

Adapted from unpublished data of L. Machlis.

[12] See footnote 8, p. 18.
[13] See footnote 10, p. 20.

In January 1944 Indio stock was prepared for study. One group of plants was root-pruned (undercut) 7 days before digging and topped when dug; a second group was topped 3 days before digging and root-pruned when dug; and a third group was topped and undercut on the day of digging. All tops were mowed at 2 to 3 inches, and the taproots were severed at 6 to 7 inches. The plants were compared with respect to desiccation tolerance and effects of common storage.

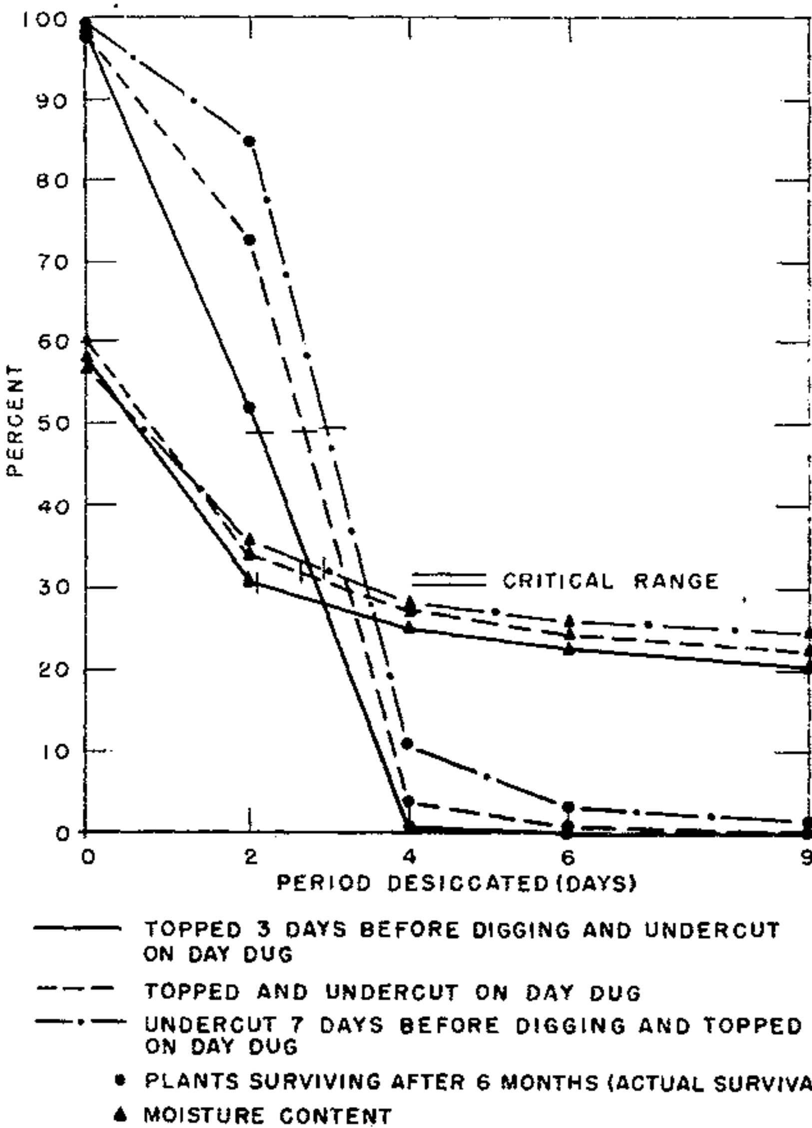

FIGURE 8.—Relation of degree of desiccation before transplanting to percentage of survival of guayule nursery stock grown at Indio, Calif., and subjected to three different treatments prior to transplanting.

The stock was dug and packed (waxed paper on six sides, no packing material) on January 13 and taken to San Clemente for further treatments. Four replicate crates of each treatment were stored for each of 2-day and 2- , 5- , and 10-week periods. Plants for the desiccation tolerance were taken from the crates not stored. Desiccation occurred while plants were spread out on a floor. The results from the study of common storage and desiccation tolerance are presented in figure 8 and table 9. The critical moisture contents, or desiccation tolerances, for the plants of the three treatments did not differ greatly. The critical moisture content was determined by using interpolated values in the percentages of recovery and moisture contents. For example, in the plants topped 3 days before digging the 50-percent recovery point (based on controls) is directly above 30.8-percent moisture. If it is assumed that at 50-percent recovery half of the plants are at or above the critical moisture content and grow and the other half are at or below the critical moisture content and fail to grow, then the mean moisture content for all of the plants would be a fairly accurate measure of the critical value.

TABLE 9.—*Survival and moisture contents of guayule nursery stock subjected to 3 predigging treatments and stored for various periods*

Prestorage treatments and storage periods[1]	Plants surviving	Moisture content
Plants undercut 7 days before digging and topped at digging time:	*Percent*	*Percent*
2 days	100	57.5
2 weeks	97.5	55.9
5 weeks	94.5	54.0
10 weeks[2]	97.0	52.8
Plants undercut at digging time but topped 3 days before:		
2 days	99.5	58.5
2 weeks	97.0	57.6
5 weeks	89.5	58.2
10 weeks[2]	92.5	57.8
Plants undercut and topped when dug:		
2 days	99.0	61.3
2 weeks	97.5	58.3
5 weeks	91.0	57.8
10 weeks[2]	95.0	57.5

[1] Temperature range 42° to 74°; mean about 55° F. Relative humidity range 10 to 80 percent, mean about 60 percent.
[2] Irrigated after planting.

For the storage part of the experiment plantings (table 9) were made on January 15, January 27, February 17, and March 23. The last count of plants growing was made on May 20. The percentages are high for each of the three treatments for all the periods of storage. The slight drop in recovery for plants stored 5 weeks might have been associated with the climatic conditions. In table 10 the dates and amounts of rainfall which occurred during the experiment are presented; it is interesting to note that after the planting on February 17 there was a period of wet weather.

Moisture contents of the stored plants remained rather high throughout the 10-week period. Very few plants sprouted in the crates, and all of the sprouting seemed to take place during the first 2 weeks of storage. A slight amount of superficial mold was observed at the end of 2 weeks; but parasitic fungi did not appear to be present, as no evidence of their activity was observed.

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TABLE 10.—*Rainfall at San Mateo nursery, San Clemente, Calif., during period of making plantings from the guayule storage experiment*

Date	Amount of precipitation	Date of planting
	Inches	
Season to date	6.63	
January 3	.19	
January 6	.21	
January 15	0	January 15.
January 27	0	January 27.
February 5	.18	
February 14	.04	
February 16	.03	
February 17	0	February 17.
February 20	.53	
February 21	.35	
February 22	1.38	
February 23	.83	
February 25	.07	
February 26	.24	
March 1	.45	
March 4	.08	
March 13	.18	
March 23	0	[1] March 23.
April 27	.71	

[1] Planting irrigated same day.

In general, the preundercut plants seemed to show greater desiccation tolerance than either pretopped or check plants. Perhaps the preundercutting made the stock slightly hardier as indicated by the slightly lower initial moisture content.

In another experiment on desiccation plants were selected on the basis of caliper from a single location of the nursery. The plants used were 3/16, 1/4, and 3/8 of an inch in diameter at the root crown. Approximately equal amounts of plant tissue were used; so in each of 5 replications 40, 25, and 10 plants were used for the 3 sizes, respectively. The plants were weighed at intervals over a 9-day period and then dried in the oven (100° C.) for determination of their dry weights. Percentages of moisture were calculated for each time of weighing, and the values obtained were plotted (fig. 9). The results showed that 1 of the factors in the rate of desiccation is size of plant. It was found that the plants of small diameter dried out more rapidly than did the larger ones. This difference is of considerable importance when irrigation or rain does not follow planting within a short time, especially under conditions of rather dry soil and warm weather.

Desiccation tolerance was also studied in relation to watering the plants before digging. Well-hardened 18-month-old plants were used before the winter rains began in October 1944 at Salinas (table 11). Half of the plants were watered 2 days before digging and the rest were left dry. Plants with roots pruned to 6 inches and tops pruned to 2 inches (leafless) were used. Moisture determinations for wet and dry plants were made at the beginning of the desiccation. At 0, 3, 6, 9, and 12 days, 10 replicate bunches of plants were picked up and wrapped in waxed paper and then plunged in moist shingletow. On the fifteenth day after digging, the plants were unpacked for a determination of moisture contents and for the planting of samples in the field and in crocks of soil in the greenhouse. For each desiccation period 70 plants were planted in the greenhouse and 100 in the field.

The initial moisture contents for wet and dry plants differed by about 10 percent (that is, wet plants were 50.7 percent and dry ones 40.8). After 15 days in storage under the conditions mentioned, the wet plants had become 2.6 percent drier and the dry ones had become 0.4 percent moister. The plants which were desiccated 3 to 12 days had descending moisture contents, with slightly higher values for the plants watered before digging than for those not watered (table 11).

After 11 weeks the growing plants in crocks in the greenhouse were counted. Under the conditions used there was no significant difference in numbers growing between the wet and dry plants, although for the 9- and 12-day desiccation periods there were fewer dry plants recovered than wet ones (table 11). In the case of the samples planted in the field, however, counts after 4½ months showed a highly significant difference between the watering treatments. The plants in the greenhouse were watered immediately after they were planted, but those in the field were set in moist soil and received only rainfall. The conditions in the field may have served to exaggerate the difference in survival due to watering the nursery stock before digging.

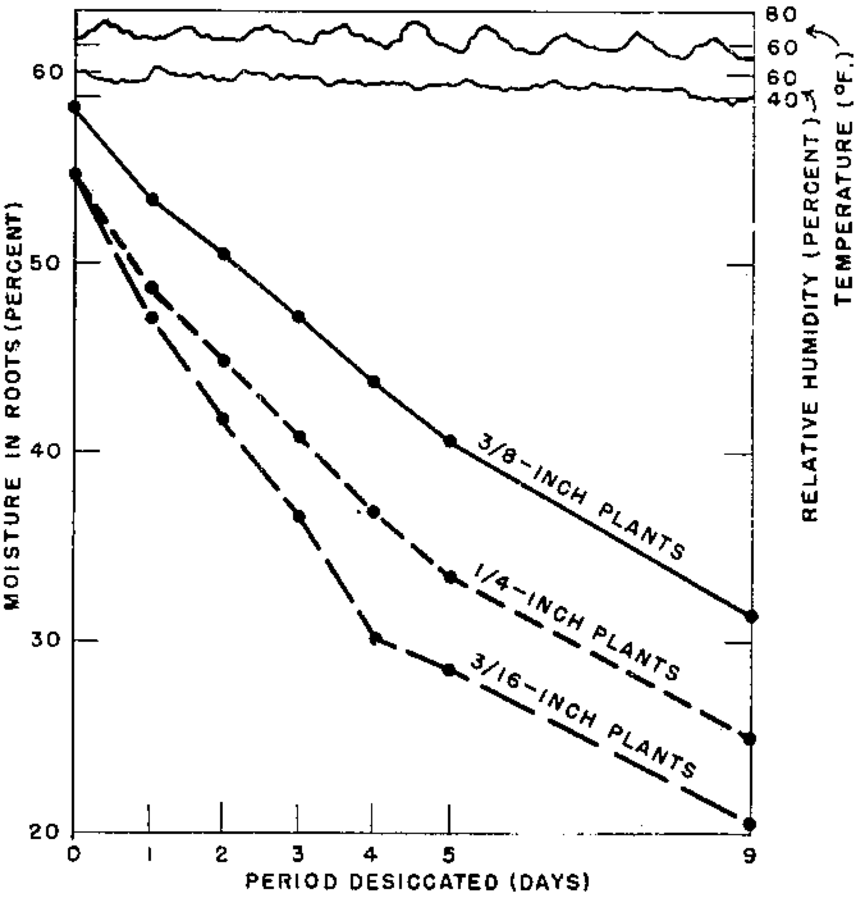

FIGURE 9.—Relative rates of desiccation of guayule nursery stock in relation to size of plant. The plants had 6-inch taproots with the laterals removed and were three-fourths-topped, so that no leaves remained.

TABLE 11.—*Effect of watering well-hardened 18-month-old guayule nursery stock 2 days before digging on desiccation tolerance*

Predigging treatment and desiccation period	Moisture content	Plants surviving when planted in—	
		Greenhouse	Field
	Percent	*Percent*	*Percent*
Watered:			
0 day	48.1	97.1	96
3 days	39.8	97.1	99
6 days	32.1	91.4	92
9 days	29.7	64.3	73
12 days	28.5	45.7	40
Not watered:			
0 day	41.2	95.7	95
3 days	36.2	100	94
6 days	30.2	88.6	90
9 days	27.8	54.2	46
12 days	26.0	35.7	19

HEATING

Unhardened guayule plants heat very readily when packed, as was determined by an experiment in April 1943, when unhardened nursery plants were sent from Carlsbad to Salinas, Calif. During 3 days in transit via railway express the plants heated to such an extent as to become blackened and dead.[14]

Such damaging effects can be overcome without refrigeration by properly packing the plants to dissipate the heat. Moist shingletow (150 to 200 percent moisture) as a packing material in crates half the standard size and wrapped with waxed paper on four sides was found to be effective in dissipating the heat during a 5-day packing and shipping experiment in May 1943.[15] Unless some special procedures, such as transplanting root-pruned plants, are in progress, however, there is little reason for packing unhardened stock as it will not survive ordinary methods of transplanting anyway.

Ordinarily, in common storage the external temperature fluctuates several degrees daily and it is not easy to detect slight heating of hardened stock. With this in mind an experiment to determine the extent of heating in well-hardened stock was started February 23, 1945. Stock of two heights was chosen to provide both leafless and somewhat leafy 3-inch tops. Six standard crates of each type were packed with waxed paper on six sides. Three of each were placed in storage at 36° to 38° F. and an equal number at 76° to 78°. Elements of soil thermographs were inserted in one crate of leafy plants and one crate of leafless plants at the higher temperatures. A Weston dial thermometer was inserted in each crate. During the experimental period no rise in temperature above that of the storage rooms could be detected in any of the crates. Examination of the plants at the end of 18 days revealed that at the higher temperature all the old leaves had dried and about half of both leafy and leafless plants had sprouted; peripheral plants showed moderate desiccation of stems and roots. Total loss of net weight by the plants was 10.2 percent.

[14] See footnote 10, p. 20.

[15] Unpublished office report by L. Machlis and L. C. Erickson, formerly assistant physiologists, Special Guayule Research Project.

On plants in cold storage no sprouting was observed and the leaves appeared green and unchanged. The conditions attending the plants of the lower temperature had reduced the loss in net weight to 3.6 percent, or to about one-third of that at the higher temperature.

This experiment substantiated general observations in other experiments that topped stock in a hardened, nearly leafless conditon did not liberate heat rapidly enough to increase the temperature of the plants noticeably, at least not when air circulation occurred among the crates, even in the temperature most favorable for respiration.

TRANSPLANTING AND POST-TRANSPLANTING RESPONSES

Degree and Season of Topping

In order to test the possibilities of transplanting over a larger part of the year than the usual winter and spring season, an experiment was set up for making monthly transplantings for a year. One nursery bed with approximately 30,000 seedlings was selected because it contained fairly uniform plants throughout. The bed had been sown May 1, 1943, and had grown with abundant moisture until September 1, when it was chosen from several others that had received the same treatment. No further water was given the plants, except the necessary prewatering of the section to be dug. During the period September 1, 1943, to October 1, 1944, approximately 13.6 inches of rain fell in the vicinity of the nursery and 80.1 percent of this occurred during December, January, and February (fig. 10). The plants made a slight growth in April as evidenced by a few new leaves and scattered flowers on approximately 10 percent of them. Thus the plants were either drought dormant or cold dormant during most of the experimental period.

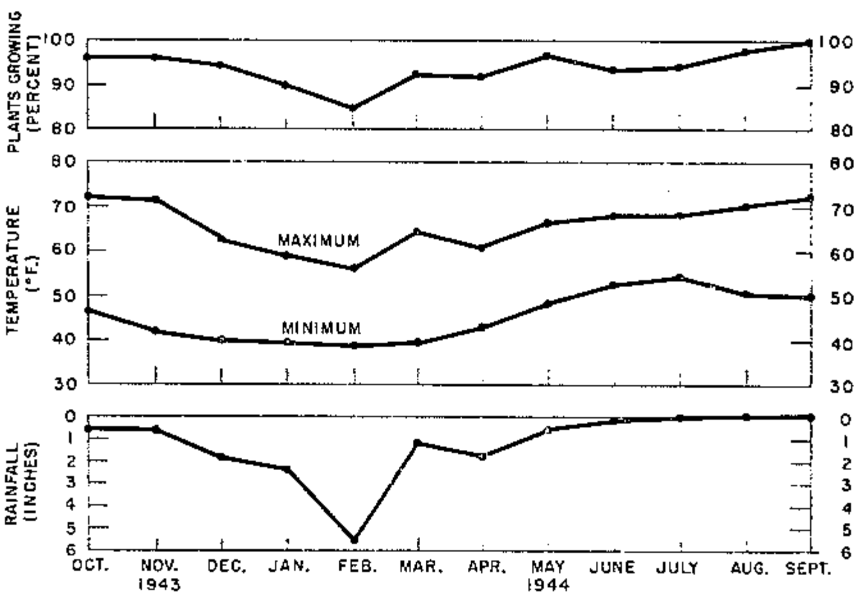

Figure 10.—Survival of seven-eighths-topped guayule plants in 12 consecutive monthly transplantings, together with monthly mean maximum and mean minimum temperatures and monthly rainfall.

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For each transplanting a section of the bed was dug. During December, January, and February prewatering was unnecessary as the ground was already moist, but during all other months the plants were prewatered 18 to 24 hours before digging. The plants were selected for uniformity of size as judged from root-crown diameter, stem height, and single, healthy taproots. Absolute size criteria for the whole period were not established, since it was realized that the stock would vary somewhat in different parts of the bed and also

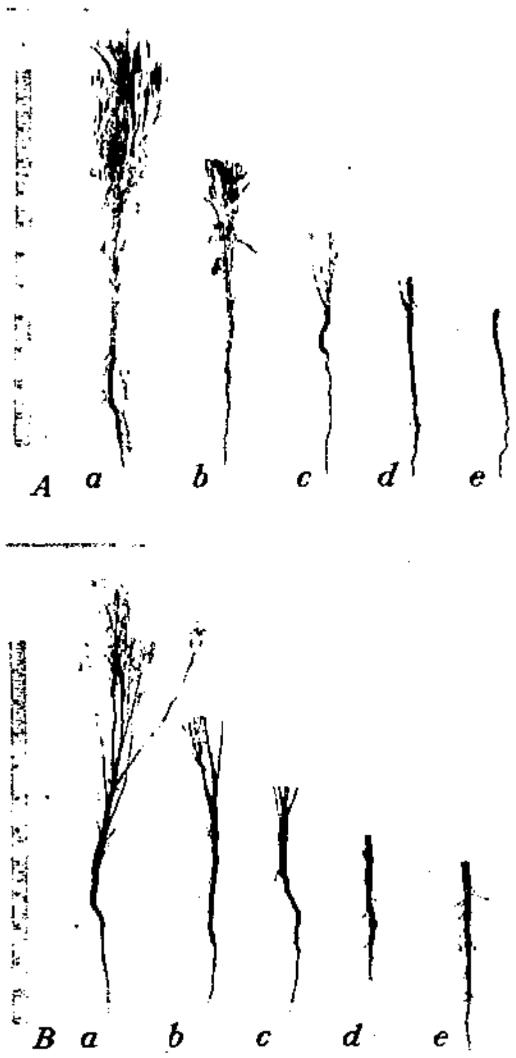

FIGURE 11.—Guayule plants topped to five levels and used in monthly transplanting experiments in November 1943, when they were 6 months old (A) and in June 1944, when they were 13 months old (B): *a*, Untopped; *b*, half-topped; *c*, three-fourths-topped; *d*, seven-eighths-topped; *e*, topped to crown.

that at least the diameter of all plants would change during the period of the experiment. Therefore, the plants were selected within general limits of 5- to 9-mm. (approximately 6/32- to 11/32-inch) diameter at the crown and between 16- and 24-cm. (approximately 6¼- to 9½-inch) stem height and all roots were pruned to lengths which varied only between 15 and 18 cm. (6 and 7 inches). The selected plants of each monthly group were then randomized into 52 bunches of 20 plants each. To these, 5 topping treatments were applied (10 bunches, or 200 plants, per treatment), and 2 bunches (40 plants) were used for gross measurements and carbohydrate determinations.

The plants were arbitrarily topped in such a manner that the following amounts of top, or stem, (by height) were removed: None, one-half, three-fourths, seven-eighths, and all (topped to crown) (fig. 11). The absolute units for these topping levels were based on the plants selected for the initial planting and were used for all plantings. Topping to these levels left all (approximately 8 inches), 11.2 cm. (approximately 4 inches), 5.6 cm. (approximately 2 inches), 2.8 cm. (approximately 1 inch), and none of stem remaining.

After the digging, selecting, randomizing, and topping, the plants were wrapped as individual bunches in heavy waxed paper. This entire process required 2 to 3 hours for preparation of the 1,000 transplants. The planting took place in all cases in less than 24 hours after digging. The planting was done by hand in randomized field plots, and furrow irrigation was applied within 24 hours except during the rainy months (December, January, and February), when the ground was wet by frequent showers. The December planting was made in the rain, showers fell before and after the January planting, and 2.05 inches of rain fell on the fourth day after the February planting.

Figure 12 shows the mean crown diameter, height of stem (including highest leaf), the dry weights of leaves, stems, and upper 6 to 7 inches of taproot, and the reserve carbohydrate content of the plant axes after removal of the leaves, as determined from samples of the stock used in each planting. Perhaps the main source of variation in these measurements was the variation in plant size in different parts of the nursery bed. Since the plants were dug by machine, it was not feasible to randomize the areas for each individual supply of nursery stock. Probably the most important thing to be noticed is that the over-all size of stock changed very little while standing in the nursery for 12 months. Growth appears to have been retarded by cool temperatures in the winter season and by lack of water in the summer season.

Although there appears to be no standardized way of determining the degree of hardening of plants, it is perhaps useful to describe in general terms the condition of the stock as it was in the nursery during the various seasons. After cessation of watering on September 1, 1943, there was little change in appearance of the plants prior to the first transplanting on October 5. Severe wilting never resulted (probably because of the heavy clay soil), but the lower leaves started to fall in October and flowering stopped earlier than on stock that continued to receive water. Carbohydrate analyses indicated that reserves were accumulated during the winter (fig. 12). In the spring these reserve carbohydrates were utilized for new growth, as indicated by the much lower percentages at that time.

Since no water was applied during the second summer and the rainfall was very slight after April 15, 1944, the nursery plants quickly exhausted the readily available water from the soil before much new growth was made. General inspection showed approximately 0.5 cm. of new stem added to each old branch. Only about 10 percent of the plants in the nursery bed flowered at all during the spring and summer. With the onset of drought conditions the levulin content quickly rose and there was a further shedding of leaves, which left only terminal clusters of small leaves (fig. 11). The plants would be considered drought-hardened from the latter part of June through September, and in general they were in exceptionally good condition for transplanting during this period when topped sufficiently to remove the leaf clusters.

Subsequent to transplanting, each plot was irrigated once. Thus, during the summer and fall months it was necessary for the plants to recover quickly or else soon be limited by a moisture deficit. The data shown in table 12 were taken at various lengths of time after transplanting and include only those plants that definitely showed new top growth. In the late-fall, winter, and early-spring months a longer time than in the warmer months was required for new growth to appear in all treatments. Plants destroyed by cultural

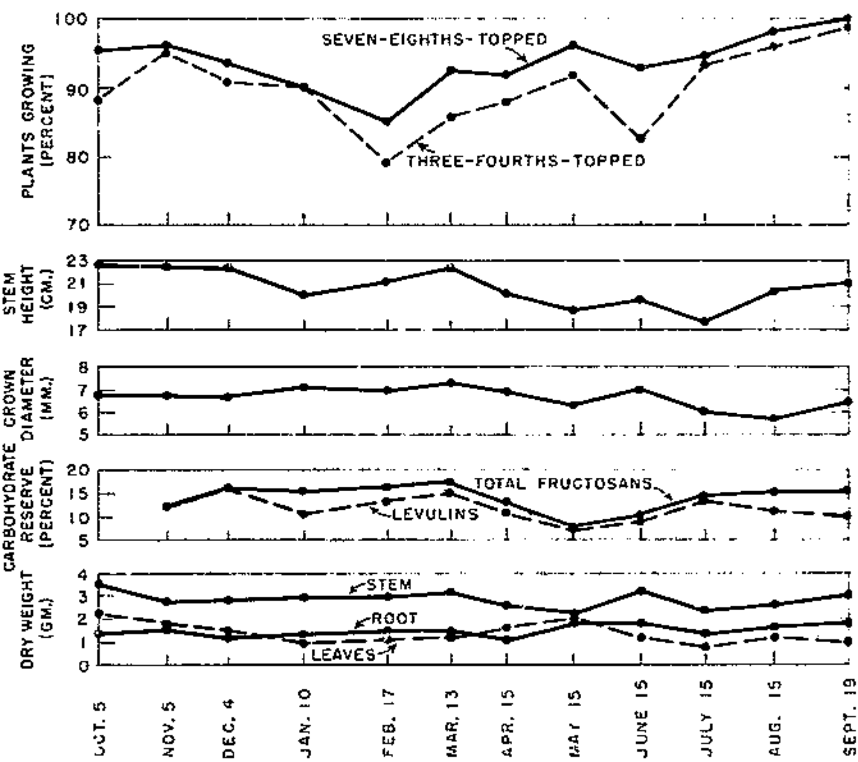

FIGURE 12.—Measurements, weights, reserve carbohydrate contents, and recovery of guayule plants in 12 consecutive monthly transplantings.

TABLE 12.—*Relation of date of transplanting and extent of topping to growth resumption in guayule*

Transplanting date and kind of stock	Plants growing [1]	Period to reach percentage shown
1943	*Percent*	*Days*
October 5:		
Untopped	32.5±3.3	228
Half-topped	78.0±5.2	228
Three-fourths-topped	87.3±3.2	46
Seven-eighths-topped	96.3±1.4	25
Topped to crown	91.9±1.6	17
November 5:		
Untopped	61.0±3.0	199
Half-topped	93.4±2.0	199
Three-fourths-topped	95.9±2.0	160
Seven-eighths-topped	97.0±1.6	36
Topped to crown	95.0±1.5	24
December 4:		
Untopped	14.5±1.7	170
Half-topped	65.5±5.5	170
Three-fourths-topped	91.0±2.9	146
Seven-eighths-topped	93.4±1.6	121
Topped to crown	71.4±4.6	121
1944		
January 10:		
Untopped	18.5±3.8	187
Half-topped	86.0±3.7	134
Three-fourths-topped	90.5±2.8	110
Seven-eighths-topped	90.0±3.3	75
Topped to crown	81.1±2.4	75
February 17:		
Untopped	13.5±2.3	148
Half-topped	29.0±3.7	95
Three-fourths-topped	79.0±4.3	68
Seven-eighths-topped	84.9±3.2	46
Topped to crown	77.7±4.4	46
March 13:		
Untopped	12.0±2.2	113
Half-topped	35.0±3.8	113
Three-fourths-topped	85.5±3.8	33
Seven-eighths-topped	92.5±1.7	33
Topped to crown	88.0±2.4	33
April 15:		
Untopped	54.5±4.9	91
Half-topped	72.0±4.7	91
Three-fourths-topped	87.0±2.8	[2] 28
Seven-eighths-topped	92.0±2.0	[2] 28
Topped to crown	84.0±4.3	[2] 28
May 15:		
Untopped	72.0±6.2	85
Half-topped	71.0±2.6	85
Three-fourths-topped	91.9±1.7	60
Seven-eighths-topped	96.5±1.5	[2] 30
Topped to crown	92.5±1.2	[2] 30
June 15:		
Untopped	4.0±0.9	86
Half-topped	51.5±5.7	55
Three-fourths-topped	82.5±4.0	55
Seven-eighths-topped	93.5±1.1	[2] 30
Topped to crown	98.0±1.0	[2] 30
July 15:		
Untopped	6.5±2.0	56
Half-topped	53.5±4.6	56
Three-fourths-topped	93.0±2.4	[2] 25
Seven-eighths-topped	94.5±1.6	[2] 25
Topped to crown	98.0±1.5	[2] 25
August 15:		
Untopped	13.5±3.1	64
Half-topped	91.5±2.1	64
Three-fourths-topped	96.0±1.4	[2] 27
Seven-eighths-topped	98.0±0.8	[2] 27
Topped to crown	96.0±1.6	[2] 27

See footnotes at end of table.

TABLE 12.—*Relation of date of transplanting and extent of topping to growth resumption in guayule*—Continued

Transplanting date and kind of stock	Plants growing [1]	Period to reach percentage shown
1944	*Percent*	*Days*
September 19:		
Untopped	8.7±2.2	53
Half-topped	86.9±2.6	53
Three-fourths-topped	98.0±1.3	[2] 30
Seven-eighths-topped	100.0±0	[2] 30
Topped to crown	98.7±1.3	[2] 30
12-month mean:		
Untopped	25.9±6.8	
Half-topped	67.8±6.2	
Three-fourths-topped	89.9±1.7	
Seven-eighths-topped	94.0±1.2	
Topped to crown	89.5±2.5	

[1] The percentages did not increase after the period shown within the 36-month period of this experiment.
[2] No earlier counts made.

operations were omitted from the percentage calculations. Damage from jack rabbits was prevented by fencing. This was an important consideration as other unprotected plantings were foraged by this rodent to a considerable extent.

The plants not reported as growing in table 12 need not all be presumed to be dead, as a large proportion of the nongrowers remained alive, but vegetatively inactive, for at least 12 months after being transplanted. The counts presented for each monthly planting were the highest values in period indicated, and they had steadily increased. Under the conditions of these tests the counts made thereafter did not change appreciably, but an additional number probably started to grow during the second spring (1945).

From table 12 and figure 10 it can be seen that the seven-eighths-topped plants consistently showed high percentages that grew after transplanting. Those three-fourths-topped were similar but gave a slightly lower percentage (fig. 12). All other degrees of topping showed greater seasonal fluctuation. Plants topped to the root crown did very well in the periods that permitted quick growth, but they showed a decrease in the fall and winter months when temperatures did not permit rapid growth (fig. 10). Transplants topped to this degree appeared to be more susceptible to rotting than the other groups when quick growth resumption was not possible. Very good sprouting was also shown by the three-fourths-topped plants during the late-summer and early-fall period of the 1944 season, at which times the plants possessed no old leaves when topped.

Untopped and half-topped plants were highly variable, but as a whole they were not satisfactory in respect to quick reestablishment.

In order to show the relation of season of the year at which the plants were transplanted and the severity of topping to survival, figure 13 is presented. These graphs show the advantage of severe topping for all seasons and the disadvantage of no stem material in the winter and spring months. There was a definite tendency toward lower survival percentages for plants transplanted during the winter months. This response was due at least partly to a slow rate of sprouting at low temperatures and the consequent changes brought about thereby. As shown in table 12 there was a steady drop in the survival percentages of the seven-eighths- and three-fourths-topped groups from November through February with higher survivals thereafter.

The effect of season on survival of the most favorable topping level (seven-eighths-topping) is shown in figure 10. It may be seen that there is a close correlation between the mean maximum temperature and survival. Statistically this is highly significant (*t* value of 0.861 with 0.834 required at the 1-percent level). Also the negative correlation between rainfall and survival is highly significant (t = 0.952 with 0.834 required at the 1-percent level). It is impossible to say from the available data which of the two environmental factors is more important in accounting for the decreased survival in the winter months. As shown elsewhere in this bulletin, the temperature in the winter practically precludes vegetative activity in guayule. Also, under exceedingly wet conditions the plants are more likely to rot (*4, 18*).

Quick recovery and high percentages of survival are the primary considerations in transplanting guayule. Other questions, however,

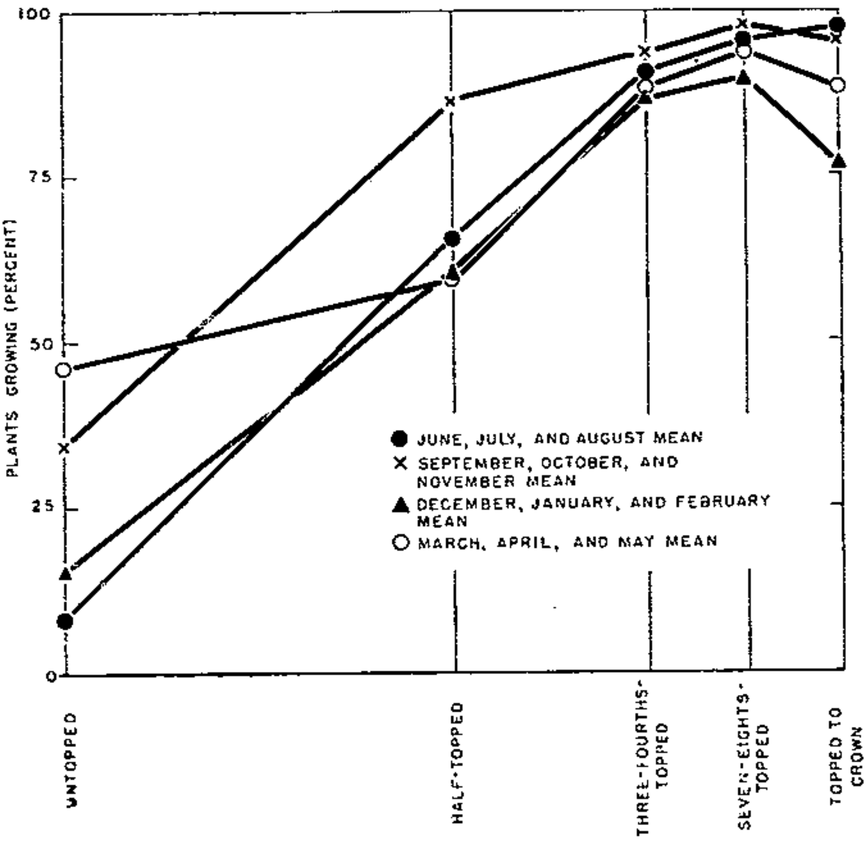

FIGURE 13.—Relation of degree and season of topping to survival of guayule transplants, Salinas, Calif.

TABLE 13.—*Fresh weights of guayule shrubs resulting from transplants topped to different levels*

Transplanting date	Approximate period in field	Mean weight per plant topped as indicated				
		Untopped	Half-topped	Three-fourths-topped	Seven-eighths-topped	Topped to crown
	Months	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
October 1943	15	[1] 241.9±16.0	243.0±15.8	267.7±15.9	262.3±13.7	265.9±15.8
December 1943	13	[1] 184.6±20.2	196.7± 8.2	173.2± 7.6	154.1± 7.6	149.9± 5.4
February 1944	11	[1] 83.3±13.5	[1] 126.5±12.1	131.1± 4.8	131.0± 3.6	123.7± 2.7
April 1944	9	143.3± 3.3	148.1± 4.3	135.8± 4.1	133.3± 5.5	150.8± 4.9
June 1944	7	[1] 48.1±12.7	73.6± 5.3	61.7± 3.6	62.1± 4.0	59.8± 2.8
August 1944	5	[1] 19.8± 3.5	36.3± 2 1	35.8± 1.9	35.7± 1.8	30.5± 1.5
Mean	....	120.2	137.4	134.2	129.8	130.1

[1] Each value is a mean of 100 plants except in cases such as this where 100 plants did not grow.

are worthy of consideration. (1) Is the size of the resulting plant affected in any way by the degree of topping? (2) Is the shape of the resulting plant affected by the pruning done at the time of transplanting? Some information has been gained on both of these points, although the limited time of the experiments prevents a final conclusion as to the importance of the observations. Table 13 shows the mean fresh weight of 10 growing plants for each replication (100 plants in each mean except where fewer plants were growing as, for example, when they were untopped) for 6 of the 12 monthly plantings as found on January 2, 1945, more than 100 days after the final planting (September 19, 1944). In most cases only 1 to 5 untopped plants of the original 20 per replication were growing. In some cases these started to grow only a few days later than those topped short, yet the mean weight was less in each of the 6 plantings sampled than in some of the topped plants. There was considerable variation in the mean weights of these young plants, some of which is not readily explainable. The mean weight of plants in each topping treatment of the February planting was, respectively, less than those of the April planting even though the former was in the field 2 months longer than the latter at the time of harvest. This was also true of the percentage of plants growing and may be related to some edaphic factor, physiological condition of the plants, or some unmeasured variation in cultural practice.

A more direct comparison of resulting plant sizes is shown in table 14, which gives the fresh weight of the largest single plant in each plot of 10 plants (9 replications and 2 different nursery stocks) grown from April 17 until December 15, 1943, with 5 irrigations during the summer period. The comparison is between untopped transplants and those three-fourths-topped (2 inches of stem remaining). These 18 plants were growing within 21 days after transplanting, but under these conditions they showed no significant difference in size after the first year's growth, regardless of the initial topping.

As for the resulting shape of the plant as a consequence of pruning at the time of transplanting, it was evident at all seasons of the year

TABLE 14.—*Effect of topping on the fresh weight per plant of the largest guayule plant per replicate, planted April 17, 1943, after 1 season's growth under irrigation*

Stock A (dug at time of transplanting)		Stock B (dug in February and stored 60 days at 30°–34° F.)	
Untopped	Three-fourths-topped	Untopped	Three-fourths-topped
Grams	*Grams*	*Grams*	*Grams*
357	293	446	423
364	438	389	482
291	455	577	464
306	493	485	390
311	381	480	461
305	447	447	506
491	374	453	339
411	331	490	395
396	406	542	596
[1] 381±26	[1] 402±21	[1] 479±19	[1] 451±25

[1] Mean; differences between untopped and three-fourths-topped stock not significant.

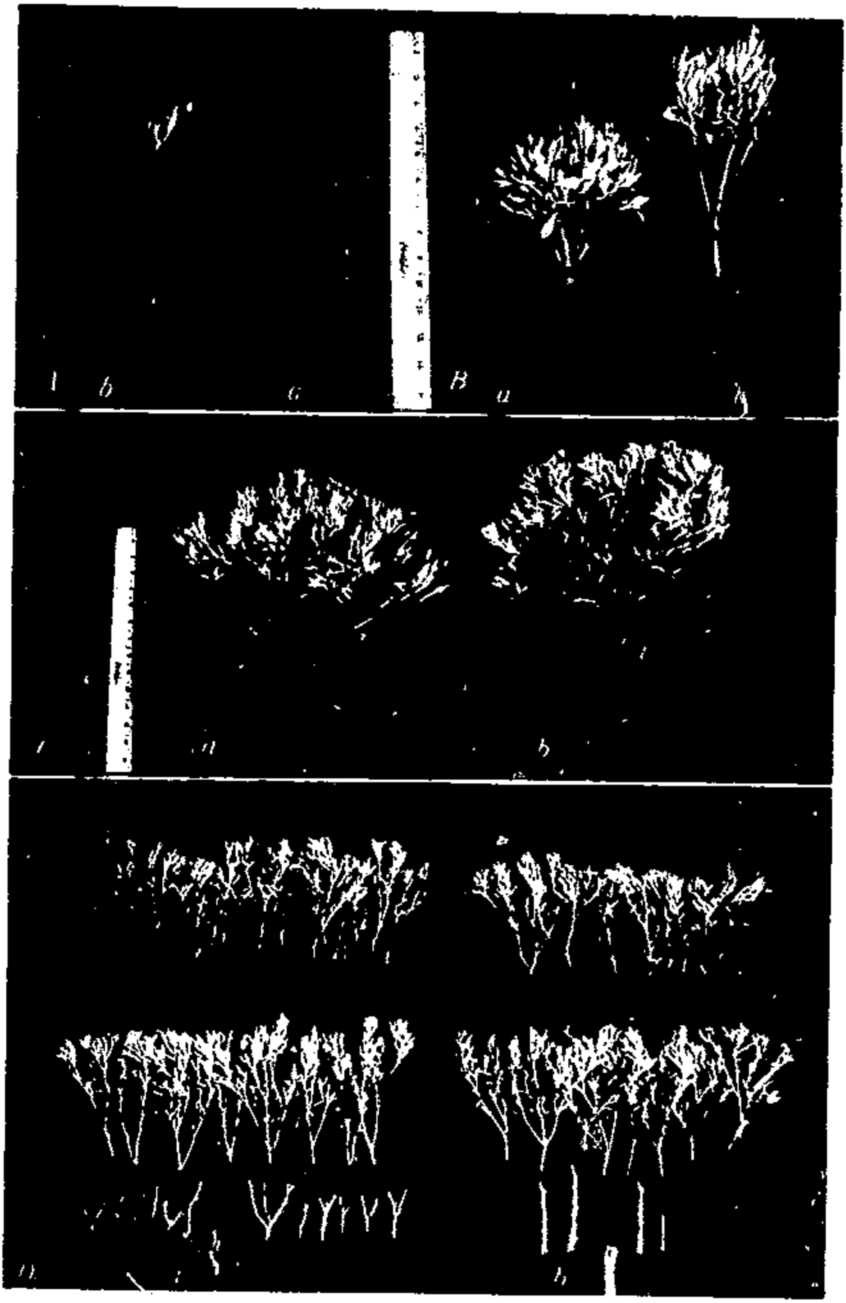

FIGURE 14.—Representative guayule plants as they appeared when transplanted (*A*), after 4 months in the field under fall conditions (*B*), and after 15 months in the field (*C* and *D*): *a*, Topped; *b*, untopped. The plants in *D* were cut apart. Note the many small main branches of the topped plant (*a*) and the fewer larger main branches of the untopped plant (*b*); this difference seems to be persistent.

that the more severely the plants were pruned the more closely the resulting bush grew to the ground (fig. 14). Also, the branching was affected by topping with an increased number of branches resulting in the more severely topped plants (three-fourths-, seven-eighths-, and crown-topped groups). Whether these responses are overcome after the first 15 months of growth is not known, however; but, as shown in figure 14, *D*, there is a larger number of branches from the original stock topped below the leaves. This effect is similar to that resulting from pollarding established plants (*14*).

An important consequence of this difference in form between untopped and three-fourths-topped plants is found in rubber contents, as is shown in table 15, where rubber percentages are presented for 8-month-old shrubs matched for size. These plants of very nearly identical mean size show a significant difference in rubber percentage in favor of the topped plants. The probable reason for this difference lies in the greater bark-to-wood ratio of the smaller and more numerous branches of the three-fourths-topped plants.

TABLE 15.—*Rubber contents of untopped and three-fourths-topped guayule transplants after 8 months in the field with 5 irrigations during the summer*

[Plants were matched for size; each determination is a mean value for 4-plant replications]

Untopped plants		Three-fourths-topped plants	
Dry weight per plant	Rubber content	Dry weight per plant	Rubber content
Grams	*Percent*	*Grams*	*Percent*
99.2	4.80	105.0	5.18
98.7	5.18	101.5	5.67
90.6	4.83	91.7	4.92
75.6	4.71	77.7	5.97
75.2	4.54	70.0	5.43
[1] 87.9	[1 2] 4.81	[1] 89.2	[1 2] 5.43

[1] Mean.
[2] Value required for significance at 5-percent level between mean rubber percentages is 0.57 percent.

The 15-month-old plants appear to be of equal size in figure 14, *C*, but the difference between three-fourths-topped and untopped plants after they were cut up is clearly shown (fig. 14, *D*). It may be seen that there were three times as many main branches in the topped plant as in the untopped one. The smaller diameter of the more numerous branches indicates a higher bark-to-wood ratio, or more parenchymatous tissue for storing rubber.

Additional data showing the tendency of topping to produce a shrub with slightly higher rubber percentage are presented in table 16. The grams of rubber per plant were calculated to show that when size of plant is also taken into account the difference between topped and untopped plants tends to become greater. This comparison of topped and untopped plants would naturally apply only to nursery stock of the shape used in the studies. It will be recalled that the long axis of untopped plants (fig. 2) was the result of dense stands in the nursery. Much shorter nursery stock or less crowded plants of the taller sort would probably not show these differences between topped

TABLE 16.—*Effect of topping guayule nursery stock on size of plant and rubber content*

Planting date	Period in field	Plants harvested	Topping level	Dry weight per plant growing [1]	Rubber content	Rubber per plant	Plants growing
	Months	*Number*		*Grams*	*Percent*	*Grams*	*Percent*
April 1943 [2]	8	37	Untopped	90.6±6.9	3.32±0.07	2.98±0.20	88 ±2.5
Do [2]	8	37	Three-fourths-topped	103.5±5.9	3.34± .11	3.42± .15	93 ±1.5
Do	8	33	Untopped	76.3±7.4	4.77± .07	3.63± .37	84 ±4.0
Do	8	35	Three-fourths-topped	106.9±7.6	5.26± .15	5.61± .43	88 ±2.9
October 1943	15	76	Untopped	65.1±4.2	5.09± .07	3.33± .17	32.5±3.3
Do	15	100	Half-topped	65.3±3.5	5.12± .12	3.32± .12	78.0±5.2
Do	15	100	Three-fourths-topped	75.0±2.5	5.17± .06	3.86± .11	87.3±3.2
Do	15	100	Seven-eighths-topped	71.1±3.5	5.16± .16	3.70± .17	96.3±1.4
Do	15	100	Topped to crown	68.4±1.9	5.20± .18	3.56± .14	91.6±1.6

[1] April planting was irrigated 5 times; October planting was irrigated once (immediately after planting).
[2] Stock dug in February and stored 60 days at 30°–34° F.

and untopped plants so definitely. However, the important point of the comparison has been to demonstrate that topping of nursery stock has not had deleterious effects on size, shape, or rubber content of the shrubs produced, but it has tended to result in a theoretically ideal plant; namely, one with many small branches and, thus, high bark-to-wood ratio for the storage of larger amounts of rubber.

Root Length

Two experiments were conducted to test the relation of root lengths to responses after transplanting in the field. On October 1, 1943, at San Clemente there was made one experimental field planting in which the length of root and the height of top were varied in combination. The planting was made in randomized blocks with 20 plants per replicate and 10 replications. Four lengths of top were included, but the data for only half- and three-fourths-topped plants are presented (fig. 15). The plants showed slower sprouting rates and lower survival percentages as the length of top was increased in all root-length categories. The half-topped plants bore several leaves, whereas many of the three-fourths-topped ones were leafless. The plants growing in the first 30 days were able to do so by virtue of the initial irrigation at the time of transplanting. There was no appreciable increase thereafter until the winter rains fell, beginning in December, after which all groups showed increases. The 200-day counts represent survival under the conditions used, as the lack of water thereafter precluded sprouting. A combination of 7-inch roots and removal of three-fourths of the top gave the quickest starting and the highest percentage of plants that grew. When the roots were 9 inches long the survival of the three-fourths-topped plants was slightly but significantly less and that of the half-topped ones insignificantly less.

A similar experiment at Salinas showed similar results except that there was an insignificant difference in the ultimate number of plants growing in the 5-, 7-, and 9-inch root classes after 180 days. There was, however, a positive correlation between the length of root and the rate of sprouting (fig. 15).

It is perhaps well to emphasize that these experiments were both started during the fall and that the plants with the shorter roots probably had their optimal chance of surviving during this period. Summer plantings would most likely exaggerate the differences found, since a greater water deficit in the short-rooted plants would accompany the higher temperatures of this season.

In order to gain some insight as to the relative ability of different portions of the taproot to regenerate lateral roots, in August 1944 there was conducted a greenhouse experiment in which the transplants were placed in aerated water. It was desired to determine to what extent the structure (longitudinal position) of the taproot governs the development of new laterals. In other words, is it desirable to preserve a certain, definite region of the taproot when transplanting or is any region capable of root regeneration if in the proper physiological condition?

Five hundred and sixty well-hardened plants of the usually selected size and uniformity were randomized into 20 replicate groups of 28

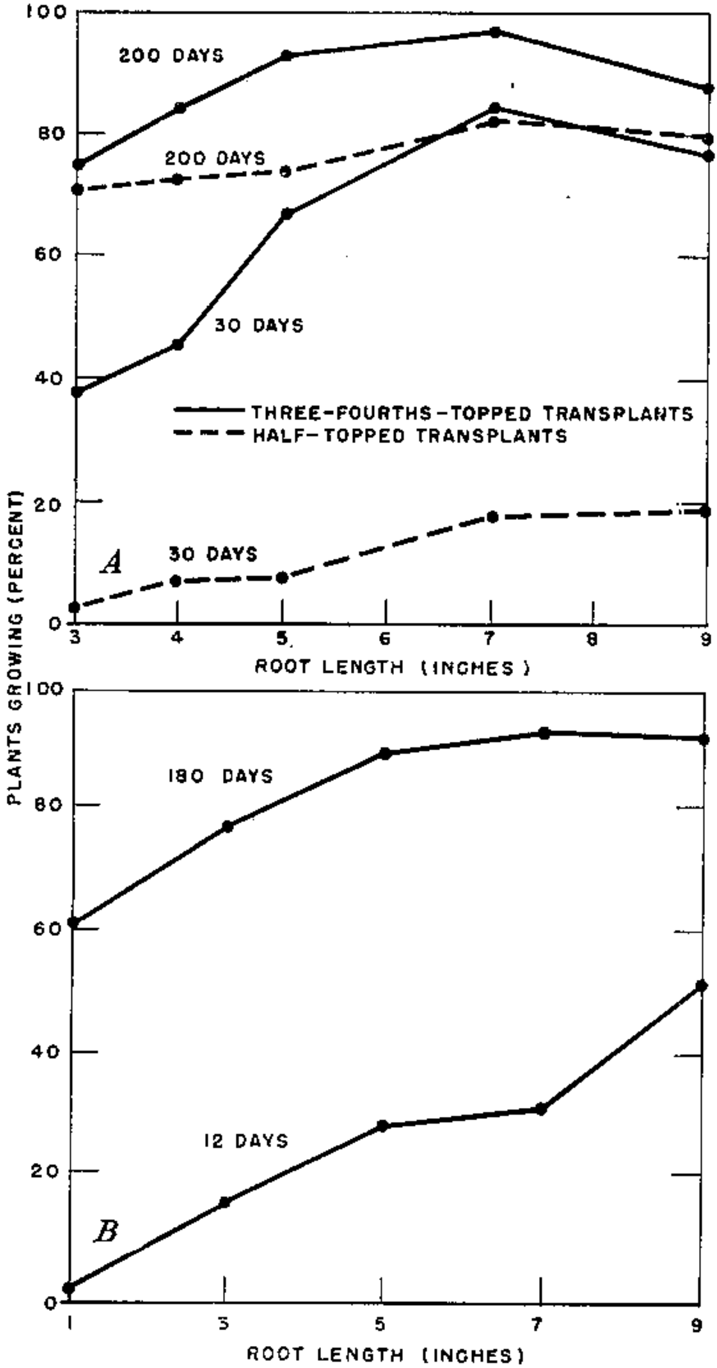

FIGURE 15.—Effect of root length on recovery of half-topped and three-fourths-topped guayule transplants in the field: *A*, Planted on October 1, 1943, at San Clemente, Calif.; *B*, planted on November 1, 1943, at Salinas, Calif.

plants each. Seven topping treatments were combined with 4 root lengths so that 28 treatments were applied (1 plant per treatment; 20 replications).

The pruning treatments applied were as follows: All tops removed by topping at the root crown (TC); 1½ inches of defoliated stem left (T-1½); 3 inches of defoliated stem left (T-3); all stem material left but only 1 side branch undefoliated and this bore 4 to 6 small leaves in a terminal cluster (1-TL); the same with 2 terminal tufts of leaves (2-TL); the same with 4 terminal tufts of leaves (4-TL); and full top with approximately 8 tufts of leaves (UT). These conditions of top were in all combinations with 3-, 6-, 9-, and 12-inch taproots from which all old laterals were removed. The plants were grown for 21 days in aerated tap water in 20 crocks of 3-gallon capacity with the 28 plants in each crock supported in holes in masonite lids. The temperature was uncontrolled and varied from 65° to 75° F., with daily fluctuations within this range.

After 21 days the plants were removed and counts made of new roots emerging on each 1½-inch segment of the taproot, measured away from the root crown. The mean determinations for rooted plants are shown in table 17. Rooting in the two groups with the most leaves (four and eight or more terminal clusters) was negligible, even with 12-inch roots, and counts are not presented for them. No distinction as to length of new roots was made in the counts.

There are numerous factors involved in the initiation of roots. Environmental factors such as temperature, light, and water are important both individually and probably in many possible combinations with internal factors. Carbohydrates, auxin, biotin, and some as yet unidentified substances all appear to play a role in root initiation (*27*). The present results represent over-all responses without purporting to assign specific effects of individual factors. With this in mind certain general effects and the interrelation of top and root can be described. Within limits, the total number of roots initiated under the present conditions was directly related to the length of taproot transplanted. If the total numbers of new roots in the upper and lower halves of the taproot were considered irrespective of the length of taproot or the condition of the top, the greater number always occurred in the lower half of the root. This was highly significant statistically and clearly indicates the possibility that the region of the old taproot is less important than the fact that the particular region occurs on the lower part of the taproot, which, of course, would be expected on the basis of the polar migration of internal growth factors which arise in the top (*24*, *27*).

The amount of top left on the plants also had a highly significant influence on the number of roots initiated. In general, the more top left the greater the number of initiated roots, but as has previously been shown (*7*, *22*) leafy transplants usually do not root readily and when numerous tufts of leaves were left attached the rooting was poor.

The effects of the increased amount of top was most marked on the lowest 1½-inch segment of the roots. It appeared as though with increased amounts of tops the additional amounts of growth factors moved to the distal end of the root and resulted in the formation of many roots there.

TABLE 17.—*Distribution of new roots on guayule transplants in water culture after 21 days for 5 degrees of topping and 4 lengths of taproots*

Taproot length	Distance from crown	Mean roots developing with topping level [1] as indicated: TC	T-1½	T-3	1-TL	2-TL	Mean	Mean total for upper and lower halves
	Inches	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
3 inches	0 – 1.5	1.82	1.85	1.85	1.0	0.0	1.30	1.30
	1.5– 3.0	6.69	7.95	7.95	7.0	2.5	6.42	6.42
Total	....	8.51	9.80	9.80	8.0	2.5	7.72	....
6 inches	0 – 1.5	2.50	2.10	1.95	1.22	1.82	1.92	5.72
	1.5– 3.0	3.16	4.05	3.95	4.50	3.36	3.80	
	3.0– 4.5	2.50	3.35	4.05	7.57	4.95	4.48	13.25
	4.5– 6.0	3.50	7.95	9.15	13.07	10.18	8.77	
Total	....	11.66	17.45	19.10	26.36	20.31	18.97	....
9 inches	0 – 1.5	1.13	1.30	2.10	1.61	1.71	1.57	9.08
	1.5– 3.0	2.73	3.65	4.50	4.69	2.57	3.63	
	3.0– 4.5	2.73	4.40	4.35	4.92	3.00	3.88	
	4.5– 6.0	2.93	4.30	3.30	4.69	3.21	3.69	18.94
	6.0– 7.5	5.32	6.45	4.45	7.15	6.43	5.96	
	7.5– 9.0	8.33	8.50	10.60	12.54	6.50	9.29	
Total	....	23.17	28.60	29.30	35.60	23.42	28.02	....
12 inches	0 – 1.5	.72	1.33	1.35	1.33	1.14	1.17	10.56
	1.5– 3.0	2.05	3.39	3.75	3.87	4.29	3.47	
	3.0– 4.5	2.11	2.67	2.70	3.80	2.28	2.71	
	4.5– 6.0	2.16	2.44	2.95	3.60	4.91	3.21	
	6.0– 7.5	2.33	4.06	4.50	5.01	5.14	4.21	24.82
	7.5– 9.0	3.21	3.94	5.80	7.14	7.57	5.53	
	9.0–10.5	4.33	4.00	6.85	10.25	8.43	6.77	
	10.5–12.0	2.78	4.55	6.30	13.93	14.00	8.31	
Total	....	19.69	26.38	34.20	48.93	47.76	35.38	....
Mean total	....	15.76	20.56	23.10	29.72	23.50	....	....

[1] See page 43 for explanation of symbols.

Relative Caliper of Transplants

For various reasons a considerable part of the nursery stock is discarded as culls. As may be seen in figure 1, many of these plants are not used because they fall below an arbitrary minimum-size limit set for acceptable planting stock. To determine whether these small plants are less desirable than the large ones, an experiment was conducted in which all of the plants (commercial strain 593) were taken from a small part of a nursery bed at San Clemente in November 1943 and graded for the following sizes: 4/32, 6/32, 8/32, 12/32, and 16/32 of an inch. Their modal size was 10/32 of an inch. Two hundred plants of each size were planted in 20-plant randomized plots replicated 10 times. The plants were three-fourths-topped and had 7-inch roots.

The results showed that fewer of the small plants survived (table 18) and that the mean size of those growing was somewhat smaller after 15 months in the field than was the mean size for the plants of greater initial caliper. However, it was noted at the time of harvest that the variation in the plants was not the same for each treatment (fig. 16). The harvested plants were weighed individually, and an analysis of variance was made of the coefficients of variability. The highly significant differences found were due to different percentages of aberrants and slow growers (8) in each size class of nursery stock. Thus, the smallest nursery stock contained the largest number of backward plants. From a practical standpoint these results are of considerable importance for it may be seen that an effective way of

Figure 16.—Relative merits of large and small plants in guayule nursery stock (commercial strain 593). Plants from a single locality in the nursery were sorted to caliper and planted in the field. The row in the foreground and the third row show unifom shrubs made by 12/32- and 10/32-inch plants, respectively. The highly irregular second row was produced by 4/32-inch plants among which were many genetic slow growers.

culling many of the aberrants and slow growers is through an elimination of the plants at the lower end of the size range.

Plants of a second experiment on caliper were planted about 10 days after those of the first one, and in this case the mode of size distribution was 5/32 inch. The difference in mode was due to soil type rather than to density or irrigation practices. The sizes used were 4/32, 5/32, 6/32, 7/32, and 8/32 of an inch. Since these plants were of the same age as those of the previous experiment but differed in mean size and thus probably in hardiness, the percentages of survival are of particular interest. Whereas in the previous experiment the smaller plants showed considerably lower survival than those of larger caliper, in the present experiment the survival was just as good for the smallest plants (table 18). However, the same concentration of slow-growing plants was found among the plants of smallest caliper.

Until a true-breeding strain of guayule is obtained, the practice of discarding the smallest plants in the nursery stock is justifiable from the standpoint of eliminating aberrants and genetic slow growers. However, the data indicate that size of transplants as such, within reasonable limits, does not result in a greatly different size of shrub after about a year's growth.

TABLE 18.—*Survival and growth of guayule nursery plants sorted according to size*

[Survival based on 200 plants; other values based on 36 plants harvested in each treatment (6 plants from each of 6 replicates)]

Size of nursery stock	Plants surviving	Mean weight after 15 months	Mean coefficient of variability	Plants that were slow growers
LARGER NURSERY STOCK OF 10/32-INCH MODAL SIZE				
	Percent	*Grams*	*Percent*	*Percent*
4/32 inch	64	223	71.0	33.3
6/32 inch	72.5	2 0	31.4	8.3
8/32 inch	88	258	29.6	5.6
12/32 inch	98.5	314	19.1	0
16/32 inch	99	318	22.2	0
Difference between means required for significance:				
5-percent level		(1)	19.9	
1-percent level			27.1	
SMALLER NURSERY STOCK OF 5/32-INCH MODAL SIZE				
4/32 inch	99	146	52.5	22.2
5/32 inch	98.5	168	52.9	19.4
6/32 inch	98	139	33.1	5.6
7/32 inch	98	182	23.9	2.8
8/32 inch	99	165	24.2	0
Difference between means required for significance:				
5-percent level	(1)	(1)	18.0	
1-percent level			24.5	

[1] Not significant.

ENVIRONMENTAL FACTORS

TEMPERATURE

The effect of temperature on the establishment of guayule transplants is of considerable interest and importance. Broyer,[16] in a study

[16] BROYER, T. C. OBSERVATIONS ON THE GROWTH OF GUAYULE UNDER GREENHOUSE CONDITIONS. Calif. Agr. Expt. Sta. Unnumb. Pub. [16] pp. 1945. [Processed.]

on root temperature and growth, found that very slow growth was made when roots of transplants were kept continuously at 10° C. (50° F.). The critical temperature for seed germination is also about 50° F.(*2*).

In the present study two experiments were undertaken to learn what limitations temperature might have on the transplanting responses during various seasons of the year. The first experiment consisted of placing 40 transplants per treatment in aerated nutrient solution in containers 8 inches in diameter and 18 inches long immersed in water baths with 10 plants per container and kept at constant temperatures of 40°, 50°, 60°, 70°, 80°, 90°, and 100° F. (*3*). At the end of 3 weeks counts and measurements were made (table 19). No rooting took place at 40°, while very slow but nearly complete rooting occurred at 50°. At 60° complete rooting occurred but about 6 days was required for the appearance of new roots as compared with 3 days at 70° and 80°. At 90° the rooting was erratic, some plants rooting quickly and others slowly. At 100° all the roots were dead and soft within 2 to 5 days, and death of the tops followed within a few days. Necrosis of the taproot was not evident at 60° or below, but at 70° there was some dieback, and at 80° and 90° it was quite pronounced in some plants. Presumably mildly parasitic organisms were active in the cases where dieback occurred (fig. 17).

Weights of new root and top growth indicated that the optimum constant temperature for the roots of guayule transplants in solution is between 70° and 80° F. A pronounced difference in the behavior of the roots was noticed as existing between those at 60° and the higher temperatures. At 60° the lateral roots branched infrequently within the time limits of the experiment, where at 70°, 80°, and 90° the roots emerging from the taproot initiated many lateral root tips.

TABLE 19.—*Recovery of guayule transplants in nutrient solution and soil kept at constant temperatures for 3 weeks*

[40 plants per treatment]

Medium and temperature (° F.)	Transplants producing new roots	Mean roots per rooting transplant	Mean dry weight per plant		Mean fresh weight of new top growth per plant
			New roots	New tops	
Nutrient solution:	*Percent*	*Number*	*Gram*	*Gram*	*Grams*
40°	0			(1)	
50°	97.5	3.2	(1)	(1)	
60°	100	18.7	0.039±0.003	0.066±0.004	
70°	100	25.4	.050± .002	.118± .009	
80°	95	23.6	.032± .005	.093± .015	
90°	85	18.1	.029± .003	.086± .010	
100°	0				
Soil:					
45°					(1)
54.5°					0.06
64.5°	100				.33
69°	92.5				.79
78.5°	95				1.12
87.2°	87.5				.92
95°	0				

[1] Trace.

The plants at 40° F. were allowed to remain in the culture solution for 7 weeks and still no new roots emerged. After the plants were transferred to solution at 70° new roots appeared in 3 days. Only 1 plant out of 40 had died during the 7-week period.

Soil checks were run at the same time; although the temperatures in the soil at a 3-inch depth differed from those of the water, it may be seen from table 19 that the optimum temperature in soil was possibly somewhat higher than it was in water culture; that is, a soil temperature of 78.5° F. resulted in the most rapid growth of tops, whereas a water temperature of 70° was best.

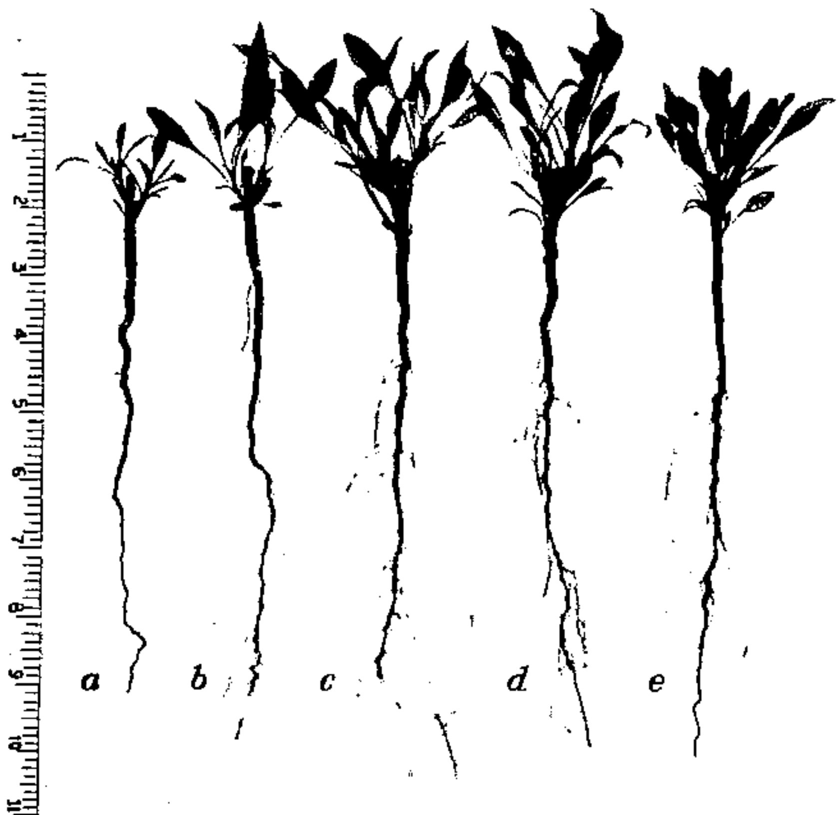

FIGURE 17—Root initiation by guayule transplants after 3 weeks in culture solution at various temperatures: *a*, 50°; *b*, 60°; *c*, 70°; *d*, 80°; *e*, 90° F. Note lack of new roots at the lower end of the plant at 90° due to dieback of the taproot common at this temperature.

In the second experiment it was desired to simulate changes in temperature found under field conditions in order to see how varying daily the lengths of time with low root temperatures influenced rooting and growth of transplants. Series at 40°, 45°, and 50° F. were maintained, and the number of hours at the low temperatures was 0, 6, 12, 18, or 24; for the remainder of the day the temperature was 70°.

Aerated nutrient solution was used, and the changes in temperature were effected by transferring the lids supporting the plants to containers with solution at the desired temperatures. At the end of 3 weeks the plants were harvested and the dry weights of new roots were determined (table 20). No rooting took place on plants maintained continuously at either 40° or 45° F. Rooting occurred at 50° as in the previous experiment, but the amount of root growth was small. When plants of the 40° and 45° series were held at 70° for 6 hours daily, rooting occurred and the amount of growth was about the same as for plants maintained continuously at 50°. When the daily period of favorable temperature was 12 hours a fair amount of growth occurred for plants in all three series. Six- and twelve-hour periods at 70° resulted in much less than one-fourth and one-half, respectively, of the amount of growth of plants held continuously at 70°. Eighteen hours daily at the favorable temperature resulted in the mean growth of about three-fourths of the mean amount found for plants held continuously at 70°.

TABLE 20.—*Mean dry weight of roots per plant on guayule transplants in nutrient solution after 21 days with daily alteration of temperature*

[24 plants per treatment at constant temperatures; 40 each for the others]

Temperature when not 70° F.	Weight of roots of plants at 70° F. daily for—					
	0 hour	6 hours	12 hours	18 hours	24 hours	Mean
	Gram	*Gram*	*Gram*	*Gram*	*Gram*	*Gram*
40°	0	0.005±	0.06±0.01	0.14±0.03	0.22±0.04	0.085
45°	0	.005±	.10± .02	.18± .02	.19± .02	.095
50°	.005±	.007±	.04± .01	.22± .02	.31± .03	.116
Mean	.002	[illegible]	.067	.180	.240	....

It appears that, except for possible lag periods produced, a temperature between 40° and 50° F. principally suspends growth of roots while they are in such a temperature range and that small increments of root growth occur when the temperature is higher.

As far as retaining dormancy in stored stock is concerned it may be seen that a temperature held continuously at 45° F. or below is adequate to prevent growth.

On the other hand, with regard to rooting of transplants in the field, it is apparent that only little activity may be expected during the cooler season (fig. 5).

In transplanting guayule, either extreme in temperature should be avoided for best results, but only the upper range of temperature is likely to cause difficulty. While low temperatures prevent growth and subject the plants with open wounds to prolonged periods of inactivity and in some cases to excessive moisture, there is a fair chance for survival in most cases as evidenced by data previously presented (table 12).

WATER

The application of water after transplanting seems to be an important phase of the procedure. Kraus (*13*) noted about 50 percent less survival of lettuce transplants when irrigation was delayed for 9 days. Also, it was noticed in Emergency Rubber Project plantings of guayule in March 1944 near San Clemente that few of the plants were sprouting in April and that many were decidedly shriveled within 1 or 2 weeks. One of the fields was on irrigated land, while the other was on dry land. As no rain was in prospect at the time that the plants were becoming seriously desiccated, the one planting was irrigated, with the result that an estimated 80+ percent of the plants revived. On the other hand, the dry-land planting received no rain until late in April (table 10), which was too late to save more than about 50 percent of the plants.

At Salinas on May 26, 1944, there was made an experimental planting in which well-hardened nursery stock was used to obtain quantitative data on the need for irrigation after transplanting during the dry season. The plants were topped to within 1½ inches of the crown so as to eliminate all the leaves, and then they were randomized into 3 groups of 160 plants each; these were further randomized into eight 20-plant replicates. One group was planted to the usual depth (crown) and irrigated; the second group was planted to the crown but not irrigated; and the third group, also not irrigated, was planted deep enough to cover the plants entirely with ¼ to ½ inch of soil.

The soil was irrigated 2 weeks prior to planting. When the soil was sufficiently dry it was chiseled and cultipacked; then the plants were set by hand and the soil was firmed around them.

At the end of 30 days the plants were dug up and examined. The data in table 21 show that all the plants in the irrigated plot had started to grow, whereas in the nonirrigated plots there was a marked difference in response between the plants of the two depths of planting. Nearly 75 percent of the plants set to the crown and not irrigated were noticeably shriveled and only 7.5 percent had sprouted. In the case where the plants were completely covered with soil (¼ to ½ inch), the rate of sprouting was much better; nearly one-half of the 61.9 percent which sprouted were visible above the surface of the soil on the thirtieth day.

TABLE 21.—*Effect of irrigation on establishment of topped guayule plants transplanted to preirrigated soil May 26, 1944, at Salinas, Calif.*

[160 plants per treatment; counts made after 30 days]

Treatment after planting	Depth of planting	Plants sprouted	Plants not sprouted	
			Plump	Shriveled or dead
		Percent	*Percent*	*Percent*
Irrigated	To crown	100	0	0
Not irrigated	do	7.5±2.3	18.7±9.2	73.8±8.5
Do	Completely covered	61.9±5.9	18.7±3.2	19.4±4.2

An abundance of water in the taproots of guayule transplants seems to be essential in the formation of new roots. It has already been shown (*7*) that one benefit of topping is prevention of a partial desiccation of the taproot before new roots are able to form. When plantings are made and irrigation or rain does not follow, the beneficial temporarily saturated condition of the soil is not present for a turgorization of the plants. Complete covering of the plants with soil was found to reduce the drying, but a set-back resulted because the sprouts had to grow up through a considerable depth of soil in cases where they emerged from the crown region.

Observations of winter-planted stock indicated that deep planting is undesirable at that season, for when buds emerge below the soil surface they frequently rot or are unable to push through the soil crust. On the other hand, the practice of setting plants deeper than the crown might be useful in dry-land planting toward the end of the rainy season when it is not certain that additional rain will follow soon after transplanting.

Cuttings Compared With Seedlings

Stem cuttings of guayule are rooted with difficulty (*19, 23*), but they present opportunities for study of homogeneous material not readily obtained from seed (*8, 20*).

Two plantings of cuttings and seedlings were made to compare the plants as to rate of growth and rubber and resin contents in order to determine whether any marked variation in development would result. However, the cuttings were not a clone and therefore would not be expected to indicate the degree to which it might be possible to reduce inherent plant variation by means of vegetative propagation. This method of propagating guayule, although of considerable scientific interest, is obviously impractical for commercial application in the production of rubber plantations.

In the first planting the rooted cuttings were readily set by machine along with regular nursery stock in April 1943. During the summer (August) a study of the root systems[17] revealed that the rate of penetration was perhaps slightly greater in the case of the best seedlings but that they did not occupy the soil quite as thoroughly as the cuttings (fig. 18). Samples were harvested during the first winter (after 8 months) and again after 22 months in the field for dry weights and rubber and resin analyses. The results are presented in table 22. Although the mean values for the cuttings were in all respects slightly higher than for the nursery stock, five replications failed to show statistical significance.

In the second experiment hardened 3-month-old greenhouse plants were used in addition to the rooted cuttings and nursery seedlings. One hundred of each were divided into 10-plant replicates and planted by hand in randomized blocks in April 1943. Comparative samples were harvested after 22 months (fig. 19), dry weights were determined, and rubber and resin analyses were made for ten 2-plant samples of each of the 3 types of plants (table 22). The slightly larger size and higher rubber and resin contents of the cuttings were again evident. In this case the differences again were not significant for

[17] Made by C. H. Muller, associate botanist, Special Guayule Research Project.

dry weights, but they were highly significant for percentage of rubber, significant for percentage of resin, and significant for yield. The hardened greenhouse seedlings excelled both cuttings and nursery plants in all respects, but they were significantly better than cuttings only in percentage of resin and grams of rubber per plant.

Inspection of the data (table 22) reveals that the higher percentage of rubber was associated with the larger shrubs. Analysis of covari-

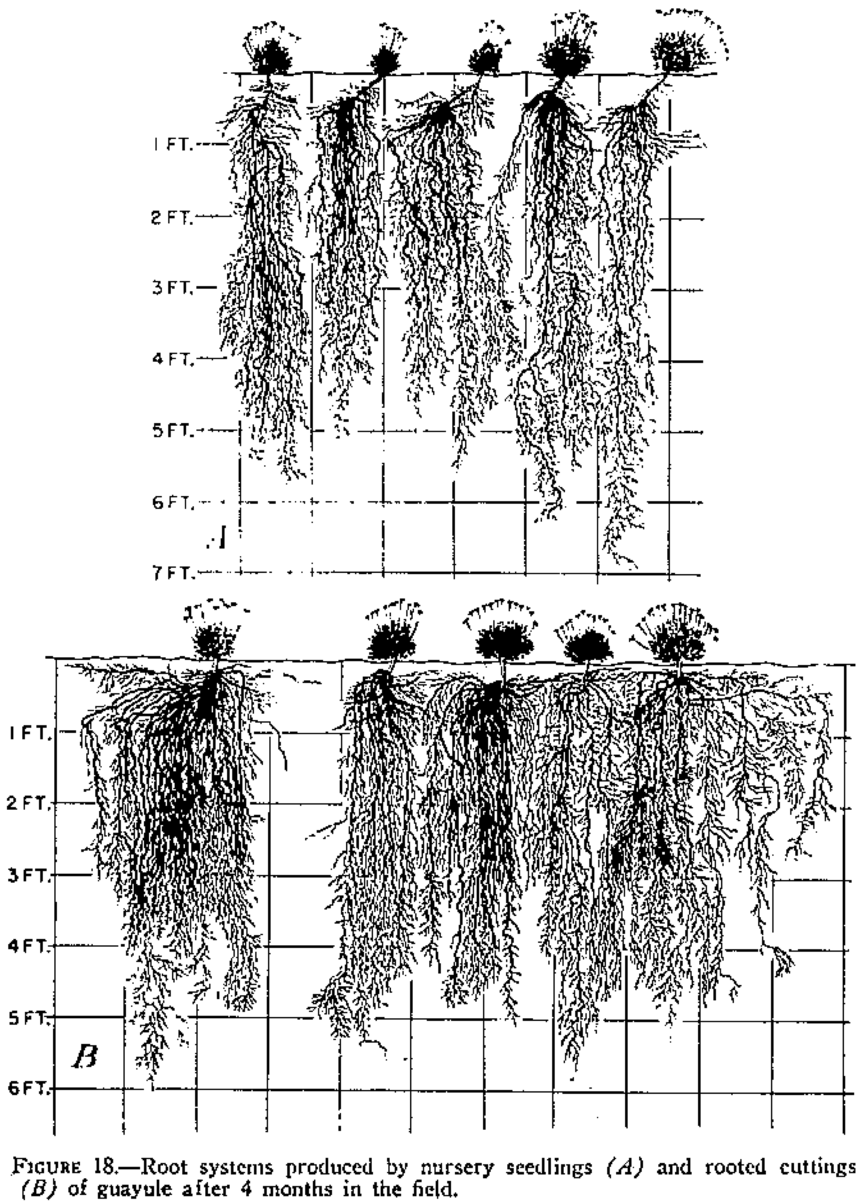

FIGURE 18.—Root systems produced by nursery seedlings *(A)* and rooted cuttings *(B)* of guayule after 4 months in the field.

TABLE 22.—*Growth and rubber and resin contents of rooted stem cuttings and seedlings of guayule*

Experiment No.	Period in field	Nature of transplant	Plants harvested	Dry weight per plant	Rubber	Resin	Rubber per plant
	Months		*Number*	*Grams*	*Percent*	*Percent*	*Grams*
1 [1]	8	Rooted cutting	10	42.6	4.17	4.85	1.78
	8	Nursery plant	10	38.5	3.70	4.51	1.42
1 [1]	22	Rooted cutting	10	210.8	6.82	6.01	14.38
	22	Nursery plant	10	153.6	6.61	5.78	10.15
2 [2]	22	Rooted cutting	20	217.5	7.90	6.18	17.18
	22	Greenhouse seedling	20	248.7	8.02	6.34	19.95
	22	Nursery plant	20	195.7	7.42	6.03	14.52
Difference required for significance:							
5-percent level				35.6	.35	.13	2.53
1-percent level				([1])	.48	.17	3.47

[1] From an analysis of variance the results were found not to differ significantly.
[2] Covariance of dry weight and percent rubber; $F=6.52$; 1-percent level$=5.49$.

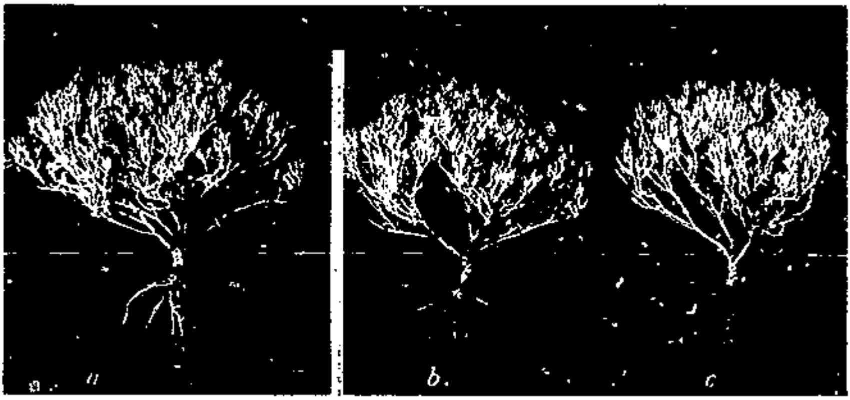

FIGURE 19.—Guayule shrubs after 22 months in the field produced by a 3-month-old greenhouse seedling *(a)*, a rooted cutting *(b)*, and a regular nursery plant *(c)*. Of 20 plants harvested in each category the ones photographed had nearest the mean weights.

ance was made to determine whether the increase in percentage of rubber could be ascribed to increase in size of shrub and the *F* value for covariance was highly significant, indicating that after adjusting all the percentages of rubber to a common plant size they still differed by a highly significant amount.

There is no evidence upon which to base explanations of these results, but certainly such things as the relative amounts of root system transplanted, relative rapidity of recovery, and reserve foods could be important factors in determining the size of shrub. Furthermore, in the case of the cuttings an unknown amount of selection was effected through the selective rooting response of the cuttings. (Note uniformity of cuttings in fig. 18, *B*, as compared with the nursery seedlings in fig. 18, *A*.) Federer (*8*) found a negative correlation between plant size and rubber percentage for commercial strain 593, but he did not cull out aberrants and slow growers, which had higher rubber percentages than the normal plants. Percentage of rubber and dry weight of plants were also negatively correlated in the growth of nursery stock under several conditions of soil moisture (*12*). The positive relation in the means for percentage of rubber and size (table 22) may in reality depend on age rather than size. Although the three categories of plants, listed in experiment 2 as being 22 months in the field, show a positive relation between percentage of rubber and size, they may have started to grow at different times. Early recovery would give the advantage of size as well as age of tissues for rubber.

FORM OF PLANT IN RELATION TO MACHINE OPERATIONS

Mechanical topping in the nursery and machine setting in the field are two operations for which it has been necessary to fit the plant partially to the existing machines. There can be no valid objection to such a practice if the modified plants give as good results as any others. This they did as far as survival is concerned, as may be seen in the various tables. Fortunately, the critical change required by the planting machine is that of slenderizing the naturally bushy guayule tops. The slenderer type of plant naturally results from the close spacing accompanying the economical use of nursery space (fig. 2). In regard to the mechanical topping of the plants it may be stated that as long as workers must pull the plants from the soil by hand after topping and undercutting have been done, it is desirable to have at least 2-inch tops left on the plants for them to grasp. Under such circumstances the existing topping machines (sickle-bar and reel types) can successfully cut the plants at the desired height. In order to have essentially leafless 2-inch tops left on the plants, the original height of the nursery stock should probably be not less than 5 inches (stem height). It has been noted that in most shorter stocks the plants are quite leafy after topping to that height.

Plants topped to the crown, 1½ inches above the crown, or 3 inches above the crown in combination with leafy and leafless stock as well as that having roots with few and numerous laterals were tried in the Holland celery planting machine. Personal preferences of the planters, based on the relative ease of handling the plants, indicated that either 1½- or 3-inch tops were preferred to crown-topped plants. However, it was possible to get the crown-topped plants set at any depth desired, even to the extent of covering them, so no objection could be raised on the inability of the machine to set the plants properly. The most undesirable type of top was the one with short spreading branches, for the holders of the planter could not grasp such plants readily. The presence of a few leaves was not objectionable on the part of either the planters or the machine, but leafy plants are not properly balanced physiologically (*7, 22*) and so the absence of all leaves in the stock is highly desirable. Very bushy root systems, probably very desirable from a physiological standpoint, were an extreme nuisance to the planters and invariably became tangled and greatly decreased their efficiency. Therefore, the physiological advantages of a much branched root system might be economical disadvantages, especially when quick recovery can be obtained by more expedient means.

CONCLUSIONS AND SUMMARY

Nursery stock is usually grown for one season in the nursery. During this period the plant is brought to the desired size for convenience in handling and finally conditioned so as to survive the process of transplanting. A study of some of the changes in the plants during hardening revealed rather small changes in carbohydrates, with the exception of the levulins, which already had been shown to be abundant in hardened stock. Rehydration values seemed useless in estimating hardiness of stock, since there were no conspicuous trends in such values during hardening. Moisture contents of guayule roots, based on the turgid condition, showed equal decreases during hardening by drought and low temperatures or by low temperatures alone. The levulin content seemed to depend on the length of time the plant was subjected to adverse conditions of either water supply or low temperature. High survival of cold-hardened stock after one wintering indicated that the subjection of nursery stock to drought is not indispensable in conditioning guayule for transplanting.

Inasmuch as hardened, relatively leafless plants survive best in transplanting there is little danger of excessive heating in stored stock. More serious are moisture for sprouting of plants, which occurs at 50° F. or above, or the rapid spread of storage fungi (e. g., *Sclerotinia*), which occurs at about 38°. Surface-dry plants without packing material were found to survive several weeks of storage when waxed paper completely enclosed them and reduced the loss of water from the plants. It was found that topped guayule nursery stock in a properly hardened condition could recover from considerable desiccation.

On the basis of data on monthly plantings for 12 successive months of nursery stock after an initial period of drought hardening, it was concluded that guayule may be successfully transplanted any month of the year under irrigated conditions in a climate similar to the one at Salinas, Calif. In this locality the warmer part of the year gave quicker resumption of growth and required one irrigation for establishment, while during the rainy months no irrigation whatsoever was needed for establishment, but the plants did not make appreciable growth until spring. Removal of seven-eighths of the top by height (all but about 1 inch of top) was found to be the best all-round topping level. Topping was shown to result in shrubs neither smaller in size nor lower in rubber content than untopped plants starting to grow at the same time. Measurements of the plants at each monthly planting revealed that without irrigation during the second season the nursery plants remained at practically constant size; this is an important point in knowing that nursery stock may be held over in good condition for 1 year or more.

The effect of root length on survival was studied in the field and in the greenhouse under water-culture conditions. It was found that short roots of 5 inches or less in the field trials were not as satisfactory from the standpoint of survival as longer roots of about 7 inches.

In water culture it was found that the number of new roots initiated on the old taproot was proportional to its length but their formation was delayed in roots 9 or 12 inches long.

The size of plant best suited to transplanting was the relatively large plant. The relatively small plants of a nursery stock contained the highest percentage of genetic slow growers in the highly variable commercial strain 593.

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