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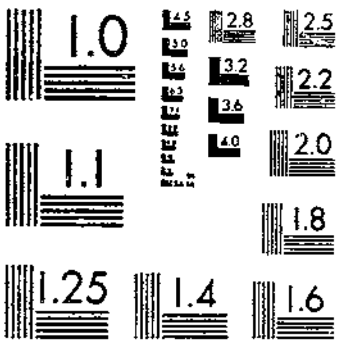

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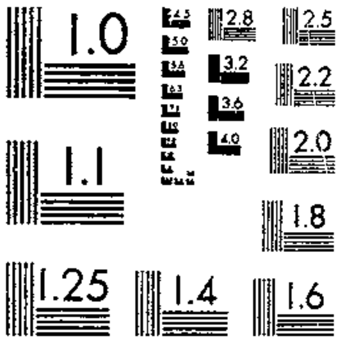

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NATIONAL BUREAU OF STANDARDS-1963-A

TECHNICAL BULLETIN No. 298 — APRIL, 1932

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

EXPERIMENTS IN NAVAL STORES PRACTICE[1]

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CONTENTS

INTRODUCTION

The two most important trees for turpentining[2] in the United States are the longleaf pine (*Pinus palustris* Mill.) and the slash pine (*P. caribaea* Morelet) which occur in the South Atlantic and Gulf States from Virginia to Texas. In Figure 1, which gives the range of the two trees, the wider distribution of longleaf is evident. Slash pine is confined for the most part to the wetter soils in the Southeast. Both occupy land that is of little or no value as farm land or pasture.

Since early days these trees have been worked for gum from which turpentine and rosin are distilled, but only recently has any system-

[1] Acknowledgment for their substantial contribution to the experiments detailed here is due L. C. Powell, W. H. Smith, and Merion Johns, of Starke, Fla., through whose cooperation was furnished the timber on which the tests were conducted. Assistance was also given by the Pine Institute of America in lending weather instruments, by a tool company in furnishing many of the tools used, and by the Bureau of Chemistry and Soils in supplying analyses of gum. The advice of Eloise Gerry and Austin Cary, of the Forest Service, has been particularly helpful. Carl F. Speh, of the Pine Institute, has also offered many valuable suggestions.

[2] For the definiteness of naval-stores and forestry terminology see Glossary, p. 54.

atic attempt been made to moderate this turpentining work for the benefit of future turpentine and timber values. A decade ago hacks with a large cutting edge were in general use. These were mostly Nos. 1½ and 2, in contrast with the No. 1 hack most widely used to-day and the No. 0 now coming into use. No. 2 hacks chipped streaks an inch deep and took off an inch of wood in height at every chipping. In four years faces were 12 feet high.

The deep chipping of earlier years has given way to somewhat more conservative work, but in the meantime a great deal of damage has been done through the mechanical weakening of the timber. In many heavily worked stands of young timber one tree out of every four has been broken by hurricane winds. (Fig. 2.) Hurricane

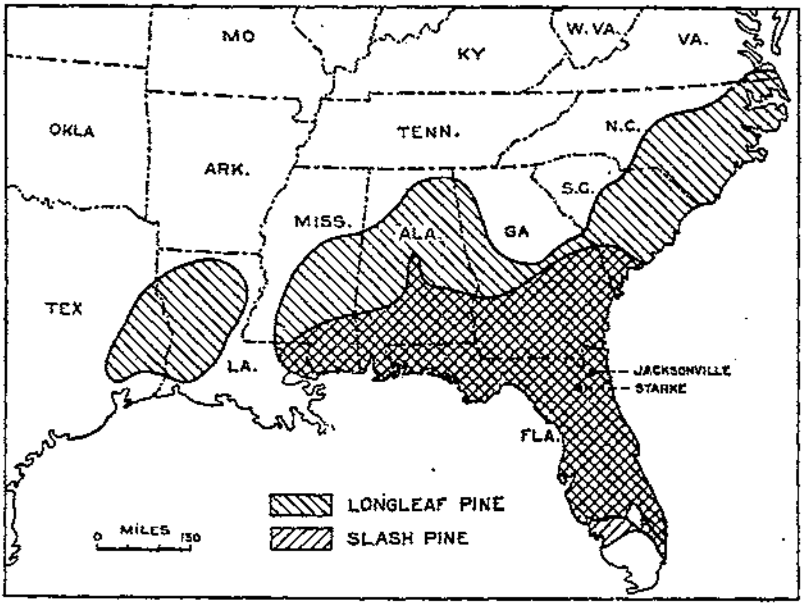

FIGURE 1.—Natural range of slash pine and longleaf pine in the Southern States

damage is ordinarily restricted to small areas, but the 1928 hurricane blew down about 1 per cent of the turpentined trees in several counties in northern Florida and southern Georgia. Vining (*40*)[3] reports a great deal of wind shake in turpentined trees following this storm. Deep chipping, aside from the mechanical damage for which it is responsible, causes a great deal of dry facing, especially in slash pine timber, and this, in turn, is followed by insect and fungus attacks, which cause further damage and loss. (Fig. 3.)

It is common to find chippers cutting away 40 per cent or more of the bark periphery for a single face, and where two or more faces are being worked concurrently the bark bars between faces are frequently cut away. Such heavy work impairs the vitality of the tree and lowers gum yields. Even where some care in chipping has

[3] Italic numbers in parenthesis refer to Literature Cited, page 57.

been exercised bark bars are often so reduced in width as to result in injury to the tree and a lowering of gum yields.

The growing local scarcity of suitable turpentine timber, combined with the keen competition for timber, has brought about the

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FIGURE 2.—Destructive methods of chipping cause heavy losses from windbreak annually

chipping of trees even as small as 6 inches in diameter, usually at a loss to the operator because of their very small gum yield. Many of these smaller trees are badly crippled by turpentining and not

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FIGURE 3.—Double facing and deep chipping followed by high water and an attack by Ips bettles have wrecked this stand

only put on no growth but, by remaining on the land in a nearly stagnant condition for years, effectively retard the establishment of new forest growth.

Annual woods burning by naval-stores men is another practice injurious to forest growth. Of course, woods burning is not confined to the turpentine stands; others beside operators are responsible for a very large number of the fires; but practically all turpentine men burn over their woods. They claim that in the past it has been unpractical, if not impossible, to exclude incendiary fires, since such fires are likely to come at a time when there is an accumulation of chips, grass, leaves, and other inflammable material around the trees. Under such conditions, even light surface fires can creep up to the turpentine faces and ignite them. Accordingly, operators rake away all grass, chips, and leaves from the trees which are being tapped, and then burn the woods. Unfortunately, trees on which old faces have been worked out, but which are still potential producers of timber as well as of later gum yields, are not protected, and these faces burn year after year.

These results of uncontrolled turpentining methods suffice to indicate the havoc such methods can bring about in ruining small trees, checking the growth rate of others, and reducing the timber value of many trees that otherwise might yield a return in both gum and lumber. Practically all the longleaf and slash pines destined for ties, poles, or lumber are turpentined before they are cut, and many of them before they reach seed-bearing size.

Thus far the industry has prospered, largely at the cost of its future well-being and with reckless disregard of the need of sustaining future supplies of raw materials. This need, so important to the welfare of the industry, has by no means been disregarded intentionally but rather for lack of any dependable information and convincing facts leading to improved practice. The need has been for systematic investigative work upon which might be based a scientific plan of naval-stores management that would insure a sustained supply of timber for the naval-stores industry and the landowner.

Studies of turpentine practice made prior to 1923 resulted in several great improvements in the industry. Such work as that of Ashe (*1*) and Herty (*18*, *19*) did much to expose the wasteful "boxing" system of 30 years ago, whereby the gum was caught in a deep niche or box cut into the base of the tree below the face. Herty's recommendations were put into practice in overmature longleaf pine in northwestern Florida on the Choctawhatchee (then the Florida) National Forest under the direction of Forest Supervisor I. F. Eldridge and Ranger E. R. McKee (*10*) in 1908. In 1916 some experiments in the use of narrow faces on virgin timber were started by McKee (*26*) on the Florida National Forest.

Before 1920 all experimental work was in virgin timber, but at that time Cary (*6*) started a number of field tests in second-growth stands, in cooperation with timber owners at various points in the South, and these have done much to attract widespread attention to the problems peculiar to second-growth working. In 1923 Cary, Gerry, and McKee (*15*) established a set of experimental plots in mature timber on the Florida National Forest, from which results were obtained that threw new light on the relation of height of streak to wood structure and gum yield.

In 1921, coincident with the establishment of the Southern Forest Experiment Station, the Forest Service began the systematic study of naval-stores practices, and in 1923 started a series of tests at a branch station at Starke, in Bradford County, Fla. This location, although perhaps a little south of the center of the region, was deemed to be representative of the second-growth turpentine timber belt. These investigations were designed to determine the best practice that would combine profitable turpentining with sustained gum yields and the conservation of southern pine forests.

Among the more important problems on which studies were begun in 1923 are the effect on naval-stores management of varying the height of chip removed with each streak, the effect on gum and timber yields of cutting deep or shallow streaks, and the effect on yields and the life of the turpentining operation of width of face and back facing. Another series of tests had to do with the effect on gum yield of stand density, tree diameter, crown size, and growth rate.

In these studies it was apparent that the species chipped must be taken into account with nearly every other factor considered. Although longleaf pine sometimes grows in mixture with slash pine, normally the two species occur in somewhat different situations. As already stated, slash pine commonly occurs on wetter land than longleaf. It might well be assumed, also, that the two species respond differently to chipping. Observation indicated that slash was more susceptible to injury than longleaf pine. Because of these differences in behavior, it was planned to duplicate as many as possible of the chipping tests in slash and longleaf.

LOCATION AND DESCRIPTION OF STARKE TESTS

No Government-owned timber suitable for naval-stores studies in second-growth stands was available in 1923, and it was therefore necessary to obtain the cooperation of private interests which would allow the Forest Service to use their timber for this purpose. From R. A. and W. H. Smith, of Hawthorne, Fla., was obtained the use of 25 acres of slash pine for experimental work (Sampson tract) and from the Smith-Powell Naval Stores Co., of Starke, Fla., the needed longleaf pine (Powell tract).

SLASH PINE AREA (SAMPSON TRACT)

The slash pine experimental area is located 7 miles southwest of Starke on the north shore of Sampson Lake, a shallow lake about 2 miles wide. The timber tract extends back from the normal shore line for a distance of 800 feet, but 90 per cent of the trees used in these first experiments occur in a band 250 feet wide close to the lake shore. The timber is fairly representative of slash pine in the flatwoods region and from the standpoint of naval-stores production may be considered about average.

The shore line of the lake is normally 200 feet from the edge of the timber. and the water level is 12 to 15 inches lower than the ground level where the timber stand commences, but a rise of 4 or 4½ feet in the lake level (such as occurs almost every year) floods the timber in a strip 200 to 250 feet wide. Such floods occurred in April, June, July, or September in 3 out of the 5 years of this record and lasted from 3 to 10 weeks. There is not more than 6 feet difference in elevation between the highest and lowest parts of this whole area. It is evident that the water table is close to the surface and that the trees seldom suffer from drought. The absolute elevation is 150 feet above sea level. The rainfall is very irregular. Almost any month from March to October may have 8 inches of rain or enough to cause a sharp rise in the water level of the lake.

The Sampson tract supports practically a pure stand of slash pine, with occasional pond cypresses (*Taxodium ascendens* Brongniart) that have been badly damaged by suppression and fires. The dominant slash pine trees were 33 to 35 years old in 1923 and averaged 82 feet tall and 11 inches d. b. h.[4] They had grown rapidly up to the age of 28 or 30 years, but at about that time a marked slowing down in the growth rate occurred because of overcrowding. In basal area, or total area of the cross sections of all trees at breast height, individual tenth acres varied at the rate of between 140 and 220 square feet per acre. The average basal area per acre was 150 square feet, as opposed to 160 square feet in normally stocked timber stands of this age and site (*39*). The number of faces per acre which it would have been possible to cut, allowing one face on trees over 8.5 inches and two faces on trees over 12 inches d. b. h., ranged from 110 to 250, with an average of 154 per acre on the 3.5 acres to which the tests were confined. The site index was found to be 95 feet (at 50 years) or considerably better than the average for the South. The trees were healthy, only a very few having visible fire scars. Fires had been infrequent and light near the lake, owing to the wetness of the soil and humus, but, even so, had been effective in removing the cypress from the stand. As a result of relative freedom from fires, the leaf litter and humus had accumulated until they were about 3 inches deep.

Because of the density of the pine stand, there is practically no underbrush or pine reproduction and only a very sparse grass cover. Where the stand is open, gall berry (*Ilex glabra* (L) A. Gray), ground laurel (*Kalmia hirsuta* Walter), huckleberry (*Gaylussacia dumosa* A. Gray), and blueberry (*Vaccinium myrsinites* Lambert) are characteristic species forming the ground cover. Several species of wire grass are common, the most typical being *Aristida spiciformis* Elliot. St. Johnswort (*Hypericum fasciculatum* Lambert) is very common along the lake shore outside the timber belt.

The soil is classified as Norfolk fine sand and is composed of 8 inches of light-gray to dark-gray fine sand surface soil underlain by a yellow subsoil. In depressions from 2 to 4 inches of muck may occur. The subsoil, when saturated, is of a quicksand type, and is wet at practically all seasons of the year, a situation favorable to the development of slash pine. The surface soil is moderately well drained.

LONGLEAF PINE AREA (POWELL TRACT)

The longleaf tract used for these turpentining tests is located about 3½ miles southeast of Starke and approximately 8 miles east of the Sampson Lake slash pine area. The timber on the Powell

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[4] Diameter at breast height (4.5 feet).

tract is typical of second-growth longleaf as it occurs in the flatwoods region.

The trees on the Powell tract are longleaf pine, with the exception of half a dozen slash pines which were not included in the test. In 1923, the age of the trees ranged from 19 to 37 years, averaging 24 or 25 years. There were 40 to 50 trees per acre of turpentine size on the tract, although the stand varied greatly in density. Diameters ranged from 9 to 14 inches at the time the trees were first chipped. Most of the area was under cultivation in 1900, and practically all of it had been cleared of old trees prior to that time, although it had not been completely stumped. Owing to the very open character of the stand, the trees were not very tall, ranging in height from 32 to 68 feet. The site index was 70 to 75 feet (at 50 years) on the cut-over part of the tract, or normal for the southern pine region. On the old-field portion it was 90 feet. Fires probably occurred on this area four years out of five prior to 1923, when the experiment was started. Since that time, it has been the practice to rake around all the trees and to burn over the tract under supervision during the winter months. This has been necessary because of the impracticability of keeping fire out of so small a stand completely surrounded by lands burned annually.

The undergrowth on the Powell tract varies considerably in density. In the center of the area, where the timber stand is light, there is little or no underbrush but an abundance of dog fennel (*Eupatorium compositifolium* Walter). Broom sedge (*Andropogon* sp.) and other grasses form a thick mat where the trees are widely scattered. In the still more open spots dwarf oaks (*Quercus chapmani* Sargent and *Q. minima* Small), huckleberries (*Gaylussacia dumosa* A. Gray and *G. nana* (A. Gray) Small), blueberry, gopher apples (*Chrysobalanus oblongifolius* Michaux), and ground laurel are most common, with very little gall berry or palmetto, (*Serenoa serrulata* (Michaux) Hooker. Of the herbaceous growth, the most abundant species is deer-tongue (*Trilisa odoratissima* (Walter) Cass). Wire grass and a species of wild oats (*Sorghastrum* sp.) are the commonest grasses.

The Powell tract lies at an altitude of 150 feet above sea level, and the relative elevation above near-by cypress ponds on the southeast and north is probably about 5 to 8 feet. Ditches put in on two sides of the tract have resulted in good drainage except in one small corner of the area, in contrast with the poor drainage on the Sampson Lake tract.

The soil, which is decidedly variable, is classified in four soil series, the Norfolk, St. Johns, Leon, and Portsmouth. The texture is fine sand, with a few minor exceptions. The Norfolk soil has been described in connection with the Sampson area. The Portsmouth soil is fine sand of a dark-gray color to a depth of 8 inches, where it grades into light-gray loamy fine sand, usually saturated at a depth of 3 feet or less. The Leon soil has a hardpan of coffee-brown color at a depth of 10 to 24 inches; the gray fine sand surface soil is underlain by a subsoil of white or light-gray fine sand. The St. John soil is also a hardpan type similar to the Leon type, with a dark-gray fine sand surface soil over a light-gray or mottled gray and yellow sandy clay subsoil. This type is characterized by poor drainage.

GENERAL CONDITIONS AFFECTING YIELDS

WEATHER RELATIONSHIPS

Weather is an important factor in gum yields. It has been found that in midsummer 80 per cent of the weekly gum flow comes within 24 hours of chipping, whereas in the cold weather, the same percentage of flow may be spread over five days. Local weather records at Starke have been kept since the spring of 1925. Prior to that time, Jacksonville, 45 miles northeast, and Gainesville, 26 miles southeast, furnished the data needed. In general, the climate of this region may be classified as temperate, verging on the subtropical. (Fig. 4.) Table 1 shows the temperature and rainfall records for all four seasons. According to Jacksonville records, there was, over a period of 55 years, an average of 122 days each

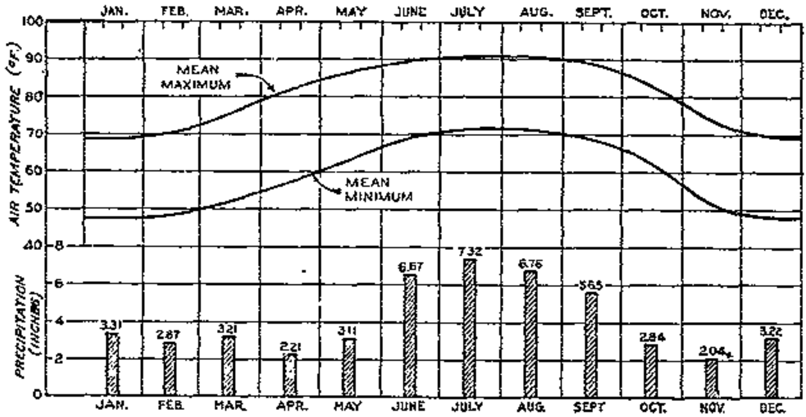

FIGURE 4.—Monthly mean maximum and minimum air temperatures (17 years) and total mean monthly precipitation (42 years) at Gainesville, Fla.

year with a measurable amount of rain; of these, 90 occur during the growing season. Gainesville records over a shorter period approximate these figures.

TABLE 1.—*Average seasonal maximum and minimum temperatures and precipitation, Gainesville, Fla.* (30)

Season	Temperature		Monthly precipitation
	Maximum	Minimum	
	° F.	° F.	Inches
Winter	69.1	47.2	3.13
Spring	81.1	57.5	2.84
Summer	90.2	70.1	6.88
Fall	81.9	60.6	3.51

Since no chipping is ordinarily done during the winter months, the weather during those months is of less importance than that during the rest of the year. Of the five chipping seasons (March to November, 1923 to 1927) during which the tests at Starke were being carried on, the wettest season was that of 1926 and the driest that in

1925. From March 22 to June 5, 1927, no rainfall exceeded 0.25 inch. This constituted a rather serious drought. The coolest seasons were in 1924 and 1926; the warmest, in 1927. The records indicate that 1926, with its cold, rainy weather, was the least favorable year for heavy gum flow, and that 1927, with its warm, relatively dry weather, was the most favorable during this 5-year period.

INDIVIDUAL VARIATION IN GUM YIELD AND SCRAPE

One of the most striking points that has come to light in the naval-stores experiments conducted by this station is the degree of variation which is found in the yield of gum from individual trees. It is not unusual to find trees alike in all external characteristics varying in their gum production by 100 per cent and in some cases even 300 per cent. This fact has also been noted in Spain by Cosculluela (*7*). Not only is it impossible to predict the gum-yielding capacity of individual trees by external characteristics, but it has also been found that, in the individual tree, the microscopic wood structure, as at present understood, can not be depended on to serve as a criterion of gum yields. This is a problem upon which Eloise Gerry is working.[5]

Large variations, particularly as between the two species, also occur in the amount of scrape formed on the face (*17*). An average of 6 per cent of the total seasonal yield of slash pine occurs in the form of scrape, and only occasional trees will run as high as 10 or 15 per cent; but longleaf pine averages 24 per cent of its total yield in this form. The economic importance of the proportion of scrape to total gum production can better be recognized when it is understood that, whereas the gum from the cups contains about 20 per cent or more of turpentine by weight, scrape contains only half as much. Because of the greater value of turpentine, slash pine, having the lower percentage of scrape, is the more valuable of the two species.

DRY FACING

Dry facing, although it is in the nature of a secondary effect of unregulated turpentining, nevertheless may quite as properly be attributed to the influence of environment and the habit of growth of the various trees in the stand and therefore can be regarded as a primary consideration influencing yield under various methods of turpentining. It is manifested in the form of a gradual drying out of the wood tissues, usually first appearing in the center of the face. No resin is produced on the particular area dry faced. Normally this drying out of the living wood tissue spreads until finally no gum is produced except at the very outside corners of the shoulders of the face.

There has been much misunderstanding about the nature of dry facing, and as a result little has been done to reduce it to the minimum that it should reach in any well-managed stand. It should be realized that the flow of gum as a result of the scarring of the outside wood serves to coat the exposed wood until healing tissue can be formed and bark built up to cover the scar permanently. Under natural conditions the success with which this healing process can

[5] Reported in a paper presented before the American Society of Plant Physiologists, New York, December, 1928, A Study of Externally Matched Southern Pines which Produce Widely Different Yields of Resin.

be completed depends altogether upon the health and vigor of the tree. One instance of the failure of this process is found in the case of the tree in a dense stand, which has failed in competition with other trees and has only a small crown area. Such a tree has not the vigor of a dominant or open-growing tree and consequently will not be so well able to respond persistently and effectively to the scarring of its bark and wood. Translated into the terms of the artificial process of chipping the tree for gum, this means that a tree lacking in vigor, as indicated by small crown or other evidences, will not be able to maintain the flow of gum that can be expected from a vigorous large-crowned tree. As it fails in this response the failure becomes evident in what we call dry facing.

Deep chipping, drought, and the chipping of trees that are too young have frequently been considered causes of dry facing. Operators who hold this view have based their opinions upon extensive observations (*3*, *5*, *16*, *20*, *21*, *24*, *27*, *28*, *35*, *37*). These are certainly contributing causes of dry facing, but it should not be forgotten that in every instance the lack of vigor of the tree is a major contributing cause and that a sturdy, full-crowned tree will withstand considerable abuse without dry facing.

As might be expected, dry facing is particularly troublesome in crowded stands where trees are less vigorous and have narrower growth rings and a narrower band of sapwood. When such trees are turpentined not only are they less able to maintain a constant response in flow of gum but also the effort exerted in response to the scarring evidently further weakens the tree. This cutting into a narrow band of sapwood interferes with the flow of sap, further reducing the vigor of the tree. Of 545 second-growth slash pine trees in a crowded stand 50 per cent exhibited some signs of dry facing at the end of the fourth year of work. In contrast, out of 1,075 slash pines growing in a more open stand on the same timber tract, only 34 per cent were dry facing at the end of the fourth year. All types of chipping were included in these stands. In two other groups of 150 slash pines each, all chipped in approved manner, only 29 per cent of the open-grown trees were dry facing at the end of the fourth year, in contrast with 40 per cent among the crowded trees.

Young longleaf trees with healthy crowns seldom dry face. However, dry facing may occur in young stands where trees through previous ill-treatment have suffered reduced growth and thus have only a thin layer of sapwood. Among old slash and longleaf pines serious dry facing is rather common, owing also to the narrowness of the sapwood which is easily cut through by heavy work.

Dry facing in itself may bring about serious loss to the operator and owner when it reaches so advanced a stage as to cause abandonment of work. This, however, is not the whole story. Dry facing is often only the first evidence of deterioration and is likely to be closely followed by insect damage, by the development of wood-rotting fungi, and eventually by the total destruction of the tree through windbreak. Even where the wood is not pitch soaked or destroyed it is very often attacked by blue stain, which causes the lowering of grade in lumber. In one record taken where dry faces in many trees showed blue strain superficially, it was found that as a matter of fact practically every dry-faced tree had been attacked by blue-stain fungi.

No reference to dry facing has been found in any of the foreign naval-stores literature which has come to the author's attention, with the exception of one Russian article (*23*). Evidently it is uncommon or seldom occurs abroad.

WORKING TECHNIC

TREE SELECTION AND MEASUREMENT

In selecting the tree groups used in the various slash pine tests, strips approximately 1 chain (66 feet) wide were run from the edge of the lake back for 250 to 400 feet. For each of these groups, 50 unchipped trees over 8 inches d. b. h. and free from fire scars were selected. The groups, therefore, were located more or less on parallel strips somewhat overlapping each other, and with conditions comparable throughout.

The location of the 50-tree groups on the Powell tract differed from this. The practice on the longleaf tract was to concentrate all the trees worked under one style of chipping into one portion of the tract. After the groups were laid out, it was found that two of the groups in the height-of-streak test occurred on Portsmouth fine sand while the third group was partly on Norfolk fine sand and partly on St. Johns fine sand. The latter group is thus on soil which is somewhat better drained than that on which the other two groups occur. The three groups used in the depth-of-chipping test all occur on Norfolk fine sand.

Diameter measurements of all trees were taken at breast height and at 9 feet above the ground. The higher point was chosen so that a remeasurement of growth might be made at the end of the test period, above the scarring caused by all but the highest chipping. Height of tree and length of crown were measured, but average width of crown was estimated. Vigor of trees was classified as poor, medium, and good, most of the trees being classified as medium. Likewise, crown class was recorded; and crown density was recorded as being thin, medium, or thick, 75 per cent or more of the crowns rating as medium. Increment borings at breast height were taken on all trees in order to determine age and the number of rings in the outer half inch of wood. This width was chosen because it represented the depth of streak cut in all but two of the groups. Remeasurements were taken at the close of the test in 1927 in order to correlate growth or changes in tree condition with the variable under consideration.

FACING, CHIPPING, AND DIPPING

Facing was done by the regular crews employed by the two firms with whom the station was cooperating.

The method of facing the trees was the same on both the slash and the longleaf areas. At the start of the tests, tins or gutters were set in cuts made with broadaxes after a rather heavy slab of bark and wood had been removed. The thickness of this wood slab was 0.5 to 0.75 inch and the ax cut for tin insertion extended in another 0.5 inch. Sloping gutters and Herty clay cups were used. The removal of the wood slab proved rather injurious, and the facing has since been modified to omit this.

The same method of raising tins was used in both the slash and the longleaf tracts. In the spring of 1924, and again in the spring of 1925, when the tins were pulled and raised to within 7 or 8 inches of the last streak of the preceding season, the tins were inserted in broadax cuts 0.5 to 0.75 inch deep, and one or more nails were used on each tin to hold it securely. In the spring of 1926, tins were tacked in place on the face, with no special preparation before tacking. It was deemed unpractical to raise the tins and cups for the last year of chipping.

The chipping season was started on or about March 15 each year. One streak was cut regularly each week, with only an occasional interruption due to lack of chippers, to weather conditions, or to other causes, until from 30 to 33 streaks had been cut. Season yields have been computed on a 32-streak season by adding or subtracting, where necessary, a proportionate amount of the last dip.

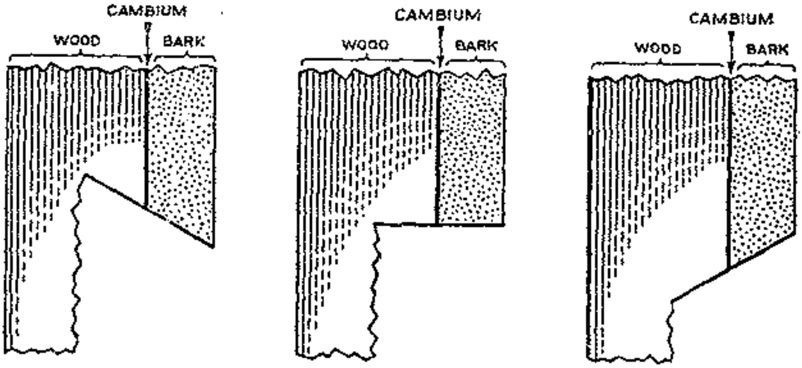

FIGURE 5.—Profile of turpentine faces, showing different types of streak

No. 0 hacks were used for all chipping except where wide streaks called for a No. 2 hack. The type of streak used is classed as a "square" streak by operators. (Fig. 5.)

The chipping specifications were quite closely followed, and small leeway was allowed. Shoulders were kept even. Face widths were marked after the first year and every tree was inspected every week.

The cups were furnished by the operator. Grades of rosin, which might be affected by type of cup, were not determined during the period of operating these tests.

The gum was dipped from the cups during each chipping season whenever the cups were full on 20 per cent of the best producers. Where necessary, on a few trees which yielded an exceptionally large amount of gum, additional cups were placed between dips. A considerable number of the trees, however, had not completely filled their cups at dipping time.

WEIGHING

In 1925 the gum from each tree in each group was weighed separately at each dipping, but in the other four years the total dip only was weighed. Water and trash, such as chips, bark, and leaves, were removed as far as practical, but some trash and water were unavoidably included in the gum weighed. At the end of the season, the hardened scrape on the faces was removed and weighed for each group, except in 1923, when not enough scrape had collected on the slash pines on the Sampson tract to warrant gathering.

Steelyard scales recording by ounces were used for weighing buckets of gum, and spring-balance scales recording by ounces and kept in careful adjustment were used for obtaining the weight of gum from individual trees.

ALLOWANCES

Gum analyses made in 1929 by the Bureau of Chemistry and Soils of 16 samples from similar tests at Starke showed a range of water content from 4.7 to 10.2 per cent, with an average of 6.8 per cent; and trash ranging between 1 and 4.1 per cent, with an average of 3 per cent. Analysis of 8 samples of scrape gave water ranging between 1 and 2.4 per cent, averaging 1.8 per cent; and trash between 2.1 and 4.2 per cent, averaging 3.3 per cent. Dip from commercial stilling operations near by had a water content of 11 to 12 per cent, and trash amounting to 2 to 3 per cent by weight. From these figures, it appears that the proportion of water was considerably higher in gum from commercial operations than in gum from the experiment station tests, whereas the proportion of trash and dirt was about the same. In later tests, in which a canvas chip paddle was used, the proportion of trash was reduced to about 0.6 per cent.

In the records of gum yield, allowance has been made for accidents such as occasional broken cups or gum wastage or trees not streaked for one cause or another. Such accidents were compensated for by adding a proportionate amount of gum to the group weighing. On the other hand, where trees have been killed by the type of chipping used on them, the group has been considered as a full group and no additional gum has been added to compensate for the loss of trees so killed. Adjustments in scrape yields were made by assuming that scrape was formed in proportion to the amount of face exposed successively as each new streak is put on. Temperature is known to affect the formation of scrape but, as definite figures on this point were lacking, no account of it was taken.

RAKING AND BURNING

Each December, pine needles, grass, and gum were raked from around all trees and the whole tract was burned. It was found not to be feasible to keep the experimental areas unburned, since they lay in the midst of timber tracts which burned every year and were so located that they could not be reached rapidly at short notice. In 1923, 1924, and 1925 the station staff burned the tracts. In 1926 and 1927 the tracts burned accidently subsequent to the raking, but without supervision. In the interval between raking and burning, leaves had blown in around several of the trees and so enabled the fire to reach the faces. In this way several of the faces were burned in each of these two years.

EFFECT OF METHODS OF WORKING ON STAND AND YIELD

HEIGHT-OF-STREAK TESTS

Height of streak, or the increase in length of face effected each time a new streak is put on, is of first importance in any general study of turpentining methods, because of its direct effect in limiting the period of working. In ordinary practice a ¾-inch streak is chipped, carrying the face up 2 feet or more a year and thereby usually terminating profitable chipping after five seasons' work. Obviously, lower streaks would allow a longer working to the same height of face. The principal question which height-of-streak tests must answer is whether gum yields by lower chipping would equal current yields and so warrant extending the chipping period beyond 5 years. If front faces can be worked from 7 to 12 years at anything like the average gum yield for 5 years, the result is bound to be of great significance and profit to the landowner, and hardly less to the operator.

The tests here described cover 5 years, but the trends which they clearly indicate give ample basis for estimating conservatively the results to be obtained from 7 to 12 years' work.

In the height-of-streak tests three groups of slash pine and three of longleaf pine, consisting of 50 trees each, were worked during a 5-year period, the three groups for each species being given, respectively, 0.75, 0.5, and 0.25 inch streaks. In each group, the width of face was kept uniform at one-third of the tree circumference at breast height, and depth of streak was 0.5 inch for all.

In the highest chipping group, the actual average height of streak was 0.73 inch, or very close to the 0.75 inch desired. The 0.5-inch height-of-streak test was chipped almost exactly to specifications. The 0.25-inch chipping deviated slightly from the desired height. In general, the streaks were kept down close to 0.3 inch, which is perhaps as near the quarter inch as could be attained on an average in any commercial operation. In 1926 and 1927 it seemed necessary to chip two heavy streaks at the beginning of the season in order to cut through the three-quarters to 1½ inches of wood that had become gum soaked over winter. This preliminary chipping increased the average height of streak to 0.32 inch.

Although one operator who has put 0.25-inch streaks on first-year work claims that the work took a third longer than the 0.5-inch chipping, the tests here recorded gave no evidence that the work was slowed down appreciably thereby, nor was any difficulty encountered in getting the work done properly.

The three groups of trees forming the slash pine height-of-streak test were closely matched as to diameter, height, age, and rate of growth, but not quite so well in size of crown, the high-chipping group having a crown width a little narrower than the other two. Comparative measurements are given in Table 21 in the Appendix.

The gum yield per group and the yield of turpentine and rosin per crop (10,000 faces) for the three styles of work included in the height-of-streak test are shown in Tables 2 and 3.

TABLE 2.—*Gum yield in relation to height of streak, slash pine, 32 streaks, 50-tree groups*

Year	0.32-inch streak		0.5-inch streak		0.73-inch streak	
	Yield	Loss	Yield	Loss	Yield	Loss
	Ounces	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*
1923	8,090		7,465		8,351	
1924	7,887	−200	7,084	−381	7,569	−782
1925	7,066	−821	6,832	−252	6,866	−703
1926	6,605	−461	6,088	−744	5,257	−1,609
1927	6,152	−453	5,504	−584	5,019	−238
Total	35,806	−1,944	32,973	−1,961	33,062	−3,332
		Per cent 24.01		*Per cent* 26.27		*Per cent* 39.90

TABLE 3.—*Calculated naval-stores yields per crop in relation to height of streak, slash pine, 32 streaks*[1]

Year	Turpentine			Rosin		
	0.32-in. streak	0.5-in. streak	0.73-in. streak	0.32-in. streak	0.5-in. streak	0.73-in. streak
	Barrels	*Barrels*	*Barrels*	*Barrels*	*Barrels*	*Barrels*
1923	57.5	52.0	58.8	175.6	162.7	181.5
1924	54.1	48.2	53.3	172.6	155.5	164.5
1925	48.0	45.8	40.2	155.0	150.5	151.2
1926	44.7	40.2	35.1	145.1	134.5	116.0
1927	39.8	34.4	31.8	136.8	123.3	112.1
Average	48.8	44.1	45.0	157.0	145.3	145.1

[1] Turpentine barrel contains 50 gallons; rosin barrel contains 420 pounds net. Bureau of Chemistry and Soils converting factors for turpentine yields used as follows: For 0.32-inch chipping, 21.9 per cent weight of dip and 9.2 per cent weight of scrape; for 0.5-inch chipping, 21.5 per cent weight of dip and 9.2 per cent weight of scrape; and for 0.73-inch chipping, 21.7 per cent weight of dip and 9.9 per cent weight of scrape. Water and trash for all groups, 6.7 per cent.

The first significant fact brought out in Tables 2 and 3 is that the 0.32-inch streaks yield quite as much as the 0.73-inch streaks. However, the true significance of the records is shown more strikingly in Figures 6 and 7 and is given a measurable value for operator and owner in the projected (dotted-line) bars of Figure 8.

The total of 225 barrels of spirits and 725 barrels of rosin produced by the 0.73-inch streak represents all that such faces can produce. The faces raised by 0.5-inch streaks can, however, be worked for at least two years more, producing an additional quantity of gum that may well bring the total naval-stores yields up to 275 barrels of turpentine and 950 barrels of rosin.

The trees chipped 0.32 inch can be worked a total of 11 or 12 years, greatly increasing the total yield. The operation is limited only by the falling off of the annual yield of turpentine to a point at which, under ordinary market conditions, turpentining no longer pays. This advantage in favor of the 0.32-inch chipping is, of course, increased in more open and more thrifty stands, where the initial year's yield is higher and a long period of profitable exploitation is correspondingly assured. A number of conditions unavoidable at the time these tests were made—such as not raising the cups in the fourth and fifth years, and the heavy ax cut made for tin insertion in the [illegible] have probably been responsible for increasing the [illegible] from year to year. Under more favorable and at the [illegible] normal conditions, there is little doubt that 0.52-inch [illegible] profitably for 12 years on a single face on [illegible] with 0.75-inch streaks.

[illegible] with [illegible] the other

[illegible] through the 1929 season, 0.52-inch chip- [illegible] has already yielded 222.9 barrels of [illegible] total possible yield of 225.2 barrels for high [illegible] of the yield expected in the next [illegible] the expected total for 10 years of [illegible] faces will then be a little over 8.5 [illegible] of their workable height.

The three groups of trees in the longleaf height-of-streak test were not exactly comparable except in density of stand, diameters, and width of face. The trees in the group chipped with 0.32-inch streaks were about 8 or 9 years older than the others and slower in

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FIGURE 7.—The two trees in the foreground show the height of faces of slash pine trees at the end of five years of work, that on the right being chipped with streaks 0.32 inch high, and that on the left with 0.5-inch streaks. Low chipping gave greater yields than medium or high chipping over a 5-year period. The low-chipped tree may be worked for five more years

growth rate. The 0.5-inch and 0.73-inch chipping groups are more closely comparable, although the trees chipped with heavy streaks were somewhat smaller than those with medium chipping. Table 21 in the Appendix shows the character of the trees in the three groups. The yields from these tests are shown in Tables 4 and 5.

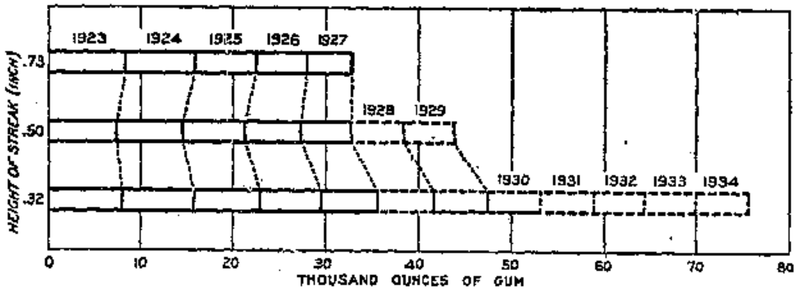

FIGURE 8.—Cumulative yields of dip and scrape on 50-tree groups of slash pine resulting from streaks 0.73, 0.5, and 0.32 inch in height. Yields are shown for five years of actual operation and as projected for the total number of years possible under the respective chipping heights. At the end of the three periods indicated all three faces have reached a height of about 10 feet

TABLE 4.—*Gum yields in relation to height of streak, longleaf pine, 32 streaks, 50-tree groups*

Year	0.32-inch streak		0.5-inch streak		0.73-inch streak	
	Yield	Loss or gain	Yield	Loss or gain	Yield	Loss or gain
	Ounces	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*
1923 [1]	6,033		6,905		7,127	
1924	5,138	−895	6,475	−430	6,791	−336
1925	4,720	−418	6,807	+332	6,075	−716
1926	5,016	+296	6,170	−637	5,238	−837
1927	3,449	−1,567	5,234	−936	4,712	−526
Total	24,356	−2,584	31,591	−1,671	29,943	−2,416
		Per cent 42.83		*Per cent* 24.20		*Per cent* 33.89

[1] Totals computed on a 32-streak basis from 22-streak yields actually measured the first year.

TABLE 5.—*Calculated naval-stores yields per crop in relation to height of streak, longleaf pine, 32 streaks* [1]

Year [2]	Turpentine			Rosin		
	0.32-in. streak	0.5-in. streak	0.73-in. streak	0.32-in. streak	0.5-in. streak	0.73-in. streak
	Barrels	*Barrels*	*Barrels*	*Barrels*	*Barrels*	*Barrels*
1924	32.4	42.8	43.7	113.9	141.8	149.8
1925	30.5	46.4	41.0	104.0	147.9	132.4
1926	33.8	40.2	34.7	112.3	135.6	114.6
1927	19.9	32.2	29.0	78.0	116.7	105.0
Average	29.2	40.4	37.1	102.0	135.5	125.4

[1] Turpentine barrel contains 50 gallons; rosin barrel contains 420 pounds net. Bureau of Chemistry and Soils converting factors for turpentine yields used as follows: For 0.32-inch chipping, 22.3 per cent weight of dip and 10.2 per cent weight of scrape; for 0.5-inch chipping, 22.9 per cent weight of dip and 11.2 per cent weight of scrape; and for 0.73 inch chipping, 22.9 per cent weight of dip and 10.9 per cent weight of scrape. Water and trash for all groups, 7.4 per cent.
[2] 1923 omitted because of incomplete record.

The yields from these tests indicate that the 0.5-inch streak is by far the most successful with longleaf pine. However, the fact that the 0.32-inch group was inferior to the other groups, especially in growth rate, makes it fair to assume that a more open and vigorous stand would have given yields more nearly equal to those of the other groups. Here, as in the consideration of slash yields, the advantage of the longer working period allowed, for example, by the use of the 0.5-inch streak, is clearly evident. In seven years a total of nearly 250 barrels of turpentine would be obtained from this group, as contrasted with a total yield of less than 200 barrels from the 0.73-inch group. This superiority is well brought out in Figure 9, showing comparative gum yields.

It is interesting to compare with these figures the results of a similar test of height of chipping in mature longleaf carried out by Cary and Gerry (*15*) in northwest Florida in 1923. A report of the first year's work showed that low chipping (0.28 inch) gave about 9 and 12 per cent, respectively, more gum than either medium (0.45 inch) or high (0.71 inch). During the second year high chipping kept pace with low. Work by other investigators (*6, v. 35, no. 22; 29; 36*) brings out some interesting results, but they are hardly

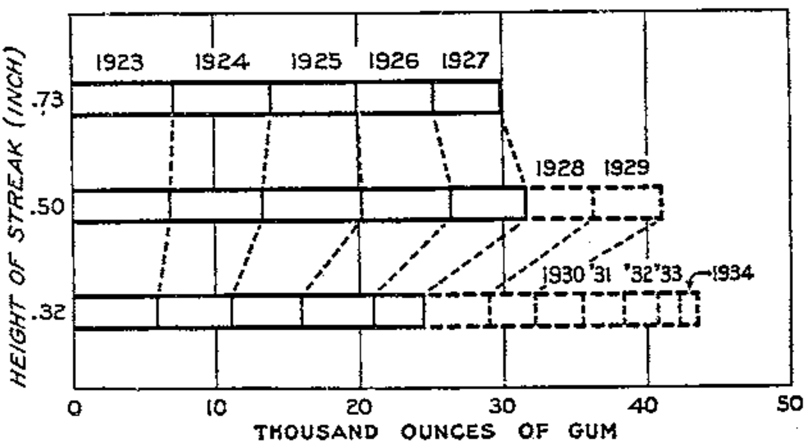

FIGURE 9.—Cumulative yields of dip and scrape in 50-tree groups of longleaf pine, from streaks 0.73, 0.5, and 0.32 inch in height. Yields are shown for five years of actual operation and as projected for the total number of years possible under the respective chipping heights

applicable to conditions in this region or are for other reasons not comparable.

In general, the results here shown indicate clearly the superiority of low or moderate chipping to high chipping in equal or greater annual yields, and still more in the additional working period per face allowed by the lower streaks. It is hardly too much to say that the operator who uses high chipping in either longleaf or slash is losing 25 to 50 per cent of the gum obtainable through more moderate chipping. In slash pine, where low chipping is clearly successful, his loss amounts to 50 per cent or more of the yield he can easily expect from front faces. Indeed, these tests, corroborated by evidence already available from further tests now under way, show plainly that high chipping can be justified only where the chipping will be immediately followed by the removal of the trees in a thinning operation or where the necessity of cutting trees for timber at an early date precludes the possibility of long-time turpentine operations. Even here, the timber owner looking forward to cutting his stand within a few years may well consider the desirability of insisting on low chipping in view of the lessened damage to his trees. To the owner cutting poles or piles, a difference in height of face of more than 5 feet (representing five years difference between high and low chipping) has an appreciable money value.

An additional advantage in low chipping and consequent longer working life of the face lies in the longer healing period allowed before back cupping starts. The low chipping should appeal in particular to the operator who expects to work timber from the same location for a number of years and to the timber owner desirous of deriving maximum continuous returns from his land and timber. The continuous working of trees over an extended period will encourage the holding of timber until it reaches usable size for lumber or other high-grade forest products. The naval-stores operator will be enabled by such practice to keep his work within a smaller area or to increase his operation on the same area. This is a distinct advantage to him. For one thing, it will enable him to have workmen continuously in the woods, which will simplify fire fighting and detection. Also, it reduces his hauling costs and simplifies woods riding and inspection.

DEPTH-OF-STREAK TESTS

In the early days of the turpentine industry, according to McDougald (*25*), operators believed that deep chipping was necessary in order to obtain gum. As an example of this practice, a stand of young longleaf pine timber in Clay County, Fla., chipped with convict labor some 30 years ago, bears streaks averaging 1½ inches deep. This was not so unusual as to cause comment at the time the trees were chipped; and since it is more difficult to cut a deep streak than a shallow one, the operators of those days must have believed that a chipper must "get the wood" if a good yield were to be obtained. In later years shallower work has been more general.

Depth of chipping is of main interest to the timber owner, for whom it is only too readily reflected in degree of dry facing (fig. 10), blue stain, insect attack, and mortality of stand, all of which greatly impair the value of his timber for subsequent lumber or pole production. Mechanical weakening caused by deep chipping also results in considerable loss from subsequent heavy windstorms.

The purpose of the tests begun at Starke in 1923 was to determine the depth of chipping which, without serious loss in gum yields, would do least harm to the tree. Like the height-of-streak tests just described, the depth-of-chipping tests extended over a 5-year period. The general character of the timber chipped was also the same as that used in the height-of-streak tests. Four groups of 50 trees each were chipped in both slash and longleaf stands to depths of 0.3, 0.5, 0.75, and 1 inch, measured from the inside of the bark radially in a horizontal plane to the deepest point in the cut. Width of face in each group was standard, one-third of the tree circumference. Height of streak was the same in all groups, 0.5 inch.

Both slash and longleaf groups were closely matched, as is shown in Table 22 in the Appendix, and were in fact safely within the

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[illegible]—Deep and ragged chipping has dry faced this slash pine tree allowable limits of error. The slash pine trees were, however, rather crowded, with crowns somewhat smaller than desirable for best gum yields. The longleaf trees growing in a moderately open stand had larger crowns.

The No. 0 hack was used on all tests. Some difficulty was encountered in getting 1-inch deep chipping, and perhaps 20 per cent of the chipping which should have been 1 inch deep was only seven-eighths of an inch. The 0.75 and 0.5 inch deep chipping was done according to specifications. The shallowest chipping actually averaged about 0.3 inch, with occasional streaks exceeding that depth.

The ax cuts made for tin insertions in the spring of 1924 and 1925 doubtless increased the damage done by turpentining and seriously vitiated the results of the shallow chipping, and reduced the significance of the yields. However, the injury was equally severe in all groups, so that any difference in damage or yields in this test can safely be attributed to difference in chipping methods.

Tables 6, 7, 8, and 9 give the yields of gum, turpentine, and rosin obtained for slash pine and longleaf.

TABLE 6.—*Gum yields in relation to depth of streak, slash pine, 32 streaks, 50-tree groups*

Year	0.3-inch streak		0.5-inch streak		0.75-inch streak		1-inch streak	
	Yield	Loss or gain	Yield	Loss	Yield	Loss or gain	Yield	Loss or gain
	Ounces	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*
1923	6,795		7,465		8,291		8,001	
1924	6,288	−507	7,084	−381	7,046	−1,245	7,188	−903
1925	6,675	+387	6,832	−252	7,453	+407	6,815	−373
1926	6,056	−619	6,088	−744	5,370	−2,083	5,292	−1,523
1927	5,936	−120	5,504	−584	4,942	−428	5,601	+309
Total	31,750	−859	32,973	−1,961	33,102	−3,349	32,987	−2,490
		Per cent 12.64		*Per cent* 26.27		*Per cent* 40.39		*Per cent* 30.77

TABLE 7.—*Calculated naval-stores yields per crop in relation to depth of streak, slash pine, 32 streaks*[1]

Year	Turpentine				Rosin			
	0.3-inch streak	0.5-inch streak	0.75-inch streak	1-inch streak	0.3-inch streak	0.5-inch streak	0.75-inch streak	1-inch streak
	Barrels	*Barrels*	*Barrels*	*Barrels*	*Barrels*	*Barrels*	*Barrels*	*Barrels*
1923	47.8	52.0	58.9	56.7	147.7	162.7	179.8	176.2
1924	44.5	48.2	49.2	49.4	136.7	155.5	153.6	157.3
1925	45.3	45.8	45.0	46.5	140.7	150.5	143.0	149.4
1926	40.4	40.2	36.0	35.8	133.6	134.5	117.7	116.2
1927	39.3	34.4	32.9	37.1	132.1	123.3	109.0	123.8
Average	43.4	44.1	44.5	45.1	139.4	145.3	140.7	144.6

[1] Turpentine barrel contains 50 gallons; rosin barrel contains 420 pounds net. Bureau of Chemistry and Soils converting factors for turpentine yields used as follows: For 0.3-inch chipping, 21.7 per cent weight of dip and 10.6 per cent weight of scrape; for 0.5-inch chipping, 21.5 per cent weight of dip and 9.2 per cent weight of scrape; for 0.75-inch chipping, 21.0 per cent weight of dip and 10.1 per cent weight of scrape; and for 1-inch chipping, 21.6 per cent weight of dip and 10.5 per cent weight of scrape. Water and trash for all groups, 6.7 per cent.

TABLE 8.—*Gum yields in relation to depth of streak, longleaf pine, 32 streaks, 50-tree groups*

Year	0.3-inch streak		0.5-inch streak		0.75-inch streak		1-inch streak	
	Yield	Loss or gain	Yield	Loss or gain	Yield	Loss or gain	Yield	Loss
	Ounces	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*
1923 [1]	5,960		6,905		6,337		6,706	
1924	5,130	−830	6,475	−430	5,329	−1,008	5,775	−931
1925	6,269	+1,139	6,807	+332	6,671	+1,342	5,583	−192
1926	4,793	−1,476	6,170	−637	4,945	−1,726	4,575	−1,008
1927	4,498	−295	5,234	−936	4,795	−150	4,461	−114
Total	26,650	−1,462	31,591	−1,671	28,077	−1,542	27,100	−2,245
		Per cent 24.53		*Per cent* 24.20		*Per cent* 24.33		*Per cent* 33.48

[1] Totals computed on a 32-streak basis from 22-streak yields actually measured the first year.

TABLE 9.—*Calculated naval-stores yields per crop in relation to depth of streak, longleaf pine, 32 streaks* [1]

Year [2]	Turpentine				Rosin			
	0.3-inch streak	0.5-inch streak	0.75-inch streak	1-inch streak	0.3-inch streak	0.5-inch streak	0.75-inch streak	1-inch streak
	Barrels	*Barrels*	*Barrels*	*Barrels*	*Barrels*	*Barrels*	*Barrels*	*Barrels*
1924	34.8	42.8	34.9	38.9	111.7	141.8	117.0	125.0
1925	44.0	46.4	46.2	38.5	135.1	147.9	144.3	120.8
1926	32.9	40.2	33.1	30.6	103.9	135.6	108.0	99.9
1927	27.8	32.2	29.2	27.0	100.1	116.7	107.1	99.8
Average	34.9	40.4	35.8	33.8	112.7	135.5	119.1	111.5

[1] Turpentine barrel contains 50 gallons; rosin barrel contains 420 pounds net. Bureau of Chemistry and Soils converting factors for turpentine yields used as follows: For 0.3-inch chipping, 23.4 per cent weight of dip and 11.5 per cent weight of scrape; for 0.5-inch chipping, 22.9 per cent weight of dip and 11.2 per cent weight of scrape; for 0.75-inch chipping, 23.2 per cent weight of dip and 11.5 per cent weight of scrape; and for 1-inch chipping, 23.2 per cent weight of dip and 11.2 per cent weight of scrape. Water and trash for all groups, 7.4 per cent.
[2] 1923 omitted because of incomplete record.

As the tables indicate, there is little to choose, so far as total yield goes, between the different depths of chipping in either species, save that the 0.5-inch chipping of longleaf produced a considerably larger total than the other depths. In both species the 0.3-inch group is perceptibly lower in yield than the groups with deeper streaks, but on the other hand this group in the slash stand has decreased but 13 per cent in yield since the first year, as against 26, 40, and 31 per cent in the other groups. In the longleaf stand the percentage of decrease is not so favorable, but the trend of annual decrease in ounces of gum indicates that in another two years (such as would be entirely possible with the 0.5-inch height of streak used here) this group would easily equal and probably excel the 1-inch group in total yield. (Figs. 11 and 12.)

Meanwhile, all evidence goes to show that the deeply chipped groups (0.75 and 1 inch) are falling off in yield at a rate that would make seven years' work distinctly unprofitable as compared with the results of shallower chipping. The trend of a later series of tests bears out this contention.

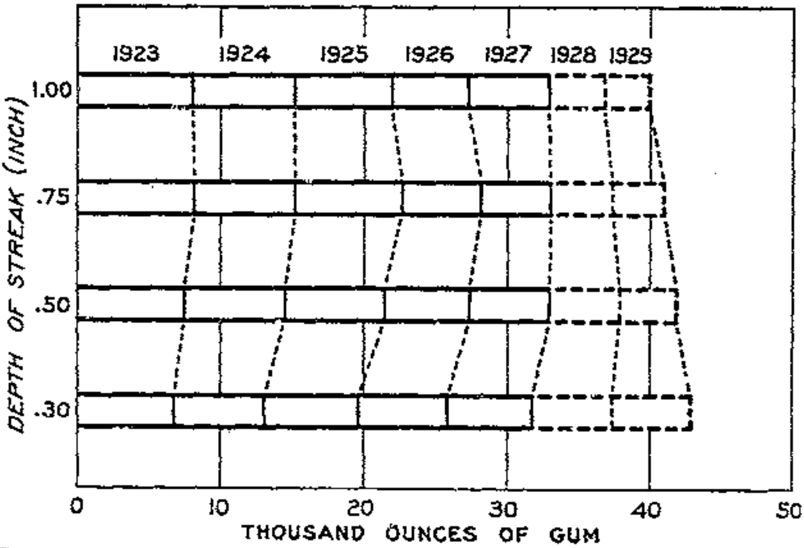

FIGURE 11.—Cumulative yields of dip and scrape on 50-tree groups of slash pine resulting from streaks 1, 0.75, 0.5, and 0.3 inch deep. Yields are shown for five years of actual operation and as projected for the two years of additional work possible with 0.5-inch height of chipping

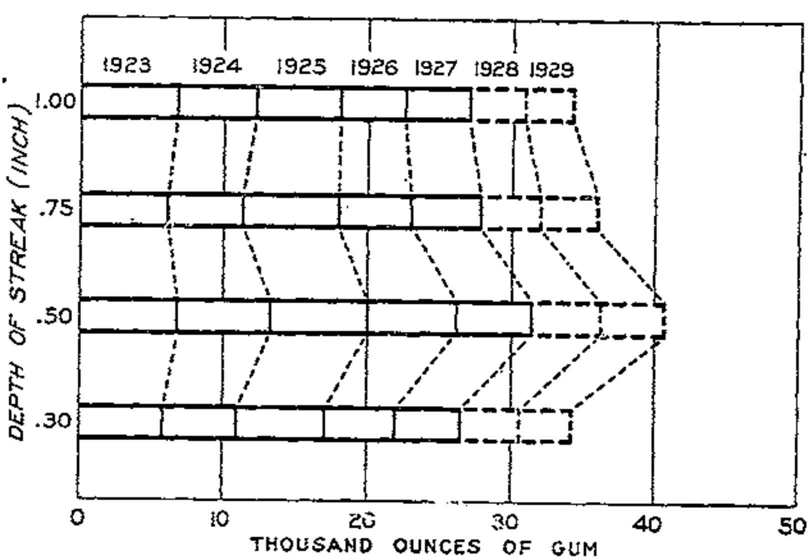

FIGURE 12.—Cumulative yields of longleaf pine similar to slash pine yields shown in Figure 11

The significance of these relationships lies in the assurance they give that there is no loss to the operator in the less destructive shallow chipping of 0.5 inch or less. The gain to the timber owner has already been mentioned.

Longleaf pine that is young and has plenty of growing space is not so easily injured by chipping as is slash pine. The mechanical weakening caused by deep chipping may, however, increase the mortality resulting from heavy windstorms. Further weakening is caused by the current practice, when raising cups, of cutting deep gashes in the old face with a broadax or gutter chisel for the insertion of tins. Dry face is a less material form of damage in longleaf, as has already been explained. Mechanical weakening with subsequent wind breakage can be avoided by the owner if he will specify shallow chipping for his timber.

In the dense slash stand in which these tests were made, the 0.3-inch group has 28 per cent of the trees partly dry faced, the 0.5-inch group 38 per cent, and the 0.75-inch and 1-inch groups 83 per cent each. These are the immediate results of depth of chipping, but, of course, they inevitably involve greater losses due to insect and fungus attack and eventual mortality. In more open stands of slash timber, such as commonly occur in the turpentine belt, the dry-face loss from shallow chipping would be reduced considerably.

The figure for percentage of dry face represents all trees having a measurable amount of unproductive wood in the streak, sometimes no more than 5 per cent of the producing area. Although less than 1 tree in 50 was dry facing so seriously that it was necessary to discontinue chipping, it is reasonable to expect that this proportion would be considerably increased were the operation to be extended beyond five years.

Nearly all of the slash pine that had dry faced by the end of the 5-year period became infected with blue stain, a combination of injuries which must result in degrade at the time the trees are cut into lumber. Unless logging takes place very soon, the dry face is almost certain to offer a point of access for boring beetles such as the turpentine borer (*Buprestis apricans* Hbst.) which is commonly found attacking slash and longleaf pines wherever dry wood is exposed. Other flat-headed borers and round-headed borers, getting into the dead wood, riddle the trunk and reduce the strength of the tree, thereby rendering it liable to windbreak as well as opening up a point of attack for wood-rotting fungi.

The results of these tests indicate that chipping to a 0.5-inch depth will yield as much gum as deeper work with considerably less damage to the timber; that in crowded stands of small-topped slash pine even shallower chipping is preferable, but that full-topped open stands of longleaf will stand a streak somewhat deeper than 0.5 inch without any undue injury.

WIDTH-OF-FACE TESTS

The facts to be determined by this series of tests included the width of face that would under ordinary circumstances produce the greatest gross yields; the most profitable face when cost of operation was figured in; the desirability of working two faces at once; and the practicability of back facing.

Roughly speaking, the success of the working is to be determined on the one hand by the actual increase of yield that may be gained by widening the face, and on the other by the effect of different degrees of scarring on the vitality of the tree, expressed primarily in dry facing and secondarily in the dying out of the trees.

In ordinary commercial turpentining operations the proportion of the tree girth cut away for a single face differs considerably but in a general way ranges from 30 per cent or less on 12-inch trees up to 45 per cent on 6-inch trees.

Two series of tests were performed on width of face. The first, extending over a period of five years, included single faces of one-fourth and one-half of the tree circumference and double faces totaling three-fourths of the circumference. The second, a 3-year test only, comprised single faces of one-fourth, one-third, and three-eighths of the circumference. Although the range of diameters covered several inches, the proportion of the circumference faced was the same in any one group.

Since it was impossible to locate suitable longleaf timber the experiment was confined to second-growth slash pine trees on the Sampson tract. The trees were growing under crowded conditions and in the first series a considerable number were small suppressed trees with poor tops. In such timber the effects of severe turpentining are accentuated.

In the first series of tests, groups of 50 trees were used for each width of face. Table 23 gives a comparison of the trees in the various groups. Trees in the intermediate group (50 per cent face) were slightly inferior in growth rate and crown size to the other two groups. However, on the whole, all are fairly well matched.

The gum, turpentine, and rosin yields obtained appear in Tables 10 and 11.

TABLE 10.—*Gum yields in relation to width of face, slash pine, 32 streaks, 50-tree groups*

Year	Single face—25 per cent		Single face—50 per cent		Double face—75 per cent	
	Yield	Loss or gain	Yield	Loss or gain	Yield	Loss
	Ounces	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*
1923	4,421		5,519		8,005	
1924	3,996	−425	4,366	−1,153	5,906	−2,099
1925	3,826	−170	4,526	+160	5,229	−677
1926	3,168	−658	3,559	−967	3,575	−1,654
1927	3,538	+370	3,633	+74	3,120	−455
Total	18,949	−883	21,603	−1,886	25,835	−4,885
		Per cent 19.97		*Per cent* 34.17		*Per cent* 61.02

TABLE 11.—*Calculated naval-stores yields for 10,000 trees in relation to width of face, slash pine, 32 streaks*[1]

Year	Turpentine			Rosin		
	Single face—25 per cent	Single face—50 per cent	Double face—75 per cent	Single face—25 per cent	Single face—50 per cent	Double face—75 per cent
	Barrels	*Barrels*	*Barrels*	*Barrels*	*Barrels*	*Barrels*
1923	32.1	38.5	55.8	100.5	120.2	174.6
1924	28.4	29.4	39.0	91.3	96.1	130.8
1925	26.4	29.3	33.0	88.1	100.6	117.0
1926	21.8	23.6	22.6	73.1	81.4	80.0
1927	23.1	21.8	18.4	82.6	82.1	71.0
Average	26.4	28.5	33.8	87.1	96.1	114.7

[1] Turpentine barrel contains 50 gallons; rosin barrel contains 420 pounds net. Bureau of Chemistry and Soils converting factors for turpentine yields used are dip yields, 21.5 per cent turpentine by weight; scrape 9.2 per cent. Water and trash, 6.7 per cent.

It is evident from the figures given in Tables 10 and 11 that the gum yields from the three groups were not proportionate to the amount of scarring done. The low yields are attributable to the density of the stand and the small size of the trees (8 inches d. b. h.). Relatively higher yields may be looked for if the stands are more open and the average size of the tree is larger. Although the heaviest work involved cutting away three-fourths of the cambium, in contrast with one-half and one-fourth for the trees in the other groups, and the areas of exposed faces were practically in the ratio of 1:2:3; yet the yields obtained were in the proportion of 1:1.14:1.36.

One interesting point brought out is that the group with double faces actually produced less gum during the fifth year of working than either of the other two groups. A great deal of this loss in yield was a result of dry facing and tree mortality due to the heavy drain on the suppressed trees, caused by chipping. This damage is shown in Table 12.

TABLE 12.—*Effect of face width on tree vitality, at end of fifth year of working, second-growth slash pine*

Width of face	Trees dry facing	Trees dead
	Per cent	*Per cent*
25 per cent	54	12.5
50 per cent	76	16
75 per cent	94	30

These figures show increasingly heavy damage with greater face widths. The trees were in a very dense stand, and from 22 to 25 per cent of the trees chipped in each group were intermediate or suppressed trees having only a slow growth prior to turpentining. Under such conditions it is not surprising to find that over half of the trees with narrow faces showed dry facing at the end of the test. The injury from narrow faces would be much less on open-grown timber. For example, some back-faced slash pines in an open stand at Sampson Lake had no trees killed by facing at the end of five years' work on the back faces, and only 29 per cent showed any signs of dry facing. Each face in this group was cut to one-third of the tree circumference. The significant point, however, in the tests here described is not the actual but the relative amount of injury done. Twice as many trees were drying out in the double-faced group as in the narrow-faced group.

Although the double face gives evidence of considerably greater total yield in five years, other considerations reduce this apparent superiority to negative values. In the first place, the additional area of wood exposed by the heavier cutting, which has a direct and proportionate effect on the vitality of the tree, is far out of proportion to the added yield. Furthermore, it must be considered that the 169 barrels of spirits gained from the 2-faced trees represents the total possible yield from these trees. No room is left for subsequent faces. Lastly, the advantage of the extra yield from the 2-faced trees is practically wiped out by the additional cost of working. To cut two faces simultaneously nearly doubles operating costs, whereas the yield from the 2-faced trees is only 36 per cent above that from the narrowest faces.

The 50 per cent faces can be operated practically as cheaply as the 25 per cent and with a somewhat greater yield. From the standpoint of immediate returns, therefore, the operator might feel justified in putting on wide faces. From the standpoint of the timber owner, however, there is no justification, because the possibility of placing future faces on trees which have been half girdled has been considerably reduced. It is possible to put another 25 per cent face on the trees with narrow faces and later a third face of the same width, but the wide-faced trees (50 per cent) will carry but one other set of narrow faces and will then have bark removed to the extent of at least 75 per cent of the circumference, or the equivalent of the three sets of faces on the original narrow-faced group.

Such records as are available indicate a slightly smaller yield from back faces than from front faces. In view of the fact that back-face yields are not much lower than front-face yields, however, and then only during the first year or two, it is believed that a third set of faces will yield nearly as much as the second set, assuming all faces on the same tree to be of the same width. Increased tree growth tends to offset increased scarring unless the trees are suppressed or decadent. It is estimated that the 25 per cent group in this crowded stand should yield annually an average of 24 barrels of spirits per 10,000 trees from the second set of faces and at least 24 barrels per year from the third set, which, when combined with the average annual production of 26.4 barrels from the first set, would give a total of 372 barrels, supposing that the chipping possibilities of the trees were exhausted by five years' working of each face. The 50 per cent group could be given a narrow second face which should yield 24 barrels of spirits per 10,000 trees annually or a total of only 262.5 barrels in the two 5-year working periods. These returns would of course be considerably greater in a stand composed of larger and more open-growing trees, where annual yields are higher and faces can be worked by low chipping for 7 to 12 years; but even these yields show a decided advantage in favor of narrow faces.

The second series of tests in the width-of-face experiment was a slight modification of the first, involving a narrower range of face widths and dispensing with the 50 and 75 per cent faces which caused so much damage.

This series, started in 1924, involved the placing of faces of one-fourth, one-third, and three-eighths of the tree circumference.

The trees used in this test had already been worked for one and one-half years with faces covering one-third of the circumference. For one quarter of the trees the face width was decreased to one-fourth of the circumference, for another quarter it was increased to three-eighths. The remaining trees were left unchanged.

The groups were worked for the remainder of the second year before yield comparisons were made. The narrow-faced and wide-faced groups were each composed of 25 trees. The intermediate group was made up of 50 trees. Comparable records of yield are available for the third, fourth, and fifth years only. Chipping was 0.5 inch deep by 0.5 inch high, one face to a tree.

The tree measurements of these groups are given in Table 23. In most respects the groups were closely comparable. No trees smaller than 8.2 inches d. b. h. were used in this test, so that in contrast with the preceding test there were few intermediate and suppressed trees. Gum, turpentine, and rosin yields for the 3-year test period are shown in Tables 13 and 14.

TABLE 13.—*Gum yields in relation to width of face (third to fifth year chipping) slash pine, 32 streaks, 25-tree groups*

Year	25 per cent face		33⅓ per cent face [1]		37½ per cent face	
	Yield	Loss or gain	Yield	Loss	Yield	Loss or gain
	Ounces	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*
1925	2,835		3,416		3,339	
1926	2,847	+12	3,044	−372	2,861	−478
1927	2,831	−16	2,752	−292	3,106	+245
Total	8,513	−4	9,212	−664	9,306	−233
		Per cent		*Per cent*		*Per cent*
		0.14		19.44		6.98

[1] Originally 50 trees in the group, but yields were halved and the group considered as a 25-tree group for purposes of comparison.

TABLE 14.—*Calculated naval-stores yields per crop in relation to width of face (third to fifth year chipping) slash pine, 32 streaks* [1]

Year	Turpentine			Rosin		
	25 per cent face	33⅓ per cent face	37½ per cent face	25 per cent face	33⅓ per cent face	37½ per cent face
	Barrels	*Barrels*	*Barrels*	*Barrels*	*Barrels*	*Barrels*
1925	37.6	45.8	44.6	124.5	150.5	147.3
1926	38.1	40.2	37.9	125.5	134.5	120.4
1927	35.4	34.4	38.7	126.0	123.3	139.4
Average	37.0	40.1	40.4	125.3	136.1	137.7

[1] Turpentine barrel contains 50 gallons; rosin barrel contains 420 pounds net. Bureau of Chemistry and Soils converting factors for turpentine yields used are dip yields, 21.5 per cent turpentine by weight, and scrape, 9.2 per cent. Water and trash, 6.7 per cent.

In this test the average measurements in inches of the cross section of producing wood cut away for the three groups bear the ratio of 1:1.20:1.41, whereas the ratio of yields is 1:1.08:1.09. This bears out in general the conclusion reached in the first series, that yields do not increase in the same ratio as increase in face widths or, more properly speaking, producing surface. In the first series face width and producing surface are proportional, but this is not the case in the second series, in which much wider faces were used. In the narrow, medium, and wide faced groups there was no significant difference in the number of trees killed by chipping, but 64, 40, and 80 per cent of the trees, respectively, were injured to some extent by dry facing. These figures are not consistent, the medium faces showing less dry facing than the narrow ones. They do show the greatest damage to the widest faces, however, and are larger than the dry-face figures for open-grown back-faced timber, which amounted to only 29 per cent, although in that group 66⅔ per cent of the bark was cut in forming two faces.

The high yields of the second series as compared with the first series of 5-year tests are due partly to better spacing of trees and partly to the larger size and better crowns. Average yields indicate that no great increase in gum production may be expected from wider faces over a 3-year period where face widths range between one-fourth and three-eighths of tree circumference. However, they show that the yields from 25 per cent faces fall off far less from year to year than those from the wider faces.

With no marked increase resulting from wider faces, the question of placing back faces on the trees assumes a new importance.

Assuming that back faces will have a width of not more than one-third of the circumference measured at the time the trees were first chipped and, further, that bark bars between faces are uniform at one-twelfth of the circumference, it is patent that the narrow-faced group may have three sets of back faces placed without a growth period intervening, but that the trees with wider front faces will require a growth period before a third face can be put on. Such a delay, postponing future yields, means a lower annual profit (figured over the working life of the tree) because of greater carrying charges.

The effect of face width on the possibility of back facing naturally brings up the question of the yields which may be expected from back faces and their relation to front-face yields from the same trees.

Measurements of back-face yields from four groups of trees are available. The first test was made in open-grown slash pine. The 50 trees in this test are described in detail on page 32 under density of stand, the measurements appearing in Table 24.

The trees were chipped 0.5 by 0.5 inch, with face widths equal to one-third of the circumference. After being chipped for three years (1923–1925), they were back faced and chipped from 1926 to 1929. It should be noted that no rest was given the trees before the back faces were put on. The back faces were about 10 per cent narrower than the front faces for the first two years but at the beginning of the third year were widened so as to be comparable with the front faces in that year.

No advance streak was used with the back faces, such as had been put on the front faces four weeks ahead of the regular chipping season in 1923. In 1923 the trees averaged 10.8 inches d. b. h. They were really too small to support a back face under good turpentine practice, even though very fair yields were obtained. Making due allowance for the difference in face widths, the yields from back faces totaled only about 9 per cent less than front-face yields in three years.

The second group of trees was in a crowded stand which had been worked for four years in a manner similar to that just described, and was thereafter given a year's resting period. The back faces then started were of the same width as the front face and were worked similarly.

These trees are described (the dense B group) on page 33, and the measurements are given in Table 24. The average diameter (d. b. h.) was 10.5 inches.

A third group of 50 trees at Sampson Lake was back faced after two years of rest following four years of work on the front faces (1923–1926). These trees were 10.6 inches in diameter at breast height in 1923.

Finally, a fourth group of 223 rather open-grown slash pines at Sampson Lake were back faced in 1930, following five years operation on front faces (1925 to 1929, inclusive). The average diameter of these trees was 9.1 in 1925. These last two groups had advance streaks at the time the front faces and back faces were cut.

Gum and naval-stores yields are given in Tables 15 and 16 for the first three groups and gum yields only for the fourth. Although the yields from back faces during the first year were noticeably lower than the first-year yields from front faces, the second-year back-face yields were considerably higher than from second-year front faces in two out of three of the tests.

TABLE 15.—*Gum yields from front and back faces, slash pine, 32 streaks*[1]

Group	Face	First year	Second year	Third year	Total
		Ounces	*Ounces*	*Ounces*	*Ounces*
1	Front	8,028	7,373	7,791	23,192
	Back	5,909	6,669	7,477	20,055
2	Front	7,738	6,219	7,114	21,071
	Back	5,310	6,850	6,680	18,840
3	Front	7,781	6,138		13,919
	Back	6,745	7,225		13,970
4	Front	26,862			26,862
	Back	22,680			22,680

[1] Groups 1 to 3 consisted of 50 trees each; Group 4 of 223 trees.

TABLE 16.—*Calculated naval-stores yields per crop, front and back faces, slash pine, 32 streaks*[1]

Group	Class face	Turpentine				Rosin			
		First year	Second year	Third year	Average	First year	Second year	Third year	Average
		Barrels	*Barrels*	*Barrels*	*Barrels*	*Barrels*	*Barrels*	*Barrels*	*Barrels*
1	Front	55.9	49.6	51.2	52.2	175.0	162.1	172.5	169.9
	Back	36.7	40.0	49.1	41.9	121.8	137.8	162.0	140.5
2	Front	53.9	43.3	47.6	48.3	168.7	135.6	156.7	153.7
	Back	35.6	44.7	44.1	41.5	114.6	148.7	144.5	135.9
3	Front	54.3	42.1		48.2	169.6	134.3		152.0
	Back	44.1	47.7		45.9	143.3	138.1		140.7

[1] Bureau of Chemistry and Soils converting factors for turpentine yields used are dip yields, 21.5 per cent turpentine by weight and scrape 9.2 per cent. Water and trash, 6.7 per cent.

In every case, the difference between first-year front-face and back-face yields was markedly reduced thereafter, to such a degree that for three years of working the back-face yields underran the front-face returns by only 11 per cent. Additional data may reduce this difference somewhat, since Groups 3 and 4 made a relatively better showing during the back-face periods than did the first two groups. The indication is fairly clear that back faces worked over longer periods in vigorous open stands will attain total yields very close to front-face yields. Indeed, with a 12-year working period per face, well-spaced trees should grow 1½ to 2 inches in diameter during the chipping period. This increase in size should result in greater yields from the second installation of faces than from the first set.

The width-of-face and back-face tests may be summed up briefly, as follows:

Relatively narrow faces, which cut away not more than one-third of the bark perimeter, maintain a relatively high gum yield over a longer period of operation than do the wider faces.

The trees with narrow faces suffer less from dry facing, and fewer trees die.

Wide-faced trees can not support three or possibly even two faces in rotation without rest periods. Such rest periods constitute a delay that means increased costs in the turpentining of the wider faced trees.

Although back faces yield somewhat less than front faces, the difference is not great.

Two faces worked at one time fall far short of yielding as much as two faces worked in rotation.

RELATION OF STAND AND TREE CONDITION TO TURPENTINING WORK

EFFECT OF DENSITY OF STAND, CROWN AREA, AND GROWTH RATE ON YIELDS

The effect of density of stand, crown area, and growth rate on gum flow (*42*) are so closely interrelated as to make any separate discussion of them difficult. Their combined influence is apparent both in yield of gum and in vigor of faced trees. Yields are manifestly lower in dense stands where many of the trees have inferior crowns and are therefore more easily injured by heavy working. (Figs. 13 and 14.) As indicated by some of the studies already discussed, thinning out dense stands by cutting or by purposely turpentining destructively the trees not desired in the stand, may greatly increase the yield per face on the released trees.

Most second-growth stands in the turpentine belt are not completely stocked with trees, but as fire protection and better forestry practices become more general, they will tend gradually to become more crowded. For this reason, it is important to know the effect of the spacing of the trees upon gum yields. To this end experiments in both longleaf and slash pine stands were begun in 1923, at the same time that most of the other turpentining tests were started.

Three groups of 50 trees each were used for the slash pine test. Two of these, designated as "dense A" and "dense B," were in a crowded stand of second growth, while the third group was in a somewhat more uneven-aged open stand on the same tract. In the longleaf pine stand, two groups of 50 trees each were chipped alike to determine the effect of crowding upon production of naval stores. One of these groups was in a rather crowded stand, and the other was made up of open-grown trees of about the same age.

The chipping practice was uniform in all groups for both species, the streaks averaging 0.5 inch deep and 0.5 inch high. Faces covered one-third of tree circumference, and streaks were put on regularly once a week during the period covered by the experiment. Table 24 gives the average tree measurements for the groups which composed these two tests.

In the slash pine test, the trees in the dense B group were somewhat smaller in crown size and slower in rate of growth than in the dense A group. As might be expected, both dense groups were much poorer in crown development and growth rate than the open group. Also, in order to obtain open-grown timber of the same diameter, it

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FIGURE 13.—Open stand of 26-year-old slash pine on the Sampson tract.

was necessary to select trees somewhat younger than the trees in the crowded stand. The trees in the open stand included only dominant trees or those free from side competition. With this type of selection, it is impossible to determine exactly the average number of trees per acre, but by computing the average area of crown space occupied by these trees and dividing it into the number of square feet in an acre, a rough estimate of density of stand may be indicated. This shows that the open stand would contain 44 per cent as many trees per acre as are in the dense A group and 29 per cent as many as in the dense B group.

The longleaf stands have had a somewhat different history from that of the slash pine. (Figs. 15 and 16.) In the longleaf tract, the trees are practically even aged and comparatively young. For about 20 years all the longleaf trees had plenty of room to develop, and it was only during a very few years prior to the start of these tests that the tree canopy in the dense stand became sufficiently

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crowded to affect crown development. The open-grown trees were still isolated when the test began.

The dense stand of slash pine averaged 9 years older than the open-grown trees. It had always been much more crowded, which had

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FIGURE 15.—Open stand of 26-year-old longleaf pine, Powell tract. Trees with plenty of growing space yield well

resulted in a lack of sufficient space to develop crowns for 8 or 10 years before the present tests were started. On the other hand, the open-grown slash occurred in an uneven-aged stand where the trees

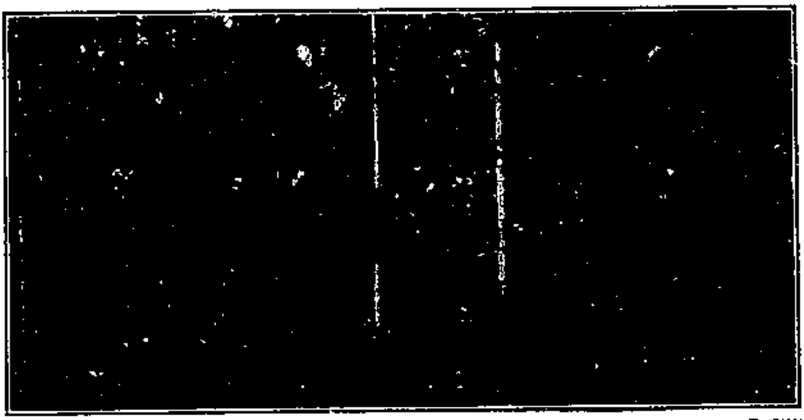

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FIGURE 16.—Dense stand of 27-year-old longleaf pine, Powell tract

selected for this test had been growing somewhat faster and had reached the same size as the trees in the dense stand at an earlier age.

There is a greater difference between the two longleaf stands than appears from the measurements recorded. (Table 24.) The open stand had but 74 per cent as many trees per acre as the crowded stand. The longleaf occurs on a much drier situation than the slash groups, and where the competition for soil moisture and food materials is much keener.

Gum and naval-stores yields in relation to density of stand are given in Tables 17, 18, 19, and 20.

TABLE 17.—*Gum yields in relation to density of stand, slash pine, 32 streaks, 50-tree groups*

Group	1923	1924	1925	Total yield	Reduction in yield
	Ounces	*Ounces*	*Ounces*	*Ounces*	*Ounces*
Dense A (170 trees per acre)	7,465	7,084	6,832	21,381	633
Dense B (260 trees per acre)	7,738	6,219	7,114	21,071	624
Open (75 trees per acre) [1]	8,028	7,373	7,791	23,192	237

[1] Estimated from total crown area.

TABLE 18.—*Calculated naval-stores yields per crop in relation to density of stand, slash pine, 32 streaks* [1]

Year	Turpentine			Rosin		
	Dense A	Dense B	Open group	Dense A	Dense B	Open group
	Barrels	*Barrels*	*Barrels*	*Barrels*	*Barrels*	*Barrels*
1923	52.0	53.9	55.9	162.7	168.7	175.0
1924	48.2	43.3	49.8	155.5	135.6	162.1
1925	45.8	47.6	51.2	150.5	156.7	172.5
Average	48.7	48.3	52.2	156.2	153.7	169.9

[1] Turpentine barrel contains 50 gallons; rosin barrel contains 420 pounds net. Bureau of Chemistr and Soils converting factors for turpentine yields used are dip yields, 21.5 per cent turpentine by weight, and scrape, 9.2 per cent. Water and trash, 6.7 per cent.

TABLE 19.—*Gum yields in relation to density of stand, longleaf pine, 32 streaks, 50-tree groups*

Group	1923 [1]	1924	1925	1926	1927	Total yield	Reduction in yield
	Ounces	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*
Dense (135 trees per acre)	6,614	4,893	5,088	3,893	3,779	24,067	2,835
Open (100 trees per acre) [2]	6,905	6,475	6,807	6,170	5,234	31,591	1,671

[1] 1923 yields computed from measured dip of 22 streaks only.
[2] Estimated from total crown area.

TABLE 20.—*Calculated naval-stores yields per crop in relation to density of stand, longleaf pine, 32 streaks* [1]

Year [2]	Turpentine		Rosin	
	Dense group	Open group	Dense group	Open group
	Barrels	*Barrels*	*Barrels*	*Barrels*
1924	30.5	42.8	103.2	141.8
1925	34.3	46.4	110.7	147.9
1926	25.3	40.2	85.6	135.6
1927	21.6	32.2	85.6	116.7
Average	27.9	40.4	96.3	135.5

[1] Turpentine barrel contains 50 gallons; rosin barrel contains 420 pounds net. Bureau of Chemistry and Soils converting factors used are dip yields, 22.0 per cent turpentine by weight, and scrape, 11.2 per cent. Water and trash, 7.4 per cent.
[2] 1923 omitted because of incomplete record.

The effect of crowding on slash pine can be seen in the difference in gum yields between the open and dense groups. The open group fell off in yield only 3 per cent by the third year, whereas the two dense stands showed a falling off of about 8 per cent in the same period. It is natural to expect that trees in the open stand should be affected less by chipping than trees in the dense stands.

Effects of crowding are much more strikingly apparent in the longleaf stand. At the end of five years the dense stand was already below the limit of profitable turpentining, but the open-grown trees could be carried through two to five years more before reaching that limit.

Similarly, whereas the 3-year gum yield of the open-grown slash is 9 per cent higher than the average for the two crowded slash pine plots, in the longleaf test for the first three years (the first being approximate) the difference in gum yields is 23 per cent in favor of the open-grown timber; for the five years of the test this difference increased to 31 per cent.

These results are corroborated by the evidence afforded by 223 slash pines on which the relationship between crown size and gum yield was noted. The relationship was worked out by computing the theoretical crown surface of each tree, assuming that this could be represented by the curved surface of a paraboloid with a height equal to the crown length and a width equal to the crown width. Having computed the number of square feet of theoretical crown surface for trees of different sizes, the average yield was plotted over the size of crown. In view of the fact that the trees with the largest diameters were also trees having the largest crowns as well as the widest faces, it was natural to expect that these trees would produce more than small-crowned narrow-faced trees. For this reason the total gum yield per face was divided by the width of face, and a figure representing the yield of gum per inch was obtained. This curve of yield in relation to crown surface is shown in Figure 17.

Clearly, an increase in size of crown results in an increased yield of naval stores. This increase is most rapid at the lower end of the curve and gradually becomes less significant with the trees of largest crown size. The curve, however, continues to rise as far as the data available in this study extend.

The advantages in favor of rapid-growing, large-crowned, widely spaced trees are even greater than the figures themselves indicate. Such trees not only produce more gum per face, fall off much less in yield from year to year, and are capable of producing profitable yields over a longer working period, but also on these trees the faces heal over more rapidly, dry facing is far less evident, and mortality attributable to turpentining is notably less.

At Sampson Lake, 584 slash pine trees were used in working out the relationship between gum yield and tree vigor as expressed by the number of rings of growth in the outer one-half inch of wood formed before turpentining. The results shown in Figure 18 indicate plainly that the faster growing trees are much better gum producers than the slower growing, within any particular tract where soil, drainage, and site are fairly uniform. This will not necessarily hold where growth conditions are variable.

Where possible, good naval-stores practice should allow for sufficient density in slash and longleaf stands in early years to result in self-pruning of the trees to a height of 8 or 10 feet, insuring a clear length of bole as high as the face will extend. At this point, the stand should be thinned to allow ample crown spread and to produce thereby a high resin yield. Some operators may desire to prune

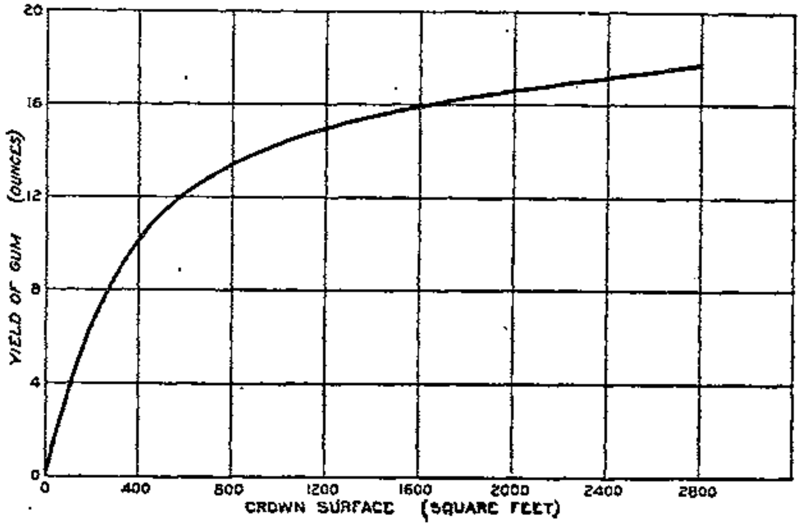

FIGURE 17.—Annual yield of gum per inch width of face in relation to crown surface, average of two years' chipping, basis 223 second-growth slash pines (chipping 0.5 by 0.5 inch, one-third circumference)

their trees by hand to a height of 16 feet while the stand is young, not only to improve resin yields but also to insure a high quality of lumber.

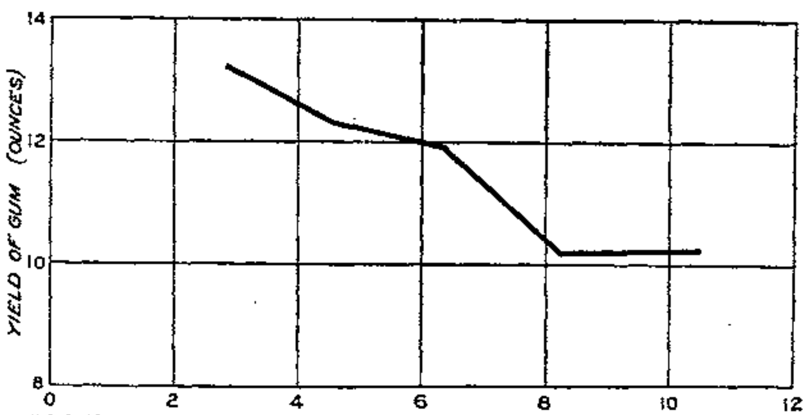

FIGURE 18.—Annual yield of gum per inch width of face in relation to growth rate. Basis 584 second-growth slash pines

It is not yet possible to state any definite conclusions as to the proper number of trees to grow per acre in order to make the greatest profit from naval stores. This number undoubtedly will be less than the best density for the production of the best quality of lumber.

GUM YIELD IN RELATION TO DIAMETER

The variation in gum yield with increase or decrease in size of tree is well recognized, but the actual proportions of this variation and the effect thereon of stand density and species have been mainly matters of conjecture. Largely because of this uncertainty, the meager profits or actual losses to the operator in turpentining small trees have gone unnoted, to the detriment of all concerned.

In testing the relation of tree diameter to yield, the commercial practice was followed of varying the width of face in proportion to the diameter of the tree. Faces were cut one-third of the circumference, measured at 4.5 feet from the ground. Three representative plots were chosen for the test, two of slash pine and one of longleaf.

The first of the slash pine plots, located on the Sampson tract, was an open second-growth stand of 223 trees ranging between 5.4 and 15.4 inches d. b. h. and including only dominants and codominants with fairly large crowns and little side competition for light and soil moisture. The second consisted of a dense stand of 139 slash pines ranging from 8.1 to 15.7 inches d. b. h., also on the Sampson tract, 38 years old, and even aged. Both stands were given 32 streaks 0.5 inch high and 0.5 inch deep. In the dense stand only the third-year work was measured by individual tree yields, but these may safely be compared with the 5-year averages from the open stand, since in the open stand the 5-year averages are practically identical with third-year yields. These relationships are shown in Figure 19 in terms of gum yield of dip and scrape, and in Figure 20 in turpentine yield per crop.

Because of the openness of the first stand, the small trees gave relatively good yields in contrast to those in the even-aged stand, where crown development was poor. The denser stand, however, produces in the graphs a steeper curve, which indicates that trees over 13 or 14 inches in diameter gave definitely larger yields than open-growing trees of the same size.

The high yields shown for small trees in the open stand deserve special comment. In ordinary practice, the Forest Service has generally assumed 25 barrels of turpentine per crop to be the lowest yield that will pay for working. According to that estimate, the data shown in Figure 20 apparently justify the chipping of trees as small as 6.7 inches in diameter. Several other considerations, however, which the chart does not reveal, must be taken into account, as they are of wide application in all operations where small trees are involved.

The first consideration is perhaps the effect on the tree, already indicated in the discussion of vigor of tree and its effect on yield. Although in open stands, 7-inch trees may yield 25 barrels or more per crop in the third year of work, as shown by the graph, not all will continue to yield to that extent in the fourth and fifth years. Only a small proportion will have a breadth and height of crown and general vigor that will enable them to support such work. In less open stands many will be killed out, and, as shown in Figure 20, in such stands no profits can be expected from trees under 8.5 inches.

Estimates given here are, moreover, based on an average market price for turpentine and rosin. With lower prices, as for example

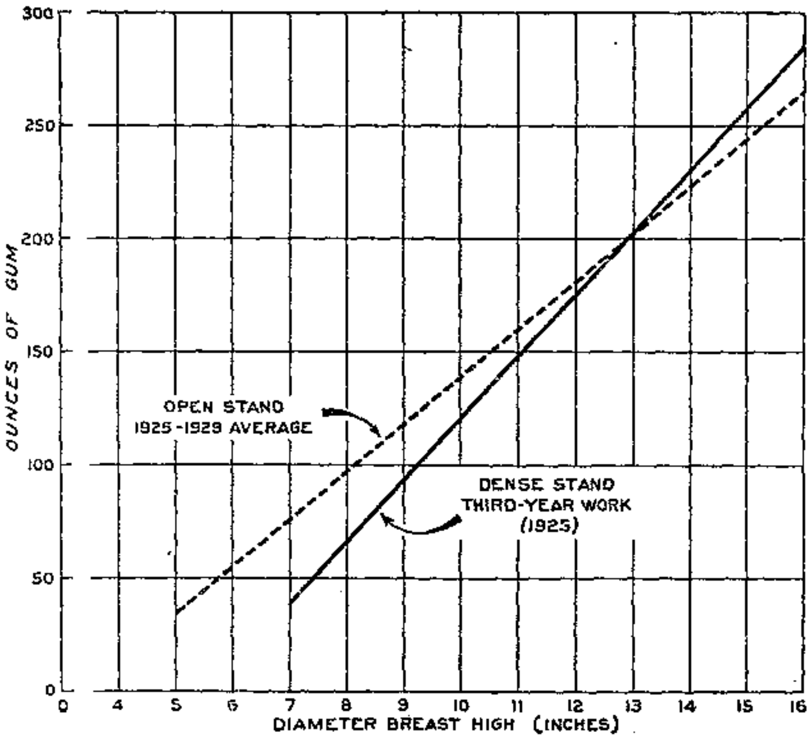

FIGURE 19.—Average annual slash pine yield of gum per tree (dip and scrape) for all diameters in open and dense stands of second growth; basis, 223 open-grown trees and 139 dense-grown trees chipped on single faces, 0.5 by 0.5 inch to one-third of circumference; 32 streaks

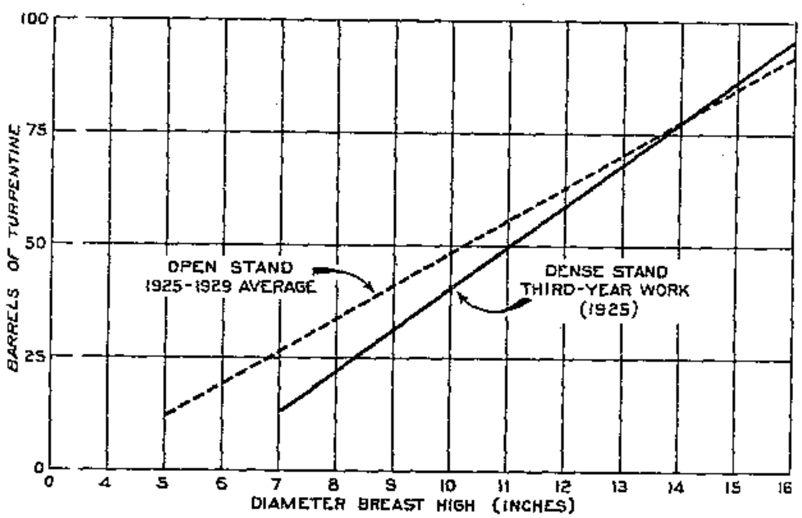

FIGURE 20.—Average annual slash pine turpentine yield per crop for all diameters in open and dense stands of second growth; basis, 223 open-grown trees and 139 dense-grown trees chipped on single faces, 0.5 by 0.5 inch to one-third of circumference; 32 streaks

in 1930, trees yielding less than 35 barrels would prove unprofitable, and the minimum diameter for working would be approximately 8 inches for a full-crowned tree in an open stand and 9 or 10 inches for any tree of less satisfactory development.

Another consideration is the stage of the operation. The minimum diameters given above may prove profitable or at least entail no great loss where the operation is already under way and overhead expense is distributed well over the work on the larger trees. To come into a new stand, however, and set up cups on trees under 9 inches in diameter, would be to run into serious losses.

The longleaf pine stand on which the relation of gum yield and diameter was studied was selected on a tract known as the Johns tract, the opportunity to work these trees being afforded through the cooperation of the owner, Merion Johns, of Starke. The timber comprises about 10 acres of second-growth longleaf with a scattering stand of slash pine in mixture and lies 2½ miles south of Starke in the flatwoods region. In density the stand may be described as fairly open. The trees ranged from 23 to 41 years of age in 1925. Measurements on the tract and on an adjacent old field indicate that growth conditions were above the normal or average for the South. This was further evident in the fact that although most of the trees above 10.5 inches had been boxed from 1911 to 1913 and the old faces burned, these boxed trees were making good growth. Fires had, however, been frequent and leaf litter was very thin.

This tract is about 140 feet above sea level and slopes gently toward a creek just to the north. The main part of it is 10 to 15 feet above creek level and is well drained. The soil is Leon fine sand. The ground cover consisted of gall berry, chinquapin (*Castanea nana*), dwarf oak, and scattered bunches of wire grass.

None of the boxed trees were used in the test, but all that were used had been worked for one year by a commercial operator. Face widths already determined averaged about one-third of circumference. No change was made in face widths, but streaks were brought down in 1925 to 0.5 inch deep and 0.5 inch high, from the somewhat heavier chipping of the commercial operator. Tins were raised in ax cuts on the face before the 1924 season started. The first streak was cut on March 23 and the thirty-second on October 10. The gum yield from each tree was recorded separately.

Altogether, 135 trees were used to make up the yield curve. Tree diameters ranged from 7 to 11.5 inches d. b. h. The yield curves in Figures 21 and 22, however, have been extended to 6 and 12 inches.

In comparing these curves with those shown in Figures 19 and 20 it should be noted that second-year yields on the Johns tract are a little higher than third-year yields on the Sampson tract. The second-year open-grown slash yields from the Sampson tract were, however, nearly 6 per cent higher than the average annual yields shown by the curves in Figures 19 and 20. A comparison of Figure 21 with the curve in Figure 19, as it would be if the values were increased by 6 per cent, indicates that gum yields from 10-inch slash and longleaf trees were identical. Longleaf trees smaller than 10 inches gave a slightly better yield of gum than the small slash, but the relation is reversed for trees larger than 10 inches in diameter. Turpentine yields from 6-inch slash and longleaf trees are nearly alike, but for larger trees the slash pine proves to be a better naval-stores tree. In general, the turpentine yields from open-grown longleaf pine trees are lower than those from slash pine trees of the same size in the open stand, because of the larger proportion of scrape in longleaf, which yields less turpentine than does dip.

The results of the tests in this favorably located longleaf tract give no indication of any need to modify the recommendations made

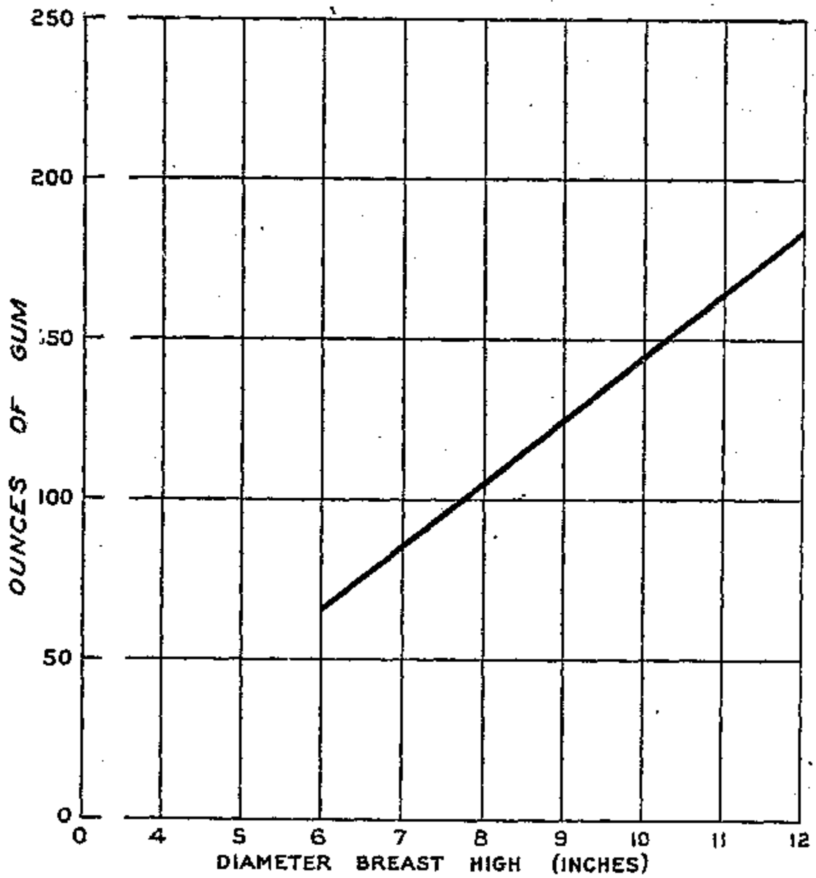

FIGURE 21.—Average annual gum yield per tree from second-growth longleaf pine (dip and scrape) for all diameters; basis, 135 trees chipped on single faces, 0.5 by 0.5 inch to one-third of circumference; second-year work; 32 streaks

above, based on the slash pine tests. The minimum diameter for a yield of 35 barrels, based on second-year work, is 8 inches. In order to obtain a yield that would keep up to 35 barrels for five years the trees would have to be nearly 9 inches in diameter at the start. Only a favorable market for turpentine and a stand of vigorous, full-crowned trees would give warrant for working timber of less than 9 inches with any confidence of profit.

The results obtained by Cary on yield in relation to size of tree (*6, v. 33, no. 40; v. 34, no. 4; v. 35, no. 25; v. 38, no. 25*) are more or less in line with the figures shown herewith, and indicate a direct relationship between gum yield and tree diameter.

EFFECT OF TURPENTINING UPON GROWTH

Timber owners are particularly concerned with the effect that turpentining has upon the growth of their timber, since they must balance loss in growth against the returns derived from the naval-stores operation. An example of what they may expect may be shown by comparing wood increment with naval-stores yields over a 25-year chipping rotation from trees first chipped when they are 9 inches d. b. h.

A 9-inch longleaf tree on a good site would be approximately 70 feet in height and would then scale 64 board feet by the international

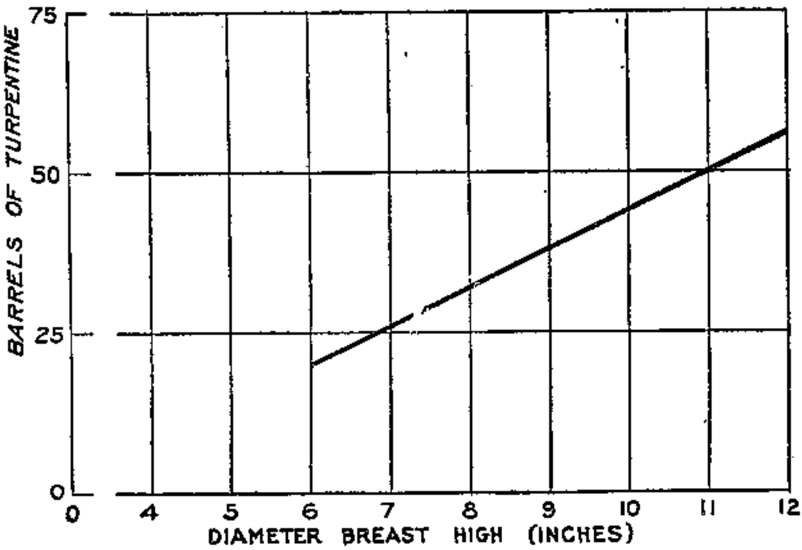

FIGURE 22.—Average annual turpentine yield per crop from second-growth longleaf pine for all diameters; basis, 135 trees chipped on single faces, 0.5 by 0.5 inch to one-third of circumference; second-year work; 32 streaks

rule (*39, p. 31*). Assuming that the tree would grow an inch in 5 years, it would in 25 years attain a diameter of 14 inches and a height of more than 90 feet. It would then scale 270 board feet, representing a volume of growth of 206 board feet, worth about $1 on a stumpage value of $5 per thousand feet. Such a tree might be chipped with streaks 0.5 inch high by 0.5 inch deep on faces each 25 per cent of the tree circumference in width for three periods of 7 years each, separated by two resting periods of 2 years each. The cupping value for these 25 years of operation would be estimated conservatively at 63 cents.

It is evident that decline in growth rate as a result of chipping may outweigh naval-stores returns on the better timber sites. Even on poorer sites, it is entirely possible for heavy chipping followed by fires to so ruin a stand that cuppage returns are more than offset by the decreased volume and value of the stand for lumber.

Any style of chipping affects growth to some extent. Cary (*6, v. 33, nos. 38 and 40; v. 35, no. 21; v. 38, nos. 26 and 27*) has shown that both diameter and height growth are adversely affected by turpentining, especially by the common practice of placing more than one face on moderate-sized trees.

Even conservative work, as practiced in France, has been shown to reduce growth. Buffault (*2*) quotes a report from Provence that maritime pine (*Pinus pinaster* Sol.) and Aleppo pine (*Pinus halepensis* Miller) have their growth reduced by 2 per cent at the maximum for "gemmage à vie" and 6 per cent for the severe "gemmage à mort." This is much less than Cary shows for American species.

On the other hand, Kienitz in Germany (*22*) claimed that tapping resulted in no actual decrease in total volume. Rings were as wide after chipping as before, although the cell walls were thinner. Weidemann (*41*) claimed that chipping had no effect on diameter growth, but perhaps caused a slight decrease in height growth. Some Germans (*34, 41*) even claim an increase in diameter growth during turpentining or immediately afterward. Schwerdtfeger claims that this amounted to one-third more growth in the five to six years following turpentining than during the period when the tree was round. These are, of course, the results of chipping that is far more conservative than anything recommended here.

In the slash pine height-of-streak test the growth rate at 4½ feet above the ground during the test period was 80, 82, and 27 per cent as great as it was just prior to the start of chipping, for the 0.32 0.5, and 0.73 inch streaks, respectively. In other words, the trees showed a decline in growth rate under all heights of chipping, but the effect was much more marked where high streaks were cut. Similar records for longleaf could not be obtained.

At 9 feet above the ground the slash trees in the 0.73-inch streak group were growing only half as fast during turpentining as the 0.5-inch group. Comparable figures for the 0.32-inch group were not taken. In the longleaf stands during the last three years of the test the 0.5-inch group made over twice as much diameter growth as the trees in the 0.73-inch group. The trees with 0.32-inch streaks were growing faster than the 0.73-inch group during this period, although they were distinctly inferior in the beginning.

It is apparent from these observations that the lower the chipping the less the growth is retarded, but that some effect will be evident with even the lowest streaks.

This is the conclusion reached by Gerry, who has shown (*12, 13, 14, 15*) that chipping usually reduces the width of ring above the face, although in certain old slow-growth longleaf trees the ring width may be the same or even wider after chipping. She has shown also (*15*) that not only do the wood rings average wider with 0.32-inch chipping than with 0.73-inch chipping, but also that there are many more resin ducts per unit of area following the narrow work.

Increased depth of streak affected the growth rate of the turpentined trees somewhat in the same way as did increased height of streak. In the slash pine tests, the growth rate in diameter at breast height during the turpentining period was reduced to 72, 83, 67, and 57 per cent, respectively, of the prechipping rate by the 0.3, 0.5, 0.75, and 1 inch deep chipping. Corresponding depths of chipping in longleaf reduced the rate of diameter growth (d. b. h.) to 77, 90, 88, and 65 per cent. The 0.5-inch chipping had least effect on diameter growth at 4.5 feet above the ground, and 1-inch chipping had the greatest effect. No reason can be advanced to account for the relatively poor showing of the trees with shallow streaks. Similarly, the diameter at 9 feet above the ground showed a slower growth rate for the deeply chipped trees than for those with shallower work, in both species.

The effect of face width on slash pine tree growth was also determined. During five years of turpentining, three groups of trees on which faces covered 75, 50, and 25 per cent of the tree circumference had diameter growth rates in the ratio of 1:1.23:1.79, respectively. These measurements were made at 9 feet above the ground on a few selected trees of equal diameters in each group. This takes no account of the large number of trees in the wide-faced group which were actually killed. Briefly, the 50 per cent faces reduced diameter growth 31 per cent more, and the two faces (75 per cent of circumference) reduced it 44 per cent more, than did the narrow faces.

Cary also finds that double-faced trees grow slower than single-faced trees during the turpentining operations. Elsewhere (*6, v. 33, nos. 38 and 40; v. 35, no 21; v. 38, no. 27*) he gives the effect on tree growth of chipping one or more faces.

It is clear that some decline in diameter growth rate must be expected as a result of turpentining, but that this may be kept to a minimum by conservative methods such as low chipping, shallow chipping, and the cutting of relatively narrow faces.

EFFECT OF CHIPPING ON SEED PRODUCTION

The effect of turpentining upon the production of seed has been studied to some extent in connection with the various naval-stores investigations at Starke. Cone-count records have been kept for individual trees on two longleaf tracts. An analysis of these records indicates no difference in cone production between turpentined and unchipped trees in the same locality. It might be mentioned, however, that no seed count was made from the individual cones from turpentined and round trees, nor was the viability of the seed tested. The controlling factor in cone production seems to be spacing or the density of stand in which the trees occur.

It seems probable that a drain on the tree's food supplies, such as is effected by turpentining, would reduce the food available for seed production.

Kienitz (*22*) concluded that seed production of Scotch pine in Germany was not reduced by turpentining. On the other hand, Planke (*31*) showed that unchipped Scotch pine produced heavier cones with more seeds and a higher germinating percentage than similar trees worked for turpentine. Forest Service records bear out Kienitz' findings. Apparently the reduction in the food supply caused by chipping has not been serious enough to affect cone formation in the southern pines.

INSECT DAMAGE

A species of flat-headed borer, the turpentine borer (*Buprestis apricans* Hbst.), is one of the commonest insect enemies of the slash and longleaf pines (*9*). The economic importance of these beetles was recognized in 1909 (*4*).

The adult beetles emerge from the trees in February and March in northern Florida. The female beetles, seeking favorable places to lay their eggs, are attracted to any exposed deadwood of pine trees. Where no turpentining has been practiced, they seek old fire scars, lightning scars, or possibly places where large limbs have broken off and exposed the heartwood. With the advent of turpentining, however, the beetles usually lay eggs on dry faces, on dry wood exposed as a result of the melting off of the gum coating during hot summer weather, in old ax cuts on faces where the wood is not covered by a protective covering of gum, or in checks on old burned faces. Forest entomologists believe that these beetles can not successfully attack faces which are well coated with gum.

The larvæ of this beetle spend three years boring in the pine heartwood before emerging as adults. Preliminary studies by the Bureau of Entomology indicate that the larvæ work for the most part in the band of wood where the heartwood and sapwood join. The borers extend their galleries a foot to a foot and a half up and down the tree, from the point of entrance. After these beetles have worked in a tree for a number of years it is weakened to such an extent that it becomes prey to the first heavy wind.

In an examination of some 11-year-old faces chipped 0.5-inch deep, 0.5-inch high, and about 12 inches wide on the Choctawhatchee National Forest, in western Florida, 24 per cent of the faces were found to have emergence holes caused by turpentine borers (*8*). In the same locality narrow French faces, 3.5 to 4 inches wide and concave in shape showed emergence holes on but 4 per cent of the trees. On both of these areas the trees had been protected from fire, and the old faces were fairly well covered with gum. In turpentined slash pines near Starke, where tins had been raised and inserted in ax cuts in the faces, 25 of the 50 trees observed were found to have been attacked by *Buprestis apricans* within two years after the raising of the tins.

The use of narrow faces and shallow chipping and the practice of tacking tins on faces rather than inserting them in ax cuts should prevent serious injury from borers, provided old faces are kept unburned.

Turpentined trees weakened or injured by heavy working or by floods, droughts, fires, or other causes may at times be attacked by various species of Ips beetles (*Ips avulsus* Eichh., *I. calligraphus* Germ., and *I. grandicollis* Eichh.) (*32, 33*). Instances of epidemics of these beetles are not uncommon, but in practically every case the insects may be considered of secondary importance, the primary cause of death being other injuries.

During the last seven years of turpentining investigations by the Southern Forest Experiment Station in slash pine, only one instance has occurred where Ips beetles (*Ips calligraphus* Germ.) apparently killed a number of trees. This happened in the late fall and early winter of 1926. Preceding the attack, heavy rains in July and August, 1926, caused the water at Sampson Lake to rise until it stood around the trees to a maximum depth of 5 feet. A strip of timber

100 feet wide bordering the lake was under water for 10 weeks. As soon as the water receded, Ips beetles attacked a number of the trees, 26 of which died during November, December, and January.

On an adjoining area of similar timber chipped by a commercial operator, there was a very heavy loss of trees from these insect attacks. On this adjoining tract of land the timber had been chipped more than 1 inch deep. Every tree over about 8 inches in diameter was worked with two faces, whereas the station trees, except for one group, were being worked with one face only. The additional weakening effect of the second face on these trees, coupled with the deepness of the chipping, caused such a drain on the vitality of the trees that about one-third of the stand in a narrow strip along the lake was killed. A few round trees also were killed during this insect attack. This loss may have been the result of an accidental spread of the insects from turpentined trees. It is not usual for these insects even when very abundant to attack healthy, vigorous trees. Aside from this one istance of killing by Ips, only an occasional tree has been noticed as dying from insect attacks.

A study was made of all trees which died on the experimental turpentine areas and which had been attacked by insects prior to their death, in order to determine whether there was any relationship between bark-borer attack and the ability of a tree to produce a large quantity of gum. There seemed to be no general rule governing insect attacks, as some of the trees were very good yielders and others relatively poor.

Southern pine beetles (*Dendroctonus frontalis* Zimm.) seldom attack slash and longleaf pines. This may be accounted for by the fact that these two species of trees produce such a large amount of resin when wounded that beetles are drowned out before their weakening effect is sufficient to dry out the trees so that breeding will be possible. According to the division of forest insects of the Bureau of Entomology (*33*), epidemics of these beetles in the turpentine pine stands are extremely rare, although a few isolated cases are on record.

Among the insects which are found in turpentine stands but which do not kill or seriously injure the turpentine pines are sawfly larvæ (*Neodiprion lecontei* Fitch) which cause injury by defoliating the trees, and tip moths (*Rhyacionia frustrana* Comst.) which sometimes kill the terminal shoots and stunt the tree growth. Other insects attack the cones, but these have little or no effect upon gum yields and are not influenced by turpentine practices.

NORMAL MORTALITY OF TREES

The average annual death rate from all causes among the 919 slash pines worked for five years in these experiments was 1.31 per cent. However, a better normal-mortality figure may be obtained by excluding the heavily worked trees or those chipped with faces covering 50 or 75 per cent of the bark surface. The loss from all causes on the remaining 619 trees was 0.85 per cent per annum. On the same tract 1,100 other trees which had been turpentined for 4 years showed an annual loss of 0.49 per cent from all causes. On the longleaf tract the loss on 350 trees worked for five years was 0.34 per cent per annum. On another longleaf tract, which has been under observation by the experiment station, 1,308 trees (about 300 of which had been boxed previously) suffered a loss of 0.57 per cent per annum over a 4-year chipping period. The average annual loss from all causes on the 3,677 trees on all tracts under observation, worked four and five years, has been 0.74 per cent. This includes the exceptionally heavy loss following the flood in 1926 in slash pine timber and a considerable loss from windbreak in back-boxed trees on one of the areas. The average annual mortality over a long period of years for second-growth pines under conservative turpentining will probably come to about 0.5 per cent. It is very difficult to distinguish the primary cause of death, but in most cases it is considered that turpentining is the primary cause, an exception being the case of trees struck by lightning.

Lightning sometimes kills the trees. Out of 2,000 slash pine trees which have been under observation at Sampson Lake since 1923, 2 trees only, or 0.1 per cent, have been struck by lightning, and both were killed. Of the 350 longleaf trees on the Powell tract, none were killed by lightning during the period 1923–1927, and on another longleaf area where 1,308 trees have been under record for four years, 3 trees or 0.2 per cent have been struck by lightning and killed. This indicates that lightning is not a very important mortality factor in second-growth pine stands in the South.

SUMMARY AND CONCLUSIONS

In 1923 a number of experiments were started by the Southern Forest Experiment Station at Starke, Fla., for the purpose of determining the best naval-stores practice in second-growth slash and longleaf pines, the two species that are the main source of naval stores in the United States. Practice so determined should supply the definite information needed to avoid the severe damage to timber stands wrought by present and past turpentining methods and to combine profitable, sustained turpentining with timber conservation.

The principal studies were undertaken in dense second-growth 35-year-old slash pine and open 25-year-old second-growth longleaf pine.

The height-of-streak test, in which three heights, 0.32, 0.5 and 0.73 inch, were tried out, revealed the following advantages in favor of low chipping:

Low chipping produces fully as much gum in five years' time as higher working.

Low working permits the continuous chipping of one face on trees 11 or more inches in diameter for 10 to 12 years, whereas moderately chipped faces are worked out in 7 years and high-chipped faces in 5 years.

This additional working should furnish from 25 to 50 per cent more gum from each face.

The longer working period provides a longer healing period before back facing is begun and avoids the delay of a long rest period before back faces can be put on.

In naval-stores management the longer working period allows for sustained operation without interruption, yielding greater returns at lower operating costs.

Where timber is soon to be cut and only a short working period is permitted, low chipping reduces damage to the butt log nearly 50 per cent over that resulting from high chipping.

The low streak results in a smaller amount of damage from dry facing.

The depth-of-streak tests comprised four depths, 0.3, 0.5, 0.75, and 1 inch. The dense slash timber suffered a greater amount of damage than would have occurred in more open stands. The results obtained in this test revealed the following advantages in favor of shallow working:

Although different depths of streak produce no significant difference in total gum yield from 5 years' working, a greater reduction in yield from year to year accompanies the deeper work, indicating a considerably lower total yield for deep chipping if the work be extended to 7 or more years.

Eleven-inch or larger trees may be worked with shallow streaks for 7 years (or even longer with lower streaks) before the gum yields are reduced to an unprofitable point, as opposed to 5 years' work with deep chipping.

Mechanical weakening of the trees is avoided.

On shallow-chipped slash dry faces are only one-third as numerous as on deeply chipped slash pine.

Injury from insect and fungus attacks on dry faces is correspondingly lessened.

In the width-of-face tests, two series of face widths were used—in one case one-fourth, one-half, and three-fourths of the circumference, and in the other case one-fourth, one-third, and three-eighths.

Only 5 years' work is possible on the 75 per cent faces, because the extreme width of face precludes the possibility of back facing. Three sets of faces, covering a minimum of 15 years, are possible on the narrow-faced group without intermediate resting periods, and one set of back faces on medium-faced (50 per cent) trees. Total yields for wide, medium, and narrow faces may thus be estimated at 168.8, 262.5, and 372 barrels of turpentine per crop, respectively.

The second series of tests showed that the groups of faces that were one-third and three-eighths of circumference yielded, respectively, 8 and 9 per cent more than the narrow faces. However, three sets of faces may be cut in succession without interruption on the one-fourth circumference group, whereas some resting period may be required in the case of the wider faces before the trees can be worked with two sets of back faces.

A study of relative yields from front faces and back faces on slash pine showed that although first-year back-face yields may be lower than virgin front-face yields, nevertheless the back-face yields are likely to increase in subsequent years, whereas front faces generally register a decline in yield from year to year. The indications are that over five or more years of work back-face yields will underrun front-face yields by only a very small amount, if indeed they do not actually exceed them. These conclusions are drawn from yields obtained from working back faces on slow-growing trees following a short working of front faces, so that the trees were very little larger when back faced than when front faces were first worked. Where 8 or 10 years elapse between the placing of the front faces and the working of back faces in fast-growing timber the increase in diameter growth is sufficient to offset any decline in yield and give a substantial increase.

A study of density of stand as it affects gum yields and the ability of the trees to be turpentined without damage indicated that more open-growing trees yield considerably more than trees in dense stands and that there is less reduction in yield from year to year where the trees have plenty of space. A study of yield in relation to crown size indicated that more gum is obtained from the trees with larger crowns. Furthermore, on these large-crowned trees growing in the open there is less dry facing and faces heal more rapidly than in crowded stands.

A study of the effect of diameter size on naval-stores yield brought out the fact that yields increase with size of tree and that trees smaller than 9 inches can not be chipped with any assurance of obtaining a satisfactory profit unless the market prices are high or the trees considerably more vigorous than the average.

All chipping resulted in a reduction of diameter growth rate. This reduction increased with greater height of streak, greater depth of streak, and the use of two simultaneous faces as opposed to single faces.

Turpentining in fairly open longleaf stands apparently did not affect the ability of the trees to produce cones.

Dry facing is an important item in naval-stores management as it impairs the value of lumber and increases the likelihood of further degrade caused by insects and fungi. Dry facing is more serious in slash pine stands than in longleaf. It increases with density of stand and with greater depth of chipping and is normally more serious whenever any other destructive agencies have weakened the trees.

The principal insect associated with turpentining work is the turpentine borer (*Buprestis apricans*). Damage by this borer may be kept under control by the use of conservative methods, such as shallow chipping and the cutting of narrow faces. Tacking tins and avoiding the use of ax cuts in the face also reduce the likelihood of damage from these borers.

The whole series of tests show that timber may be chipped for a much longer time than under present commercial methods, with a higher sustained yield and less damage to the trees, provided low streaks, shallow streaks, and narrow faces are used. Also, if work is confined to trees above 9 inches in diameter, well spaced, and with plenty of crown, gum yields may be considerably increased. The results from all the stands under observation at Starke indicate that annual mortality in second-growth turpentine stands may be kept down to 0.5 per cent, provided conservative methods are employed.

A hypothetical example will illustrate in a very general way the prospective high yields and high returns to the timber owner where improved methods are employed, in contrast with the low returns from ordinary work.

Assuming a 70-acre stand of slash timber with 150 trees per acre averaging 9 inches d. b. h. at 27 years,[a] or a workable stand of

[a] Figures represent an average of the open stand at Sampson Lake.

approximately 10,000 trees, what may be expected from it as a reasonable maximum yield?

Many operators would cut two faces per tree, using streaks one-half inch high and one-half inch deep, and work the faces for five years. The indicated yield for one face per tree as shown in Figure 20, is about 40 barrels of turpentine per crop for 9-inch trees, but with two faces per tree the yield per face is reduced to about 75 per cent of this figure or 30 barrels. So double facing would yield 150 barrels per crop in five years' time. The whole tract would cup two crops yielding 300 barrels of turpentine. The trees would then be worked out at 32 years of age and should be cut. Presumably, they could be replaced in 27 or 28 years by a similar stand duplicating the yields at the age of 32 years or netting 600 barrels of turpentine in the 37 or 38 years since work was begun on this 70 acres.

In contrast with this procedure an improved method would include the following: One face per tree; face width equal to one-third of tree circumference; streaks one-half inch deep and one-fourth inch high; tins and cups raised yearly to a maximum height of 5 or 6 feet from the ground; back faces put on after one year's rest; three faces per tree in succession.

Such a tract would cup one crop, yielding an average of 36 barrels of turpentine annually for 12 years.[7] The 12-year yield would be 432 barrels. After a 1-year rest the trees would be 40 years old and at least 10½ inches in diameter, supposing that they grew 1 inch each 6½ years during turpentining. On trees of any given diameter, yields from back faces will be about 90 per cent of the yield from front faces. Accordingly, for the second 12-year chipping period the yields should be 90 per cent of 50 barrels or 45 barrels annually; that is, 540 barrels in 12 years' time. When these faces are worked out the trees will be 52 years old and nearly 12 inches d. b. h. A third crop of faces should then yield about 50 barrels yearly at a conservative estimate, or 600 barrels per crop for the 12 years. The trees will then be 65 years old and many of them 14 to 16 inches in diameter. They should then be cut.

The total yields for 38 years since the operation began in this manner would be 1,572 barrels of turpentine for the whole tract, as opposed to 600 barrels under the usual plan.

Under the more usual, short-time method of operation, at a leasing price of 15 cents a face for five years' time or $1,500 per crop, the revenue to the timber owner whose trees are worked by unimproved methods would amount to $2.37 per acre annually from five years' work on each of two sets of double faces for the 38 years from the time turpentining began up to the end of operations on the second stand.

On the other hand, when 36 years of work is possible on each tree during the 38-year period, the revenue at 3 cents per face per year would be $4.26 per acre yearly for the 38 years after the stand has reached workable size. This is a net gain of $1.89 per acre per year derived from the use of improved methods. The naval-stores revenue has been increased by 80 per cent.

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[7] This is 90 per cent of the average annual yield for the first 5 years, as shown on the curve in Figure 20. Since there is a gradual reduction in yield each year, the yield for 12 years would not average so high as for the first 5 years.

In addition to this increased naval-stores revenue, the use of improved turpentine practices will also indirectly bring in more revenue from stumpage, because the trees are larger and have a greater value for higher priced commodities.

Turpentining is not inconsistent with forest conservation when properly done, nor are high yields inconsistent with conservative chipping methods. Light working is to the interest of both the timber owner and the naval-stores operator.

APPENDIX

COMPARISON OF TREE GROUPS USED IN STUDIES

Tables 21 to 24 give particulars of the tree groups used in the various tests, based on 1923 average-tree measurements.

TABLE 21.—*Comparative measurements of tree groups used in height-of-streak tests*

SLASH PINE

Height of streak	Diameter at— 4½ feet	Diameter at— 9 feet	Height	Crown Width	Crown Length	Rings in last 0.5-inch growth	Age
Inch	*Inches*	*Inches*	*Feet*	*Feet*	*Feet*	*Number*	*Years*
0.32	10.88	----------	71.6	14.5	----------	5.3	35
.50	10.72	9.78	73.4	15.8	----------	5.4	35
.73	10.79	10.00	70.7	11.3	----------	5.4	35

LONGLEAF PINE

0.32	9.73	9.23	55.50	17.68	31.10	5.56	36
.50	9.70	8.92	47.59	20.84	32.24	3.00	27
.73	9.35	8.94	48.22	22.16	31.54	4.14	28

TABLE 22.—*Comparative measurements of tree groups used in depth-of-chipping tests*

SLASH PINE

Depth of streak	Diameter at— 4½ feet	Diameter at— 9 feet	Height	Crown Width	Crown Length	Rings in last 0.5-inch growth	Age
Inch	*Inches*	*Inches*	*Feet*	*Feet*	*Feet*	*Number*	*Years*
0.30	10.83	10.0	70.14	10.4	15.1	5.28	35
.50	10.72	9.8	73.39	15.8	----------	5.42	35
.75	10.75	10.0	73.22	12.6	15.6	5.56	35
1.00	10.81	10.1	71.34	14.0	16.8	5.66	35

LONGLEAF PINE

0.30	9.99	9.38	47.69	27.7	32.5	2.78	22.0
.50	9.70	8.92	47.59	20.8	32.2	3.00	27.5
.75	9.62	----------	50.75	23.0	32.8	3.06	24.5
1.00	9.56	9.13	53.67	21.4	31.8	3.22	26.0

TABLE 23.—*Comparative measurements of tree groups used in width-of-face tests, slash pine*

SERIES 1

Width of face (circumference)	Diameter at —		Height	Crown		Rings in last 0.5-inch growth	Age
	4½ feet	9 feet		Width	Length		
Per cent	*Inches*	*Inches*	*Feet*	*Feet*	*Feet*	*Number*	*Years*
25	8.2	7.6	----------	12.6	20.4	5.4	33
50	8.4	7.7	----------	9.8	18.3	5.8	33
75	8.5	7.8	----------	12.2	19.5	5.2	33

SERIES 2

25	10.4	9.7	76.0	18.3	24.0	5.58	35
33⅓	10.7	9.8	73.4	15.8	----------	5.42	35
37½	10.4	9.7	72.1	17.2	22.7	6.24	35

TABLE 24.—*Comparative measurements of tree groups used in density-of-stand tests*

SLASH PINE

Stand density	Trees per acre	Diameter at—		Height	Crown		Rings in last 0.5-inch growth	Age
		4½ feet	9 feet		Width	Length		
	Number	*Inches*	*Inches*	*Feet*	*Feet*	*Feet*	*Number*	*Years*
Dense A	170	10.7	9.8	73.4	15.8	20.5	5.4	35
Dense B	280	10.5	9.8	73.1	12.8	15.5	6.1	35
Open	[1] 75	10.7	9.6	----------	24.0	28.9	4.6	26

LONGLEAF PINE

Dense	135	9.4	----------	56.1	18.2	28.8	3.8	29
Open	100	9.7	8.9	47.6	20.8	32.2	3.0	27

[1] Estimated.

GLOSSARY OF FORESTRY AND NAVAL-STORES TERMS [8]

Advance streak.—One or more streaks cut in advance of the regular chipping season for the purpose of stimulating oleoresin production.

Apron.—A flat metal strip attached or inserted in a horizontal plane in a tree immediately above the cup to direct the oleoresin from the face into the cup.

Back face.—A face placed on a tree already turpentined on one or more faces; usually a second face placed on the side of the tree opposite the first or front face.

Bark bar.—The vertical strip of unchipped bark between two faces.

Barrel.—Turpentine barrels hold 50 gallons. A barrel of rosin, known as a round barrel, weighs about 500 pounds gross or 420 pounds net. Market quotations for a barrel of rosin are based upon a theoretical barrel of 280 pounds gross weight.

Blue stain.—A blue-gray discoloration of sapwood caused by minute vegetable organisms; often called sap stain.

Breast height.—Four and one-half feet above the ground.

Box.—A cavity cut in the base of a tree to collect the oleoresin produced when the tree is chipped. Cups are now almost universally used in place of boxes.

[8] Sources consulted: *11*, *38*.

Chip.—(Noun) The wood removed by chipping. (Verb) To cut a streak or wound a tree for the purpose of allowing the oleoresin to flow.

Chip paddle.—A board or canvas screen placed against the tree during chipping to shield the cup from bits of wood or bark.

Close cupping.—Overworking a tree by cutting too many faces.

Crop.—(1) Ten thousand turpentine faces. (2) The total yearly production of naval stores for the entire industry.

Crown.—The portion of a tree composed of live limbs and foliage.

Crown class.—A classification of trees according to the proportionate amount of direct sunlight which the crown receives. The most commonly recognized classes are dominant, codominant, intermediate, and suppressed.

> *Dominant.*—Trees having the crown free to light on all sides because of greater height.
>
> *Codominant.*—Trees having the crown free to top light and some side light; trees somewhat shorter than dominant.
>
> *Intermediate.*—Trees having the crown shaded on the sides but free to light at the top.
>
> *Suppressed.*—Trees having the crown entirely overtopped and shaded.

Crown diameter.—The average maximum width or spread of the tree crown.

Crown length.—The distance from the base of the lowest live limb to the highest point of the crown.

Cup.—(Noun) A receptacle of earthenware, galvanized iron, aluminum, or other materials, made in various shapes, used for catching the flow of oleoresin resulting from chipping. (Verb) To work for turpentine.

D. b. h.—Diameter at breast height (4½ feet).

Depth of streak.—*See* Streak depth.

Dip.—(Noun) The oleoresin which collects in the cups as distinct from the scrape, or that which hardens on the face. (Verb) To gather the oleoresin from the cups and collect it in barrels to be taken to the still.

Dry face.—A face on which the secretion of resin has stopped over all or a part of the streak, as the result of interference with the normal flow of sap behind the face.

Face.—(Noun) The total scarred surface of a turpentined tree formed by the cutting of successive streaks. (Verb) To slab off the bark and occasionally wood in preparation for setting the aprons or gutters.

Face height.—The measure of the vertical distance between the bottom of the first streak and the top of the last streak, measured along the shoulder or edge of the face.

Face width.—The measure of the horizontal distance between two edges or shoulders of a face, measured in these studies by a flexible tape across the face surface.

Flatwoods.—The poorly drained level portion of the southern coastal plain on which grow forests of slash and longleaf pines.

Gum.—Synonymous with oleoresin or resin.

Gutter.—A V-shaped metal strip or trough inserted or attached obliquely immediately above the cup to direct the oleoresin into the container.

Gutter chisel.—A wedge-shaped tool (used with a maul) for making a slit in the wood of a tree for the insertion of gutters or aprons. (Fig. 23, 2.)

Hack.—A cutting tool used in chipping trees to induce the production of oleoresin. The cutting edge of the American hack is a sort of half-round or U-shaped gouge, set on a wooden stock which is weighted at the end. Several sizes are made, based on the width of the U. No. 0 is seven-eighths inch wide, No. 1 is 1 inch wide, No. 1½ is 1⅛ inches, and No. 2 is 1¼ inches. (Fig. 23, 5.)

Height of streak.—*See* Streak height.

Height of face.—*See* Face height.

Herty cup.—An earthenware container shaped like a flower pot.

Increment boring.—A cylindrical core extracted from a tree by means of a hollow auger for the purpose of determining age or growth rate of the tree by observing the annual rings of growth.

Jump streak.—A streak cut in new wood a short distance above the peak of the face in such a way that a narrow strip of uncut wood is left between the new or jump streak and the old face.

Naval stores.—Originally all material used in the construction of wooden vessels, including timber, lumber, masts, yards, flax, tar, pitch, rosin, and cordage. Now used to denote turpentine, rosin, pitch, tar, and other chemical products extracted from oleoresin.

Oleoresin.—An oily resin or gum extracted from many species of pines as distinct from the watery sap. This oleoresin is produced by living cells surrounding the resin canals or ducts.

Operator.—A producer of naval stores. An operator, besides working trees, usually extracts and distills the oleoresin.

Peak.—The sharp projecting point of wood at the middle of the top of a face formed by two streaks sloping downward toward each other.

Pull.—(1) To cut a streak on a high face by means of a puller (fig. 23, 6) or chipping tool mounted on a long handle and pulled through the wood by the chipper; (2) to extract or remove aprons or gutters by means of long-handled forceps called gutter pullers.

Raise cups.—To change the cups from a lower position to a point close to the top of a face in order to lessen evaporation from gum running over a long face.

Resin.—Synonymous with oleoresin, or gum.

Ring.—The annual layer or ring of wood produced by the tree in a season.

Rosin.—That portion of the crude oleoresin, freed from trash and water, which remains after volatilization of the turpentine by distillation.

Round tree.—A tree in which no turpentine face has yet been cut.

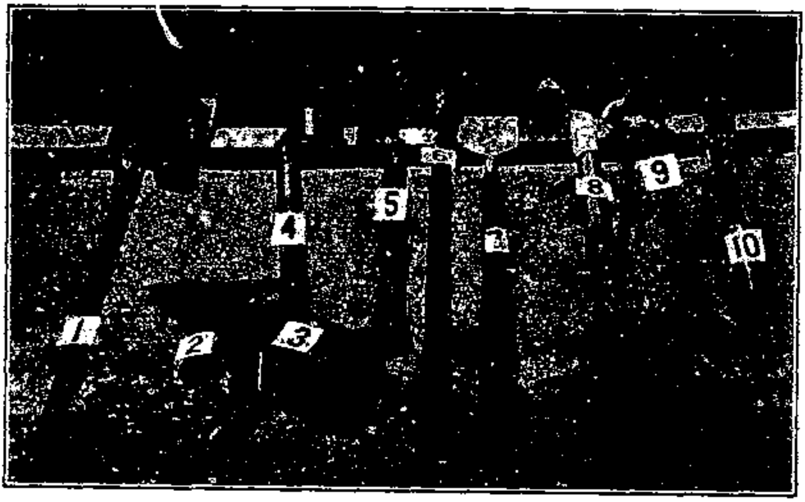

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FIGURE 23.—Turpentine tools: 1, Broadax; 2, gutter chisel, pringle; 3, maul; 4, hogal; 5, hack; 6, puller; 7, push-down scraper; 8, pull-down scraper; 9, gutter puller; 10, dip iron

Scrape.—Hardened oleoresin which forms on a face, as distinct from that which runs down into the cup to form dip.

Shoulder.—The outside edge of a face where the streak first cuts into the wood.

Site index.—A figure which represents the tree-growing quality of land as expressed by the height in feet of the average dominant trees at 50 years.

Spirits.—*See* Turpentine.

Streak.—A wound formed when a tree is chipped. In American chipping, this consists of two downward cuts meeting in a V. The angle at which the tool is tilted in the chipper's hands determines whether a shade streak, square streak, or sun streak is cut. (Fig. 5.) A streak cut with a French chipping tool is formed by removing a thin slab of bark and wood, shaped like an inverted U.

Streak depth.—The horizontal measure of a streak taken radially from the inside of the bark at the deepest point.

Streak height.—The vertical measure of a streak taken along the grain.

Streak width.—Streak height.

Tin.—A comprehensive term synonymous with apron or gutter. Any type of metal strip used to guide oleoresin from the face into the cup.

Turpentine.—The volatile oil, often called spirits, which is one of the main constituents of oleoresin derived in the process of distillation. A complex chemical substance composed primarily of terpenes, expressed by the general formula $C_{10}H_{16}$.

Turpentining.—The process of working a tree to obtain oleoresin from its gum; as commonly used, the term may also include the distilling process.

Virgin faces.—Faces during the first year of chipping.

Width of face.—*See* Face width.

Width of streak.—*See* Streak height.

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