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EFFECT OF SULFURIC ACID ON GUM YIELDS FROM SLASH AND LONGLEAF PINES

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FROM SLASH AND LONGLEAF PINES

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The naval stores season of 1942 saw the first commercial use of chemical stimulants to increase gum yields from naval stores pines in this country. Since that time 5 years of intensive research on many phases of this problem has been completed. The detailed work of 1942 and 1943 is summarized in a previous publication (9). 1/ This earlier publication also included a complete historical summary of previous work done on chemical stimulation, both in this country and abroad, since its inception about 14 years ago. A comprehensive review of the general history of the gum naval stores industry, and recent developments in chemical stimulation methods, is covered in two other articles (6, 29). Detailed instructions to the practitioner on the use of sulfuric acid are published in the trade journals (11) and will not be given here. The present technical note starts with the carefully controlled naval stores experiments of 1944, and summarizes all of these studies through 1946.

EXPERIMENTAL TECHNIQUES

The most efficient experimental approach to testing a number of different treatments in naval stores studies consists of random assignment of trees to treatment groups on the basis of graduated gum-yielding abilities determined by calibration streaks. The details of this method have been described (9). Enough replications (varying from 10 to 20 trees) were used for each treatment so that statistically significant yield differences greater than about 15 percent could be detected, the precision depending on the purpose of the specific experiment.

Species differences in response to chemical treatment were noted in early work, so most experiments were set up for both slash and longleaf pines in order to find the optimum treatment applicable to each. Second-growth stands of slash and longleaf pine of varying ages and diameters, and chiefly of a single species, were used in these tests, representing the range of timber types in the vicinity of Olustee, Florida.

Gum yields were obtained for each tree at regular intervals

1/ Figures in parenthesis refer to similarly numbered articles under LITERATURE REFERENCES.

throughout the season on a weekly, biweekly, or triweekly chipping and weighing schedule. This method provided data on the yield trends for both individual trees and treatment groups. Valuable information on effectiveness of acid at different seasons was also obtained by this procedure.

Miscellaneous details of experimental technique include the following: face-widths were generally one-third of the circumference; tins were tacked on, both in the case of virgin faces and when tins were raised; streaks were chipped 1/2 inch deep and 1/2 inch high with a No. 0 hack unless otherwise specified; and bark chipping was done with a standard bark chipping hack. The chemical solutions were applied with either a DeVilbiss hand pump gun, or an early model of the Florida lung-power spray gun. All experiments were designed to allow for statistical examination of the data by analysis of variance.

INVESTIGATIONS AND RESULTS

The general objective of the research reported in this note was to determine the best chemical treatment techniques that would increase gum production or the efficiency of gum harvesting, or both.

To accomplish these objectives, portions of previous experiments were continued, and new studies, covering many phases of chemical stimulation, were started. Since some experiments were quite comprehensive, cross references will be made frequently under the separate headings in the following discussions.

The results from some of these studies are tentative in character, as only preliminary tests were made. In other instances the results are quite indicative of what may be finally expected, because supporting evidence is either available in replications in the station's work, or substantiated by work elsewhere. The qualifications applicable to each phase of study are pointed out in detail in the discussion so as to avoid erroneous conclusions. It should be remembered that these studies, though complete in themselves, do not cover all possible aspects, and no one treatment can be recommended to cover all circumstances or to meet every need. Much remains to be done under a continuing program to define more closely optimum techniques of a practical nature.

Depth and height of chipping.--Current accepted practice in respect to depth and height of chipping is not static, but streaks about 1/2 inch deep and 3/8 to 1/2 inch in height are the most commonly used. With the advent of chemical stimulation a need arose for a further study of variations in depth and height of chipping when different chemicals were used at different concentrations, and a study of the concurrent effect of frequency of chipping. Preliminary studies, conducted during 1942 and 1943, were discussed in a previous publication (9). A continuation of the 1943 work, and a new study for 1944, are reported in tables 1 and 2 respectively. Bark chipping was again used in the new work because of the initial success with this chipping method. The process of bark chipping consists of cutting off all bark down to the wood in a strip of designated width.

Table 1.--Gum yields for 4 years of turpentining with different depths and heights of chipping, and different frequencies of chipping and treating

SLASH PINE

Chipping frequency and treatment[1/]	Gum yield per crop[2/]				Relative gum yields			
	1943	1944	1945	1946	1943	1944	1945	1946
	Bbls.[3/]	Bbls.	Bbls.	Bbls.	%	%	%	%
Weekly								
Untr. 1/2 x 1/2	202.7	225.6	257.6	291.8	100	100	100	100
Untr. BC x 1/2	187.5	179.8	153.9	-	92	80	60	-
Acid 1/2 x 1/2	284.1	300.3	326.0	-	140	133	127	-
Acid 1/2 x 3/4	320.2	313.9	306.9	-	158	139	119	-
Acid BC x 1/2	261.8	240.3	222.5	-	129	106	86	-
Acid BC x 3/4	349.6	295.4	266.3	-	172	131	103	-
Biweekly								
Acid 1/2 x 1/2	189.0	199.9	232.9	215.8	93	89	90	74
Acid 1/2 x 3/4	220.2	240.4	280.9	255.4	109	106	109	88
Acid BC x 1/2	185.8	221.5	233.4	200.9	92	98	91	69
Acid BC x 3/4	248.1	227.9	239.8	220.8	122	101	93	76

LONGLEAF PINE

Chipping frequency and treatment	1943	1944	1945	1946	1943	1944	1945	1946
Weekly								
Untr. 1/2 x 1/2	144.6	114.8	126.1	126.6	100	100	100	100
Untr. BC x 1/2	137.4	94.9	84.6	-	95	83	67	-
Acid 1/2 x 1/2	231.0	200.8	215.4	-	160	175	171	-
Acid 1/2 x 3/4	215.0	138.5	170.6	-	149	121	135	-
Acid BC x 1/2	257.0	188.7	201.7	-	178	164	160	-
Acid BC x 3/4	237.0	165.9	162.0	-	164	144	128	-
Biweekly								
Acid 1/2 x 1/2	132.1	102.3	122.1	117.3	91	89	97	93
Acid 1/2 x 3/4	135.6	121.4	139.3	138.3	94	106	110	109
Acid BC x 1/2	163.7	124.1	132.4	130.5	113	108	105	103
Acid BC x 3/4	167.3	132.4	139.4	131.5	116	115	110	104

1/ Fractions, i.e., 1/2 x 3/4, indicate chipping 1/2 inch deep and 3/4 inch high; 40% sulfuric acid used on slash pine and 60% on longleaf. BC indicates bark chipping.

2/ Average yield per crop (10,000 faces) for number of weeks indicated:
1943, 30 weeks; 2 untreated weekly streaks in addition, yields not included.
1944, 30 weeks; 4 untreated weekly streaks for last 4 weeks, yields included.
1945, 32 weeks; 6 untreated weekly streaks for last 6 weeks, yields included.
1946, 32 weeks; 6 untreated weekly streaks for last 6 weeks, yields included.
Applies to both slash and longleaf pine except in 1943 longleaf 32 weeks, last 2 weekly streaks untread and yields included.

3/ One barrel contains 435 pounds of crude gum.

The results in 1943 showed that 1/4-inch chipping height did not result in adequate gum flow with acid treatment. This treatment was dropped in the continuation of the study. For untreated chipping 1/2 inch deep and 1/2 inch high there was a steady increase in yields for the three-year period (table 1). This increase was more pronounced for slash than for longleaf. The reverse was true for untreated bark chipping 1/2 inch high, in which the yields decreased during the same period. The greatest decrease from year to year occurred with weekly acid-treated chipping 3/4 inch high.

Table 2.--Relative gum yields for various depths and heights of chipping at different frequencies, with and without chemical treatment (1944)

Chipping frequency and treatment 1/	Slash pine				Longleaf pine			
	Depth of chipping				Depth of chipping			
	½ in.	Bark depth			½ in.	Bark depth		
	Height of chipping (in.)				Height of chipping (in.)			
	½	½	3/4	1	½	½	3/4	1
	Percent of control 2/				Percent of control 2/			
Weekly								
Untreated	100	69	--	--	100	63	67	58
Biweekly								
Untreated	57	47	72	57	38	27	32	34
Acid	--	109	115	126	99	102	118	107
Triweekly								
Untreated	47	40	36	35	27	21	28	21
Acid	--	82	85	81	66	69	81	78
Monthly								
Untreated	44	32	40	28	24	17	21	15
Acid		50	57	62	54	62	59	69

1/ 40% sulfuric acid used on slash pine and 60% on longleaf.
2/ Base yields (bbls. per crop) for the controls chipped weekly 1/2 inch deep and 1/2 inch high were 163.7 and 105.9 for slash and longleaf pine respectively; for a 32-week season for slash (except 33 weeks for triweekly groups) and 28-week season for longleaf (except 27 for triweekly).

All others were essentially equal or showed only nominal decreases. In the case of acid-treated weekly bark chipping 3/4 inch high, the large decrease tends to support the observation that yields decline more from year to year when the more intensive types of treatment are used. This observation is further supported by a comparison of the yearly trends for the weekly treatment with those for treatment every 2 weeks (biweekly).

In any one year, when acid was used, there were no statistically significant yield differences between the various heights and depths of chipping for this experiment, though there appeared to be a general trend toward higher yields for bark chipping, and chipping 3/4 inch high. Seasonal trends during the second and third year failed to show the high peaks associated with all treatments the first year, and treated bark chipping failed to hold up as long during the 1945 season as 1/2-inch-deep chipping. This was probably due to the higher intensity level of treatment for treated bark chipping, which is discussed later in detail.

Aside from frequency of chipping, the results of another study shown in table 2, taken as a whole, show that bark chipping 3/4 inch high resulted in significantly greater yield increases than 1/2- or 1-inch-high chipping, both for treated and untreated trees of slash and longleaf pine. There were no significant differences between species. Yields from 1-inch-high chipping, though apparently somewhat higher with a monthly chipping schedule, were definitely lower at other frequencies of chipping. It is unlikely that many operators will chip and treat at monthly intervals, since this is not economically feasible. Thus 1-inch-high chipping can be of little practical significance. On the other hand, chipping 3/4 inch high would be profitable, particularly on a biweekly or triweekly schedule.

Results to date of studies on depth of chipping indicate that yields from untreated bark chipping are about 20-30 percent less than those from chipping 1/2 inch deep. However, when acid is used, there are no significant differences between chipping down to the wood (bark chipping) or 1/2 inch into the wood. In some cases bark chipping offers advantages that might influence its use. Bark chipping requires less physical effort, can be taught to inexperienced labor quickly, tends to reduce wind-breakage (with tack-on gutters), and leaves a relatively round butt section when turpentined for short turpentining periods.

The optimum height of chipping depends in part on the aims of the operator. Chipping 1/4 inch high did not yield sufficient quantities of gum when acid was used. On the other hand, gum yields from 3/4-inch-high chipping were greater than either chipping 1/2 or 1 inch high with acid treatment. Although about 16 percent more gum is obtained with 3/4-inch high chipping, the face is used up nearly 50 percent faster, and the operator must choose between more gum with shorter face life, or less gum and longer face life.

<u>Frequency of chipping and treatment</u>.--The seasonal trends exhibited by untreated and treated trees, chipped and treated at various intervals, have been illustrated in a previous publication (9). The basic, most significant single factor shown, was the prolongation of gum flow with chemical treatment. Gum flow, instead of slowing down markedly after 3 or 4 days as in untreated chipping, begins at an accelerated rate, drops off much more slowly, and continues in appreciable quantities for 3 weeks or longer. Thus, chipping and

treating at intervals greater than one week is good business (11, 15, 16). This statement is substantiated by the results shown in tables 1 and 2.

Over a period of three years chemical treatments held up better with biweekly than weekly chipping, as indicated in table 1. On the average, in this experiment, about the same amount of gum was obtained from biweekly chipping with acid as from weekly untreated streaks. This was particularly true for longleaf pine where relative gum yields tended to be higher for the entire three years in acid-treated biweekly chipping. Although actual yields tended to increase during the first 3 years of the experiment for the untreated trees in slash pine, the relative gum yields for all the weekly acid treatments decreased markedly, compared to the conventional untreated chipping 1/2 inch deep and 1/2 inch high. This does not mean that weekly acid-treated chipping is a poorer method for 3 years of work, since the best weekly treatment resulted in 941 barrels of gum per crop for the 3-year period (for slash) compared to the best biweekly method that resulted in 741 barrels of gum. However, reduced production costs, associated with infrequent treatment and chipping, are an important factor. A more comprehensive study of long chipping intervals yielded the results shown in table 2.

From a practical standpoint, the results shown in table 2 indicate that for the greatest quantity of gum for the season, if chemical treatments are not used, conventional chipping 1/2 inch deep and 1/2 inch high is best. However, if acid treatments are used, more gum can be obtained <u>at any frequency of chipping</u>, than from untreated trees chipped at the same frequency. The better frequencies of chipping with acid treatment, from the standpoint of greatest returns for the labor expended, are the biweekly and triweekly schedules.

Gum yields (for the season) with treated monthly chipping were only half those obtained with untreated weekly chipping 1/2 inch deep and 1/2 inch high. The rate of gum flow is much lower during the fourth week following acid treatment, and possible undesirable physiological and anatomical changes occur concurrent with the long interval that treated bark is left on the tree. On more frequent chipping the tissue which might be damaged is removed before the most undesirable effects appear.

Further information from other studies, presented later in this note, is given in tables 17 and 18, where acid mixtures were used. Several frequencies of chipping and treatment were used in the experiment reported in table 18. These results substantiate the previous work and further emphasize the value of longer intervals of chipping and acid-treatment.

A portion of another experiment (table 3) also shows the same relative yield results for 2 years of turpentining with different frequencies of chipping and treatments, for a number of different treatments. Weekly treatments showed marked yield increases over untreated weekly chipping for each year, with a decline the second year. Yields from biweekly treatment averaged a little lower in the second year than in the first for slash pine, while longleaf yields were about the same for both years. The same species differences were evident for triweekly chipping and treatment, but at a lower level.

Table 3.--Gum yields for 2 years of turpentining with different frequencies of chipping and treatment

Chipping frequency and treatment 1/	Gum yields per crop 2/				Relative gum yields			
	Slash		Longleaf		Slash		Longleaf	
	1945	1946	1945	1946	1945	1946	1945	1946
	Bbls.	Bbls.	Bbls.	Bbls.	%	%	%	%
Weekly								
Untreated	217	231	126	118	100	100	100	100
Acid	334	334	248	206	154	144	197	174
Acid-arsenic	292	--	246	--	135	--	195	--
Acid-ars.-slant	365	--	232	--	168	--	184	--
Acid-slant	334	296	209	191	154	128	166	162
Biweekly								
Acid-arsenic	229	--	127	--	105	--	101	--
Acid-ars.-slant	186	183	142	138	86	79	113	117
Triweekly								
Acid-arsenic	163	--	124	--	75	--	98	--
Acid-ars.-slant	160	175	83	96	74	76	66	82
Acid-slant	154	186	100	--	71	80	79	--

1/ All bark chipping 1/2 inch high with regular "peak" face; except weekly untreated chipping was 1/2 inch deep and 1/2 inch high, and "slant" indicates a continuous slanted streak made across the entire face. 40% sulfuric acid used on slash pine and 60% on longleaf; acid-arsenic solutions consisted of 11.5 grams of arsenic pentoxide per liter of acid.

2/ Average yield per crop (10,000 faces) for 32 weeks, with 6 untreated weekly streaks for the last 6 weeks, except only 5 untreated streaks for the triweekly groups.

As pointed out previously (11), infrequent chipping and treatment offers much in the way of increased efficiency. One can get a much greater yearly output per man by using acid treatment on a 2- or 3-week chipping and treatment schedule. For instance, a chipper who works 5,000 faces a week would normally produce around 100 barrels of gum during the season in average timber. But by working 8,000 faces on a biweekly chipping and acid treatment schedule, the same chipper would produce about 176 barrels of gum. A triweekly schedule, allowing him to chip 12,000 trees, would raise his yearly production to around 210 barrels of gum--over twice the amount of gum normally produced by one laborer. Further, these infrequent chipping and treatment methods use up the faces only one-half to one-third as rapidly as weekly chipping, depending on the height of chipping.

Intensity of treatment.--Experiments have shown that a slash or longleaf pine tree is capable of producing considerably more gum than is usually obtained from the common turpentine practice of merely chipping about 1/2 inch deep and 1/2 inch high. Unusual chemical stimulation methods indicate that for a limited time very large amounts of gum can be obtained (13). Experience has shown there is a time limit, however, on an unusually high rate of gum flow.

The rate of gum removal and the excess yields of gum that may be obtained from a tree are dependent on a number of factors which include intensity of treatment, duration of each treatment-intensity level, and the time of the year chipping and treatment are started and stopped. Some of these have been briefly discussed elsewhere on the basis of previous experiments, under "Effective treatment period" (9).

Intensity level of treatment combines the factors which influence the rate of removal of gum from the tree. Some treatments by their nature give large quantities of gum in a relative short time, or moderate quantities over a longer time, which may be months or even years. On this basis various treatments can be classed as high, low, or intermediate levels of intensity.

The lowest intensity level of treatment commonly used is typified by the untreated weekly chipping, either bark chipping or 1/2 inch deep and 1/2 inch high. The other two intensity levels, all using acid, are triweekly chipping as the lowest level, and skip treatment (skip treatment is weekly chipping and biweekly treatment) and weekly acid treatment both in the highest intensity level of treatment. On the basis of two years' work in one experiment discussed later, it appears that triweekly chipping with acid might be even less intensive than weekly untreated chipping, though this is a trend only with the differences not statistically significant.

As a rule chemical stimulants markedly increase gum yields at the beginning of the season. Studies of seasonal trends based on weekly chipping with acid treatment indicate that increased yields attributable to applied chemicals reach a maximum a little past mid-season. A sharp decline in effectiveness of applied chemicals begins to occur after about 20 treated streaks, and eventually reaches a point at which no significant yield increases are obtained. This is particularly true of the more intensive treatments. Thus there is a period of as much as 10 weeks at the end of the season when application of chemicals brings little or no extra gum yield. The length of this period may vary because of a number of circumstances which include the time chipping and treatment starts in the spring, the number of treated streaks, the intensity of treatment, and seasonal variations.

When chipping and treatment are started in late spring and early summer, the decline in increased gum production usually comes later in the year, but in any event occurs several weeks before the end of the season. The number of treated streaks probably plays the biggest role here, in that the more treated streaks put on before the time of the natural seasonal decline, the sooner the reduction in yield occurs. The converse is also true; the fewer treated streaks each tree receives before reaching the usual point of diminishing gum yields, the more prolonged is the period of increased gum flow. Intensity of treatment, however, may modify this trend, since usually the more intensive treatments, although resulting in maximum gum production, have a shorter effective treatment period. Weekly chipping with acid treatment falls in this latter category.

The use of stronger acid concentrations and complete thoroughness of application would also contribute to a more intensive treatment, and tend to shorten the effective treatment period. Weather conditions which change the usual seasonal trends also probably influence the length of the period in which applied chemicals are effective.

Intensive treatments, besides their influence on the length of the effective treatments period, also affect the results at the beginning of the next season's work. For instance, if the intensity of the previous season's chemical treatment has been high, then the yields of the first few treated streaks generally will not be above those of untreated streaks (9).

The results of an experiment designed to delineate these relationships are given in tables 4 and 5. The first 2 years' results are compared in table 6.

The significant relationships of this study center around the long-time yields for four intensity levels of treatment. Treated and untreated trees, with variations in the number of treated streaks, are included in these levels. As mentioned previously (9), there was reason to believe that a certain yield level for each tree exists that could not be exceeded without lowered future yields. In general the results of the study summarized in tables 4, 5, and 6 substantiate this theory.

Data in table 6 indicate the differences in yield between 1944 and 1945 for each treatment. The same relative differences occurred in the 1944-46 and 1945-46 comparisons. All three comparisons indicate (for both species) that yields for triweekly acid treatment, the least intensive used, held up best during successive years, regardless of how many streaks were treated. The skip treatment (every streak chipped and every other streak treated) was the next in intensity, and this held up well when 6 or 9 streaks were treated out of a possible 15 treated streaks for the season. When 12 or 15 streaks were treated, however, the yields were considerably lower the following year. This was most pronounced when all 15 of the "skip" streaks were treated; here the 1945 seasonal yields were lower than those of 1944 by about 20 barrels per crop. The weekly acid treatment was the greatest in "intensity," and the second year yields were below those of 1944 in all cases except when only 12 of the 30 streaks were treated. The greatest drop occurred when all 30 streaks were treated, with from 30 to 40 barrels per crop decrease for slash and longleaf respectively. It is also interesting to note that the whole level of yields for all treatments in longleaf dropped about 15 barrels per crop, while in slash they remained essentially the same for the less

Table 4 --Gum yields for 3 years of turpentining slash pine with four different intensity levels[1] of treatment

Chipping frequency and treatment[2]	No. of treated streaks[3]	Gum yields per crop			Relative gum yields		
		1944	1945	1946	1944	1945	1946
		Bbls.	Bbls.	Bbls.	%	%	%
Weekly							
Untr. 1/2 x 1/2	0	165.5	179.3	234.4			
Untr. 1/2 x 1/2	0	163.0	169.9	220.7	100	100	100
Untr. 1/2 x 1/2	0	149.0	155.1	206.0			
Untr. 1/2 x 1/2	0	166.6	175.0	206.1			
Untr. BC x 1/2	0	138.7	123.1	129.7			
Untr. BC x 1/2	0	156.1	150.9	155.1	87	78	65
Untr. BC x 1/2	0	122.2	123.5	126.0			
Untr. BC x 1/2	0	143.9	134.5	149.3			
Acid 1/2 x 1/2	12	191.3	210.2	222.5	119	124	103
Acid 1/2 x 1/2	18	212.7	210.3	218.6	132	124	101
Acid 1/2 x 1/2	24	235.9	207.4	220.3	147	122	102
Acid 1/2 x 1/2	30	251.3	243.7	241.1	156	144	111
Acid BC x 1/2	12	179.0	171.6	154.2	111	101	71
Acid BC x 1/2	18	221.0	223.0	221.6	137	131	102
Acid BC x 1/2	24	233.9	226.6	235.6	145	133	109
Acid BC x 1/2	30	281.5	238.9	250.5	175	141	116
Skip[4]							
Acid BC x 1/2	6	160.1	169.9	170.8	99	100	79
Acid BC x 1/2	9	177.4	200.3	204.5	110	118	94
Acid BC x 1/2	12	194.9	205.1	205.0	121	121	95
Acid BC x 1/2	15	257.0	237.2	234.5	160	140	108
Triweekly							
Acid BC x 3/4	4	118.4	132.4	132.9	74	78	61
Acid BC x 3/4	6	114.3	135.0	136.5	71	80	63
Acid BC x 3/4	8	106.7	130.0	137.0	66	77	63
Acid BC x 3/4	10	124.9	126.2	146.4	78	74	68

1/ Intensity levels: (1) Weekly untreated; (2) Weekly acid; (3) Skip acid; (4) Triweekly acid.

2/ The 4 treatment groups of untreated 1/2 x 1/2, and those of BC x 1/2, are similar in all respects, each being untreated for 30 weeks. They are dummy comparisons included to facilitate and strengthen the statistical handling of the data and design of experiment. 40% sulfuric acid was used on all treated trees.

3/ All groups were chipped for a period of 30 weeks. After the designated number of treated streaks all groups were chipped weekly without treatment for the balance of the 30-week period.

4/ Skip treatment involves weekly chipping and biweekly acid treatment.

Table 5.--Gum yields for 3 years of turpentining longleaf pine with four different intensity levels1/ of treatment

Chipping frequency and treatment2/	No. of treated streaks3/	Gum yields per crop			Relative gum yields		
		1944	1945	1946	1944	1945	1946
		Bbls.	Bbls.	Bbls.	%	%	%
Weekly							
Untr. 1/2 x 1/2	0	116.1	105.2	113.3			
Untr. 1/2 x 1/2	0	103.9	94.1	100.7	100	100	100
Untr. 1/2 x 1/2	0	117.7	108.0	117.0			
Untr. 1/2 x 1/2	0	99.5	88.0	96.9			
Untr. BC x 1/2	0	109.1	86.0	79.7			
Untr. BC x 1/2	0	106.3	88.2	82.0	99	89	75
Untr. BC x 1/2	0	106.7	88.4	79.3			
Untr. BC x 1/2	0	109.9	87.3	77.6			
Acid 1/2 x 1/2	12	131.2	118.1	118.2	120	120	110
Acid 1/2 x 1/2	18	147.0	123.3	125.1	134	125	117
Acid 1/2 x 1/2	24	183.8	155.8	161.7	168	158	151
Acid 1/2 x 1/2	30	188.9	159.1	154.1	173	161	144
Acid BC x 1/2	12	139.4	127.3	122.4	128	129	114
Acid BC x 1/2	18	167.6	121.0	128.3	153	122	120
Acid BC x 1/2	24	161.8	113.7	119.3	148	115	111
Acid BC x 1/2	30	189.5	147.5	146.7	173	149	137
Skip4/							
Acid BC x 1/2	6	110.2	100.2	114.0	101	101	107
Acid BC x 1/2	9	131.4	116.9	107.2	120	118	100
Acid BC x 1/2	12	183.4	162.2	171.2	168	164	160
Acid BC x 1/2	15	176.0	152.0	139.2	161	154	130
Triweekly							
Acid BC x 3/4	4	88.6	76.5	79.8	81	77	75
Acid BC x 3/4	6	88.8	85.2	86.5	81	86	81
Acid BC x 3/4	8	103.1	88.8	101.3	94	90	95
Acid BC x 3/4	10	118.5	123.6	105.2	108	125	98

1/ Intensity levels: (1) Weekly untreated; (2) Weekly acid; (3) Skip acid; (4) Triweekly acid.

2/ The 4 treatment groups of untreated 1/2 x 1/2, and those of BC x 1/2, are similar in all respects, each being untreated for 30 weeks. They are dummy comparisons included to facilitate and strengthen the statistical handling of the data and design of experiment. 60% sulfuric acid was used on all treated trees.

3/ All groups were chipped for a period of 30 weeks. After the designated number of treated streaks all groups were chipped weekly without treatment for the balance of the 30-week period.

4/ Skip treatment involves weekly chipping and biweekly acid treatment.

Table 6.--Gum yield differences between 1944 and 1945 for different intensity levels of treatment on a crop basis[1]

SLASH PINE

Chipping frequency and treatment[2]	No. of weeks of treatment			
	12	18	24	30
	Bbls.	Bbls.	Bbls.	Bbls.
Weekly				
Untreated 1/2 x 1/2	+ 13.8	+ 6.9	+ 6.1	+ 8.4
Untreated BC x 1/2	- 15.6	- 5.2	+ 1.3	- 9.4
Acid 1/2 x 1/2	+ 18.9	- 2.4	- 28.5	- 7.6
Acid BC x 1/2	- 7.4	+ 2.0	- 7.3	- 42.6
Skip				
Acid BC x 1/2	+ 9.8	+ 22.9	+ 10.2	- 19.8
Triweekly				
Acid BC x 3/4	+ 14.0	+ 20.7	+ 23.3	+ 1.3

LONGLEAF PINE

Weekly				
Untreated 1/2 x 1/2	- 10.9	- 9.8	- 9.7	- 11.5
Untreated BC x 1/2	- 23.1	- 18.1	- 18.3	- 22.6
Acid 1/2 x 1/2	- 13.1	- 23.7	- 28.0	- 29.8
Acid BC x 1/2	- 12.1	- 46.6	- 48.1	- 42.0
Skip				
Acid BC x 1/2	- 10.0	- 14.5	- 21.2	- 24.0
Triweekly				
Acid BC x 3/4	- 12.1	- 3.6	- 14.3	+ 5.1

1/ Average yield difference in barrels per crop (10,000 faces); plus (+) signs indicate 1945 yield greater than 1944, and negative (-) signs 1945 yield less than in 1944.

2/ All groups were chipped for a period of 30 weeks. After the designated number of weeks of treatment all groups were chipped weekly for the balance of the 30-week period. A concentration of 40% sulfuric acid was used on slash pine and 60% on longleaf. Skip treatment is weekly chipping with biweekly treatment.

intensive treatments. The same relative decreases are also evident from 1945-46 comparison.

Thus, these results substantiate our previous conception that exceeding the production capacity level of a tree lowers subsequent yield levels. The triweekly acid treatment proved to be the least intensive used, while skip and weekly acid treatments were progressively more intensive, and resulted in greater decreases in yields the second and following years. The use of untreated streaks at the end of the season substantially reduced the second-year drop in yields for the skip, and particularly the weekly acid treatments.

Other evidence to substantiate these conclusions is given in table 1. It is clearly evident in this experiment that relative gum yields from weekly acid-treated trees declined from year to year, dropping from 150 to 109 percent on an average in the 3-year period. During this same period yields from biweekly acid-treated trees were relatively constant, showing no significant variations for the 3 years. The same relationship was true for the experiment reported in table 3.

The naval stores operator must know these basic facts about treatment intensity levels to enable him to select the method best fitted to his objective. If he desires to get the maximum amount of gum from a tree over a long period of time at low cost, the best method for him to use is the least intensive, such as triweekly chipping with acid treatment. If he wants to get the highest naval stores return from a tree in a relatively short time, then a more intensive turpentining method would be chosen. It is efficient to select the working method on the basis of intensity level, in order to fit the system to be used in the woods.

Number of faces.--Preliminary work in early fundamental studies indicated that large quantities of gum may be obtained from a single tree in a relatively short time by using more than one face per tree. The methods used were not practical, but the basic revelation, that a tree is capable of producing very large quantities of gum in a short time, was established. This finding suggested that there was a possibility of obtaining a naval stores return rapidly from selected trees that were to be removed from the stand for wood products, under some forms of forest management. Thus, development of suitable techniques that result in the maximum gum production per tree, in a given length of time, were needed to insure the greatest returns to the woodland owner from naval stores, in addition to that from wood products. Since the high yields of preliminary work were obtained with more than one face per tree, the initial experiments were designed to find the optimum number of faces consistent with high gum yields.

The results of the first study to delimit the number of faces per tree that would prove most feasible for commercial practice are given in table 7. In this experiment the first two faces were placed on opposite sides of the tree one foot above the ground. The faces in successively higher pairs were centered above bark bars that separated the next lower

Table 7.--Gum yields for 3 years of turpentining with various numbers of faces per tree

SLASH PINE

Treatment[1]	No. of faces	Gum yields per crop[2]			Relative gum yields		
		1944	1945	1946	1944	1945	1946
		Bbls.	Bbls.	Bbls.	%	%	%
Untr. 1/2 x 1/2	1	151.3	170.0	177.2	100	100	100
Untr. BC x 1/2	1	121.1	135.9	141.8	80	80	80
Do.	2	100.9	106.4	106.2	67	63	60
Do.	4	60.7	-	-	40	-	-
Do.	6	42.9	-	-	28	-	-
Acid BC x 1/2	1	232.0	172.2	165.7	153	101	94
Do.	2	160.0	129.4	122.2	106	76	69
Do.	4	82.2	-	-	54	-	-
Do.	6	48.9	-	-	32	-	-

LONGLEAF PINE

Treatment[1]	No. of faces	1944	1945	1946	1944	1945	1946
Untr. 1/2 x 1/2	1	111.4	103.8	98.9	100	100	100
Untr. BC x 1/2	1	89.1	83.1	79.1	80	80	80
Do.	2	83.0	72.5	68.8	75	70	70
Do.	4	60.7	-	-	54	-	-
Do.	6	43.0	-	-	39	-	-
Acid BC x 1/2	1	153.0	124.3	124.5	137	120	126
Do.	2	141.5	113.8	121.4	127	110	123
Do.	4	82.2	-	-	74	-	-
Do.	6	48.9	-	-	44	-	-

1/ Weekly chipping and treatment with 40% sulfuric acid on slash pine and 60% on longleaf.
2/ Average yield per crop (10,000 faces) for number of weeks indicated. 1944- 30 weeks (28 for longleaf); 4 untreated weekly streaks for last 4 weeks. 1945 and 1946- 32 weeks; 6 untreated weekly streaks for last 6 weeks.

pair. In other words, if the first two faces were on east and west sides of the tree, the two above were north and south, and so on. The vertical spacing of the pairs of faces was such that a distance of 4 inches would remain between pairs at the end of a full season of chipping. Except for the untreated control group, with one face chipped weekly 1/2 inch deep and 1/2 inch high, all faces were bark chipped weekly 1/2 inch high. The experiment was duplicated in old-field slash and second-growth longleaf pine.

It is evident that acid treatment is necessary, where more than one face per tree is used on small trees, if sufficient gum yields are to be obtained to make a profitable operation. Yields per face in both slash and longleaf were only about 60 to 70 percent of the yields from trees chipped without treatment in the conventional manner with one face. Also, progressively less gum was obtained per face with an increase in numbers of faces per tree. Total yields per tree for two-, four-, or six-faced trees were more than those obtained from single-faced trees. From a practical standpoint, however, the increased chipping costs would not make multi-faced trees a practical method to use for trees between 9 and 14 inches d.b.h. when the faces were not treated with acid.

Acid treatment increased the total yields of multi-faced trees considerably, but yields per face for the trees with four and six faces were very low. Results with two faces per tree were much greater. Also there was considerable mortality when more than two faces per tree were used. This is another illustration that gum yields cannot be maintained for any great length of time with an intensive working method.

With two acid treated faces per tree the yield from slash pine decreased about 35 percent during the 3-year period, compared to the untreated controls, but in longleaf pine remained about the same from year to year. For the first year of work the yields per face exceeded those for untreated regular chipping by 6 and 27 percent for slash and longleaf respectively. Yields in slash pine fell off rapidly the second year and declined still further in the third year.

From this experiment alone it would appear that two faces per tree were the maximum that should be treated with acid, and that yields drop off in slash but remain constant in longleaf for the 3-year period. From the standpoint of average profit for a landowner <u>interested primarily in naval stores</u>, multi-cupped trees less than about 14 inches in diameter treated with acid every week do not offer many advantages aside from getting about twice the yields <u>per acre</u> for the first year of work, compared to standard untreated chipping, with the operation possibly limited to one year of work in slash pine. In longleaf comparable yields could be expected over a 3-year period, assuming that the results in this study indicate what might be expected elsewhere. With weekly chipping 3 years is about the maximum length of time acid treatment can be conveniently made with our present equipment.

For the timberland owner interested in the maximum quick return on his land holdings, however, turpentining with two faces offers distinct advantages which will be discussed in the final section of this note.

A supplemental test in second-growth slash pine, using trees selected for an intermediate cutting, substantiated the information obtained in the old-field slash experiment. The results, using four faces per tree, are given in table 8. Two separate areas were used, and the results for each area were quite comparable. For one year's work the four-faced trees yielded about 2.25 times more gum than the untreated trees with conventional untreated chipping, though the yield per face was only 55 percent as much.

Table 8.--Gum yields from 1 or 4 faces per tree in slash pine averaging 9 inches in diameter, to be removed in an intermediate cutting (1944)

Treatment 1/	No. of faces	Gum yields per crop 2/	Relative gum yields
		Bbls.	%
Area I			
Untreated 1/2 x 1/2	1	177.0	100
Acid BC x 3/4	4	97.4	55
Area II			
Untreated 1/2 x 1/2	1	142.0	100
Acid BC x 3/4	4	83.2	59

1/ Weekly chipping and treatment with 40% sulfuric acid. Second growth slash with Area I in flat woods and Area II bordering a cypress pond.
2/ Average yield per crop (10,000 faces) for 26 weeks.

Table 9.--Gum yields from 1 to 4 faces per tree in slash pine averaging 15 inches in diameter, to be removed in a harvest cutting (1944)

Treatment 1/	No. of faces	Gum yields per crop 2/	Relative gum yields
		Bbls.	%
Untreated 1/2 x 1/2	1	283.2	100
40% Acid-BC x 3/4	4	181.4	64
60% Acid-BC x 3/4	4	167.0	59

1/ Weekly chipping and treatment with sulfuric acid.
2/ Average yield per crop (10,000 faces) for 24 weeks.

During 1944 another experiment involving four faces per tree was set up in an over-mature stand of slash pine growing on the border of a pond where the trees averaged 15 inches d.b.h. Both 40 and 60 percent sulfuric acid were used, as indicated in table 9. The percent yield increase over the untreated 1/2 x 1/2 inch chipping was only slightly greater than for smaller trees in the second-growth and old-field slash pine types with four faces per tree. From the standpoint of yield per face, the quantities of gum obtained were low compared to the controls. However, the yield of 180 barrels of gum per crop (for 40 percent acid) might make this an operable chance, besides resulting in a high yield of over 700 barrels of gum per crop of 10,000 trees. Some mortality also occurred near the end of the season. However, other methods to be discussed later appear to offer promise of more profitable turpentining techniques.

Since little was known regarding optimum multiple-cupping techniques a separate study involving several additional variations was also conducted during 1944. The results obtained from using these techniques are given in table 10. Instead of the run-of-the-mill trees, the trees used were those marked for an improvement cutting in an old-field slash pine stand. The object here was to learn what yields in a single season could be obtained from trees of this type, which included wolf trees, as well as crooked, cankered, and closely spaced individuals. Both weekly and biweekly chipping and treatment intervals were used. The three-faced trees treated had face widths one-half the curcumference, each successive face being oriented 90 degrees from the last in a clock-wise direction.

Table 10.--Gum yields from varying numbers and widths of faces per tree in slash pine over 9 inches in diameter, to be removed in an intermediate cutting

Chipping frequency and treatment 1/	No. of faces	Gum yields per crop 2/	Relative gum yields
		Bbls.	%
Weekly			
Untreated 1/2 x 1/2	1	139.8	100
40% acid BC x 1/2	1	209.5	150
Do.	4	97.2	70
60% acid BC x 1/2	4	103.0	74
Biweekly			
40% acid BC x 1/2	1	115.7	83
Do. 3/	3	99.4	71
60% acid BC x 1/2 3/	3	127.7	91
40% acid BC x 1/2	6	54.6	39

1/ Acid treatment with sulfuric acid.
2/ Average yield per crop (10,000 faces) for 26 weeks; 4 untreated weekly streaks for last 4 weeks.
3/ Face widths one-half the circumference; all other one-third circumference.

One interesting result of this experiment was the relatively large total yields obtained with three faces, each one-half the circumference, which received biweekly chipping and 60 percent acid treatment. Although the yields per face did not vary significantly from the untreated control yields, the total yield per tree was far greater than any of the other treatments used. It is important to note here that the three-faced trees were more profitable in several ways: they produced more gum; they were visited only half as frequently; and they obviously required less chipping time than the four- or six-faced trees. This method, however, is only applicable when a rapid-tapping method is needed with the objective of only one year of turpentining. This experiment also provided us with the first evidence that acid-treated faces wider than the conventional one-third circumference may be useful in rapid-tapping systems of turpentining.

In 1945 a 3-year experiment was designed to make use of our best knowledge gained in previous experiments reported in tables 7-9 inclusive. This study, set up on the pattern indicated in table 11, had as its objectives delimitation of the quantity of gum yields prior to harvest cuttings or thinnings, and determination of the limit in years for profitable working, by the methods used in this experiment. All the trees over 6 inches d.b.h. on approximately $2\frac{1}{2}$-acre areas were used; the slash pine over 9 inches d.b.h. averaged 38 per acre, and those between 6 and 9 inches d.b.h. averaged 178 per acre. On the longleaf area there were 43 trees per acre over 9 inches d.b.h. and 81 per acre between 6 and 9 inches d.b.h. Each diameter group was divided in half, on the basis of calibration yields, and accorded treatments indicated in table 11.

Table 11.--Gum yields for 2 years of turpentining with 1 or 2 faces per tree in 2 size classes of slash and longleaf pine, to be removed in thinnings

Tree size and treatment 1/	No. of faces	Gum yields per crop 2/				Relative gum yields			
		Slash		Longleaf		Slash		Longleaf	
		1945	1946	1945	1946	1945	1946	1945	1946
		Bbls.	Bbls.	Bbls.	Bbls.	%	%	%	%
9 inches + d.b.h.									
Untreated 1/2x1/2	1	155.6	179.1	144.5	153.0	100	100	100	100
Acid BC x 1/2	2 3/	181.6	185.4	191.0	175.6	117	104	132	115
6-9 inches d.b.h.									
Untreated 1/2x1/2	1	100.6	107.7	86.4	86.6	100	100	100	100
Acid BC x 1/2	2 3/	104.2	101.6	110.6	100.1	104	94	128	116

1/ Weekly chipping and treatment with 40% sulfuric acid on slash pine and 60% on longleaf.
2/ Average yields per crop (10,000) faces for 32 weeks for slash pine and 33 weeks in longleaf for 1945; 32 streaks for both species in 1946. In both species the last four weekly streaks were untreated.
3/ Face widths four-tenths circumference each; all others with face width equal to 1/3 the circumference.

It is evident for the 2-year period that, with the methods used, working two faces per tree is practical for trees over 9 inches d.b.h. Yields per face were greater than for untreated one-faced trees in each of the 2 years. Similar to a previous experiment (table 7), yields in longleaf were somewhat better than in slash pine.

While face yields from two-faced trees under 9 inches d.b.h. were at least equal to the one-faced untreated controls of the same size, the yield levels were about 30 percent less per face than for trees over 9 inches d.b.h. From a practical standpoint, it may be possible to work profitably an area using two faces on small trees even though yields are lower, since there are twice as many faces per acre. However, the lowest yield level that can be tolerated and still make a profitable operation is not shown, since the cost variables of each operation will determine the minimum yield level permissible. Further information on yields from trees of small sizes will be given later.

Width of face.--Within certain limits gum yields tend to increase with width of the face. As indicated before (table 10) wider faces on multi-faced trees often result in greater gum yields. It was not known at that time, however, what effect higher chipping would have on yields. The study shown in table 12 was started in 1945 to determine the simultaneous effect of varying face width and chipping height, in order to get a rapid-tapping technique that would result in considerable gum yield increases within a relatively short period of time.

Table 12.--Gum yields for 2 years of turpentining with one or two faces per tree, and varying face widths and chipping heights

No. of faces, face width, and treatment 1/	Gum yields per crop 2/				Relative gum yields			
	Slash		Longleaf		Slash		Longleaf	
	1945	1946	1945	1946	1945	1946	1945	1946
	Bbls.	Bbls.	Bbls.	Bbls.	%	%	%	%
One-face								
Untreated 1/2x1/2	217	231	126	118	100	100	100	100
Acid BC x 1/2	334	334	248	206	154	144	197	174
Two-faces								
Face width 1/3 cir.								
Acid BC x 1/2	222	-	169	-	102	-	134	-
Acid BC x 3/4	226	-	162	-	104	-	129	-
Face width 4/10 cir.								
Acid BC x 1/2	240	211	185	158	111	91	147	134
Acid BC x 3/4	263	252	211	182	121	109	167	154

1/ Weekly chipping and treatment with 40% sulfuric acid on slash pine and 60% on longleaf.
2/ Average yields per crop (10,000 faces) for 32 weeks; last 6 weekly streaks untreated.

The results in table 12 clearly show that wide faces on two-faced trees yield appreciably more gum than conventional faces one-third the width of the tree circumference. Both methods result in face yields greater than those for single-face untreated controls. These methods are definitely practical for use in pre-cutting turpentining practices for a period of 2 years.

Along with wider face widths, it is also shown that chipping 3/4 inches high is definitely better than 1/2 high for the 2-year period. This study is being continued and the results for 3 years of work will be available at a later date.

Single wide faces of varying widths were tried, using bark chipping and acid treatment, as another portion of the experiment reported in table 12. The results appear in table 13. The yields were markedly higher with wider faces for both years of work, but yields the first year were much greater. Slash pine face widths three-fourths of the circumference gave yields the first year about double those for regular untreated faces one-third circumference in width. For longleaf pine the ratio was about 2.5 to 1. During the second year of work these increases were 1.4 and 1.6 times greater for slash and longleaf respectively.

Table 13.--Gum yields for 2 years of turpentining trees with faces of different widths

Treatment and face width 1/	Gum yields per crop 2/				Relative gum yields			
	Slash		Longleaf		Slash		Longleaf	
	1945	1946	1945	1946	1945	1946	1945	1946
	Bbls.	Bbls.	Bbls.	Bbls.	%	%	%	%
Untreated								
1/3 circumference	217	231	126	118	100	100	100	100
Acid								
1/3 circumference	334	334	248	206	154	144	197	174
1/2 circumference	358	346	257	207	165	150	204	176
3/4 circumference	430	339	319	259	198	147	253	219

1/ Weekly bark chipping 1/2 inch high except for the untreated group which was chipped 1/2 inch deep; 40% sulfuric acid on slash pine and 60% on longleaf.
2/ Average yield per crop (10,000 faces) for 32 weeks; last 6 weekly streaks untreated.

Thus, the yields from one wide face per tree, with bark chipping and acid treatment, approximately equal or surpass those from two faces per tree for 1 and possibly 2 years. Although wide-face tin-installation costs exceed those for average-width faces, the decreased labor cost for the season of chipping and treating, compared to working two faces per tree, more than makes up for the difference as a rule. It remains to be shown whether one very wide face is any better than two moderate-width faces per tree, when turpentining is carried on for 3 successive years. Current work is now under way to provide a partial answer to this problem.

Shape of face.--Early experimental work indicated that a "slant" streak resulted in as much gum as a regular "peak" face or more. The slant method of bark chipping consists of completion of the streak in one continuous operation clear across the face. The streak is almost level in virgin faces, but becomes more slanting as streaking progresses up the tree. The peak method of chipping is essentially the same, except that two slanted streaks are made which meet near the center, and become progressively steeper as chipping progresses up the tree. When used with acid-treated bark chipping in the preliminary experiment, slant streaks gave even more gum than the regular peak method.

Table 14.--Gum yields from two face shapes for various treatments and frequencies of chipping

Chipping frequency and treatment 1/	Gum yields per crop 2/			
	Slash		Longleaf	
	Slant face	Peak face	Slant face	Peak face
	Bbls.	Bbls.	Bbls.	Bbls.
Weekly				
Acid	334	334	209	248
Acid-arsenic	364	292	232	246
Acid-ars.-phos.	336	321	222	241
Biweekly				
Acid arsenic	186	229	142	127
Triweekly				
Acid-arsenic	160	163	83	124
Acid BC x 3/4	144	135	123	109
Acid-ars. BC x 3/4	158	151	132	138

1/ All bark chipping 1/2 inch high unless otherwise stated; 40% sulfuric acid on slash pine and 60% on longleaf. Acid-arsenic solutions contained 11.5 grams of arsenic pentoxide per liter of 40 or 60 percent sulfuric acid. Acid-ars.-phos. solutions contained 215 grams of phosphoric acid (85%) per liter of 40% sulfuric acid, and 322.5 grams for 60% sulfuric acid, with 11.5 grams of arsenic pentoxide added.

2/ Average yield per crop (10,000 faces) for 32 weeks; last 6 weekly streaks untreated, except only 5 untreated streaks for the triweekly groups.

The two methods of chipping were later contrasted in an experiment reported in table 14, where variations in chipping frequency and chemical treatment were also used. These results indicate that on an average, yields from slant bark chipping are essentially equal to those from regular peak chipping, under the variety of methods used in this experiment. In longleaf pine slant chipping appeared to yield slightly less gum in some instances, but the differences are not consistent or statistically significant.

Slant chipping has the advantage of saving time in chipping and contributing toward better workmanship. The chipper doesn't have to reverse his grip on the hack when making a slant streak (12), so this source of waste motion is eliminated. Since most chippers can perform better when chipping either right- or left-handed, a better job with less effort can usually be done.

Diameter of tree.--It is important to know, from the standpoint of getting the greatest return from each acre of forest land, the relative yields that may be expected from trees in the lower diameter classes, particularly where stand-improvement measures are contemplated. The results of a single-season test of trees ranging from 4 inches d.b.h. upward are given in table 15.

Table 15.--Gum yields from treated trees of different sizes compared with those from untreated trees 9-14 inches d.b.h.

Diameter of tree (b.h.) 1/			Gum yields per crop 2/		Relative gum yields	
Range	Average					
	Slash	Longleaf	Slash	Longleaf	Slash	Longleaf
Inches	Inches	Inches	Bbls.	Bbls.	%	%
4.0-4.9	4.7	4.50	75.9	36.7	35	29
5.0-5.9	5.5	5.51	112.3	53.2	52	42
6.0-6.9	6.5	6.48	168.1	98.2	78	78
7.0-7.9	7.5	7.43	233.4	119.9	108	95
9.6-14.0	10.5	10.0	216.7	126.4	100	100

1/ Trees over 9.6 inches d.b.h. were chipped weekly 1/2 inch deep and 1/2 inch high without treatment, with face widths 1/3 the circumference. All other groups were bark chipped 1/2 inch high weekly and treated with acid-arsenic mixture with face widths 6/10 the circumference. A 40% sulfuric acid-arsenic mixture was used on slash pine and 60% on longleaf.
2/ Average yield per crop (10,000 faces) for 32 weeks, last 6 weekly streaks untreated.

It appears that with acid treatment of faces six-tenths the circumference in width, normal yields can be obtained from trees as small as 7.5 inches in diameter. The yield from acid-treated trees of this size was equal to the yield from untreated trees averaging 10.5 inches in diameter with face widths one-third the circumference, as indicated in table 15.

The lowest diameter tree that can be worked profitably will depend on the actual costs to each operator, balanced against the returns from the general average yields shown in table 15. The wider faces used here would probably increase tin installation costs; chipping and treating costs per tree would also tend to be higher than for regular untreated faces one-third the circumference in width. Considering these factors, it is likely that working trees 7.5 inches d.b.h. would definitely increase costs but the effect on net profit cannot be foretold except for a specific set of conditions.

It should be noted that the site condition for longleaf was below average. Hence it is probably best to use the percentage figures in the table in projecting the data to other areas. For a particular method of turpentining on a given tract there is a certain marginal yield, or minimum yield of gum per face, that will meet all costs of production. Knowing costs, and the average yielding ability of the area, application of the percentage figures above will make it possible to arrive at the lowest diameter trees that can profitably be worked. The same reasoning applies to selecting any multiple cupping technique.

Initial yield capacity.--It was noted among the earliest experiments that trees of different gum-yielding abilities varied in their response to chemical stimulants. These relationships were studied in an experiment summarized in table 16. The slash pine results are particularly consistent with other experiments, and typify the general responses obtained. The variability in longleaf may be attributed to relatively fewer trees for testing purposes.

Trees were grouped into the high-yielding, average-yielding, and low-yielding categories on the basis of a series of calibration streaks. All trees of a given species were relatively uniform in diameter and crown class, and were growing intermingled, thus minimizing major site differences.

The results for each of the 3 years of working were consistent. From the standpoint of percent increase, based on untreated trees of the same yielding capacity, the low yielders responded to acid treatment to a much greater degree than the average or high yielders, and the average yielders also responded better than the high yielders.

The following data are based on untreated bark chipping where yields average about 80 percent of untreated chipping 1/2 inch deep. This does not detract from the interpretation of results, however, since the same relative differences still apply.

Table 16.--Gum yields for 3 years of turpentining trees of different initial yield capacities, with and without acid treatment

Initial yield capacity[1]	Treatment[2]	Gum yields per crop[3]						Relative gum yields					
		Slash			Longleaf			Slash			Longleaf		
		1944	1945	1946	1944	1945	1946	1944	1945	1946	1944	1945	1946
		Bbls.	Bbls.	Bbls.	Bbls.	Bbls.	Bbls.	%	%	%	%	%	%
High	Untreated	256.8	223.4	243.6	177.7	135.7	134.9	183	168	174	164	155	169
	Acid	352.5	287.7	283.4	328.2	251.5	248.3	251	216	202	304	287	312
Average	Untreated	140.2	133.0	140.0	108.0	87.7	79.6	100	100	100	100	100	100
	Acid	281.5	238.8	250.0	189.5	147.5	146.7	201	180	179	175	168	184
Low	Untreated	69.6	82.8	94.9	50.3	40.6	46.5	50	62	68	46	46	58
	Acid	208.6	161.7	180.1	162.1	117.7	117.4	149	122	129	150	134	147

1/ Relative initial yield capacity determined on basis of 4 weekly streaks bark chipped 1/2 inch high at the start of the 1944 season.
2/ All bark chipping 1/2 inch high; 40% sulfuric acid on slash pine and 60% on longleaf.
3/ Average yield per crop (10,000 faces) for 30 weekly streaks.

The yield increases due to acid treatment in slash pine for the high, average, and low yielders in 1944 were 37, 100, and 200 percent, and in 1945 were 29, 80, and 95 percent, respectively; in 1946 the same comparison gave yield increases of 16, 79, and 90 for the high, average, and low-yielding trees. This indicates definitely that, on the basis of percent yield increase over untreated chipping, greater proportional yields are obtained from acid treatment of trees in the lower yielding categories, and these relative yield differences hold up better from year to year. This has been noted also in other studies (3).

Another method of making these comparisons is to consider the yield increases in barrels per crop due to acid treatment for each yielding type. In 1944 the increase for high yielders was 96 barrels per crop, for average yielders 141 barrels, and for low yielders 139 barrels. The respective yield increases in 1945 were 64, 96, and 79 barrels, and in 1946 were 40, 110, and 85 barrels per crop. Thus the extra number of barrels of gum obtained from treatment in the low and average groups was at a relatively high level, but was somewhat lower in the high-yielding group.

These results, coupled with trends noted in other experiments for both 1944 and 1945, suggest the possibility that, in general, acid treatment tends to increase yields to a greater degree in the lower-yielding than in the higher-yielding categories, or under conditions not suitable for yield stimulation in trees of the latter type. It is entirely possible that excessively high yields during the early portion of the treating season reduce the ability of higher yielding trees to respond to chemical stimulants, particularly with a more intensive treatment such as on the weekly schedules. Seasonal-trend curves indicate that the yield from treated high yielders was very great for the first half of the season, but fell to almost the same level as the untreated high-yielding group for the last 12 streaks. In contrast to this, the treated low yielders showed greatly increased yields for practically the entire season. The average yielders were intermediate, with the treated trees falling to the untreated level at about the end of the effective treat-period (about the 24th streak). The same trend exhibited in other experiments was noted here also: greater periodic fluctuations from week to week are associated with the higher yield-level groups.

Chemical mixtures.--Early work on chemical combinations, involving the use of two or more chemicals in the same solution (9), gave promise that some combinations might be as good or better than the single solutions tested to date. In addition, some of the chemicals added to sulfuric acid appeared to act as iron-corrosion inhibitors (30), as well as aiding in promoting greater yield increases. Two of these chemicals were used in the study summarized in table 17.

During the two seasons of work acid-arsenic solutions resulted in somewhat greater yields than treatment with sulfuric acid only. This held true for both slash and longleaf pine. The addition of phosphorous to sulfuric acid appeared to help some in slash pine, but in longleaf pine the yields were equivalent to those obtained with sulfuric acid alone.

Table 17.--Gum yields for 2 years of turpentining trees treated with different chemical mixtures

Treatment 1/	Gum yields per crop 2/				Relative gum yields			
	Slash		Longleaf		Slash		Longleaf	
	1944	1945	1944	1945	1944	1945	1944	1945
	Bbls.	Bbls.	Bbls.	Bbls.	%	%	%	%
Untreated	139.8	176.3	101.3	110.4	100	100	100	100
Acid	209.5	214.9	149.4	138.7	150	122	147	126
Acid-arsenic	250.2	227.3	159.3	123.7	179	129	157	112
Acid-phosphorous	240.9	221.5	149.6	139.4	172	126	148	126

1/ All weekly bark chipping 1/2 inch high except weekly untreated which was chipped 1/2 inch deep and 1/2 inch high; 40% sulfuric acid used on slash pine and 60% on longleaf. Arsenic and phosphorous concentrations given in table 14, footnote 1.

2/ Average yield per crop (10,000 faces) for: 1944- 26 weeks, last 4 weekly streaks untreated; 1945- 32 weeks, last 6 weekly streaks untreated.

Following the initial results obtained in 1944, another experiment was set up in 1945 to delimit more closely the relative effectiveness of these two chemical mixtures at different chipping and treatment sequences and to test the effect of a three-chemical solution. In table 18 a summary of the results is given. A statistical examination of the data shows no significant differences between the three chemical mixtures used, compared with sulfuric acid. The yields of trees treated with acid-arsenic treated on biweekly and triweekly schedules were comparable to those with acid alone. This is further illustrated in table 3, where slant bark chipping was also used.

The significant conclusion from these experiments on chemical mixtures is that combinations of arsenic and phosphorous compounds in sulfuric acid do not cause a decrease in yields compared with sulfuric acid alone. Where the addition of arsenic or phosphorous to sulfuric acid for inhibiting iron corrosion is necessary, it may be done without fear of any gum-yield decreases because of this addition.

These studies, although not indicating any consistent yield increase because of additions of arsenic or phosphorous in the concentrations used, are not exhaustive. There are many other chemicals and chemical combinations that might be equally or even better adapted to use in chemical stimulation of gum flow. Further work on a moderate scale is under way.

Table 18.--Gum yields from trees treated with various chemical mixtures at different frequencies

Chipping frequency and treatment 1/	Gum yields per crop 2/		Relative gum yields	
	Slash	Longleaf	Slash	Longleaf
	1945	1945	1945	1945
	Bbls.	Bbls.	%	%
Weekly				
Untreated	216.7	126.4	100	100
Acid	333.5	248.5	154	197
Acid-arsenic	291.8	245.8	135	194
Acid-ars.-phos.	321.4	241.1	148	191
Biweekly				
Acid-arsenic	229.0	127.1	106	101
Triweekly				
Acid-arsenic	163.2	124.8	75	99

1/ All bark chipping 1/2 inch high except weekly untreated which was chipped 1/2 inch deep and 1/2 inch high; 40% sulfuric acid used on slash pine and 60% on longleaf.
2/ Average yield per crop (10,000 faces) for 32 weeks; last 6 weekly streaks untreated, except only 5 untreated streaks for the triweekly group.

GENERAL DISCUSSION

Increasing turpentining efficiency.--There are two general approaches to the problem of increasing the efficiency of turpentining operations. First, production of gum may be maintained at a level approximating normal practice with greatly reduced production costs. Second, larger gum yields may be obtained at the same or only slightly greater production costs per tree.

Application of sulfuric acid is the first step toward increasing efficiency. Although a single chipper can chip and treat only about 4,000 trees per week, compared to 5,000 when no acid is applied, his production per year is increased from an average of 100 barrels of gum to about 126 barrels if he chips and treats on a weekly schedule.

Much greater efficiency in turpentining is obtained, however, when the frequency of chipping and treatment is on a biweekly or triweekly schedule. This has been brought out in the section of "Frequency of chipping and treatment," and more details are given in previous publications (9, 11, 15, 16, 18).

When acid is used, yield differences between chipping 1/2 inch deep or bark depth are negligible. However, bark chipping has many advantages, as pointed out previously, and its use contributes to greater efficiency.

Considering all experiments reported in this note, chipping 3/4 inch high, particularly on a biweekly or triweekly chipping schedule, appears to be the most efficient method to use, where the progress up the tree is not the major concern. For any given frequency of chipping, streaks 3/4 inch high will use up the workable face height appreciably faster than streaks 1/2 inch high, and the total yield of gum will be somewhat less for the total working height of the face. However, greater yields are obtained for the same amount of work with the greater chipping height. With weekly acid-treated chipping 3/4 inch high, maximum gum yields will be obtained for the first year of work, but yield increases will usually be less in subsequent years. This disadvantage disappears when more infrequent chipping and treating schedules are used.

Increased efficiency is also obtained when face widths are greater than the customary one-third circumference in width. Although tin installation costs may be increased somewhat, the greater quantities of gum obtained more than offset this apparent disadvantage. Wide faces should be used only for specific purposes, however, as discussed later.

Acid treatment results in the greatest increase in efficiency on poor timber. The section on "Initial yield capacities" illustrated greater yield increases among trees of low-yielding capacities. These increases amounted to almost $2\frac{1}{2}$ times the yield the first year, compared to untreated trees of the same low-yield capacity, (based on chipping 1/2 inch deep) and were about $1\frac{1}{2}$ times as great in the succeeding 2 years. This large extra amount of gum was produced at only slightly greater costs.

To sum up, those techniques of acid treatments contributing most to increased efficiency are: bark chipping, biweekly or triweekly schedules, bark chipping 3/4 inch high, and, under some circumstances, wide faces and working poorer timber under the above principles.

Rapid turpentining.--With the traditional system of turpentining to a 9-inch diameter limit, under which turpentining dominates timber management, there is very little room for rapid turpentining. However, there is now a strong trend toward selective cupping, in which the trees to be cupped and removed in the next cutting are chosen on the basis of the silvicultural needs of the stand rather than on the basis of diameter.

The system of selective cupping is based on the logic: (a) worked-out trees must be cut promptly after turpentining because of their low growth rate and high mortality; and (b) it follows that under good management the trees to cup are the ones that the forester would remove in the next cutting. As stated by McCulley (24)..."Trees should be selected and marked for both cupping and cutting according to the requirements for maximum productivity and profit per acre and not solely according to diameter."

If for silvicultural reasons a stand that is to be cupped selectively will need thinning or other cutting in less time than it takes to work a tree by ordinary methods, then rapid-tapping methods are in order. For example, rapid-tapping methods are needed in certain overstocked stands of slash pine that need thinning within a period of 1 to 3 years.

Rapid-tapping techniques may also be useful to certain pulpwood or timber company owners who may prefer not to tie up their lands on any but short-term leases. On areas where there is a very good pole market, rapid-tapping techniques suit the needs of owners who wish to turpentine for only a short time and leave the butt in the best possible condition for the pole market.

There are three general methods of turpentining that will produce large quantities of gum in a relatively short time. The producer's aims determine which method offers the most advantages.

One turpentining method to increase yields consists of using acid treatment with weekly bark chipping 3/4 inch high. This method will result in large gum yields the first year, but the yield will fall off in succeeding years, though still being greater than untreated regular chipping. Extra gum yields and profits can be obtained by this method, particularly the first year, but the profits will not be as high the last 2 years of work during the 3-year period as by another method; and the average profit for the 3-year period will be lower because of the yield drop the last 2 years. Changing to a biweekly schedule will reduce production costs and give a greater profit for the 3-year period.

Another rapid-tapping method is to use two faces per tree. The best multi-faced method we know of to date is to use two faces four-tenths of the circumference each on each tree, and bark chip 3/4 inch high on a weekly schedule using acid treatment (see tables 11 and 12). The yields from each face are sufficient to make this a profitable naval stores operation, and the yields per acre are twice those usually obtained with one untreated face per tree. It is not yet known whether a biweekly schedule under these circumstances is more desirable, but work is under way to give a partial answer to this problem.

An alternative method that may be used to obtain large yields in a short time is the use of one wide face per tree. According to the results for 2 years of work (table 13) weekly bark-chipped acid-treated faces one-half or three-fourths of the circumference in width have given large yield increases. These yields per tree have not been as great as from two-faced trees, but it is possible that the labor costs on an acre basis would be reduced, thus increasing profits from the turpentining operation. Although some chippers are paid on a production basis, others are paid according to the number of faces chipped. In the latter case, on the basis of chipping costs of regular faces, this labor cost would be reduced by using one wide face per tree. However, it is probable that the chipper will have to be paid more to chip a face one-half to three-fourths of the circumference, than for chipping a regular face one-third of the circumference in width. Also the costs of tin installations would probably be higher. In either case the extra cost attached to one wide face would probably not equal that for two faces per tree. But yields from one wide face do not equal those from two faces. In choosing between the methods of two faces or one wide face, a careful cost analysis for each operation would have to be made. Again, biweekly chipping with one wide face might offer many advantages, but the results of work under way are not yet available to establish this point.

In either event, the methods of using one wide face or two faces per tree would be sound forest management when used according to best selective cupping practices (24, 26).

SUMMARY

This brief summary gives only pertinent facts of each phase studied, with none of the inter-relationships that have been indicated in previous discussions. Studies to date indicate that:

1. Where acid is used, there is no essential difference in yield between bark chipping and chipping 1/2 inch deep. A 3/4-inch-high streak yields more gum than one 1/2 or 1 inch high.

2. The variation in yield resulting from various frequencies of chipping and treatment offers a number of choices in methods to meet specific objectives. Over a 3-year period weekly chipping and treatment resulted in greatest yields, though yields progressively declined from year to year, compared to untreated weekly chipping 1/2 inch deep and 1/2 inch high. Yields held up better with biweekly or triweekly chipping for a 3-year period. With acid-treatment, yields with biweekly chipping equalled or exceeded those from weekly untreated chipping, while triweekly yields averaged slightly less. Either of these latter frequencies offers a more efficient working method from the standpoint of labor saving and reduction in unit production costs.

3. Total gum yields over a period of years appeared to be dependent on the working method used. Some methods, called high-intensity treatments, gave high gum yields for a relatively short time. One example of the latter is weekly chipping with acid treatment. A low intensity treatment is illustrated by triweekly chipping with acid where relatively large gum yields were maintained over a longer period of time. The method for the naval stores producer to use is that intensity of treatment best adapted to his operating objective.

4. Use of more than two faces per tree, even though they were acid-treated, was not practical on trees of ordinary size. Gum yields from each acid-treated face on two-faced trees were essentially equal to those from single untreated faces on trees chipped 1/2 inch high and 1/2 inch deep. Increasing the chipping height up to 3/4 inches, or the width of each of the two faces up to four-tenths of the circumference, gave still further yield increases, which were fairly well maintained over a 2-year period, particularly in longleaf pine. Two wide acid-treated faces offer a practical rapid-tapping method.

5. One wide acid-treated face, one-half or three-fourths of the circumference, appears to yield gum equal to or even greater than two untreated faces per tree for 1 and possibly 2 years of work.

6. Slant chipping gives yields equalling those of the usual peak face, and has the advantage of possibly saving time and contributing toward better workmanship.

7. Working trees under 7 inches d.b.h. by any method used does not

appear to be practical. Turpentining of trees 7 to 8 inches d.b.h. may be profitable if costs are kept low. Yields from this size of tree, when wide acid-treated faces were used, were about equal to untreated regular chipping of trees averaging 10.5 inches d.b.h.

8. Acid treatment tends to increase yields to a greater degree in trees of low yield capacity, than in trees of high yield capacity. The overall yields from acid-treated high yielders were from two to three times those from average-yielding trees which were not treated.

9. The addition of iron-corrosion inhibitors, such as arsenic and phosphorous, to sulfuric acid did not cause any decline in gum production compared with the use of acid alone.

10. Techniques of acid-treatment which contribute most to turpentining efficiency are bark chipping, biweekly or triweekly schedules, bark chipping 3/4 inches high, and, under some circumstances, using wide faces or two cups per tree, and working poorer timber under the above principles.

11. Two rapid-tapping techniques, leading to maximum productivity and profit per acre, seem practical. These include the method of two faces per tree with each face four-tenths of the circumference, or one wide face per tree equal to one-half to three-fourths of the circumference in width. Both methods involve weekly bark chipping 3/4 inches high with acid treatment. Choice of method depends on the operating circumstances of each producer.

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