EFFECT OF SLASH MULCH AND SLASH BURN ON PINE AND SPRUCE PLANTINGS

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THE CONNECTICUT AGRICULTURAL
EXPERIMENT STATION
NEW HAVEN

Bulletin 548—April, 1951

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The disposal of slash produced in normal silvicultural improvement operations, such as weeding, thinning and pruning, is not ordinarily a problem, aside from the possible fire hazard at certain times of the year. The slash material is either scattered or piled and, if piled, it may or may not be burned.

However, in the process of clear cutting or as a result of severe wind or ice damage when large quantities are produced, slash disposal is more difficult. Should this debris be gotten rid of as quickly and cheaply as possible by burning or dumping, or does it have value if left on the land? Can it be used to improve growing conditions on a poor site? What is its effect on the soil?

Some years ago the author was shown plots in a plantation on Merrimac soil in the Pack Forest near Warrensburg, New York, in which growth of pine and spruce trees had been markedly increased by a heavy mulching with pine slash. Untreated trees were not only small but severely chlorotic (6).

In Connecticut there are several areas of apparently similar, light, relatively infertile soil (Merrimac series) on which planted trees do rather poorly, especially during the first few years of an open field planting. Except in small localized spots, however, they do not have the unhealthy, chlorotic appearance so much in evidence in the Pack Forest plantation.

The slash accumulation resulting from clean-up operations in parts of the Rainbow Plantation following the 1938 hurricane provided the opportunity to test out under Connecticut conditions the value of a slash mulch. At the same time data were obtained on the effect of burning scattered slash. The results are reported in this bulletin.

LITERATURE REVIEW

The literature dealing with the effect of slash on tree growth in plantations is rather limited. Lutz and Chandler (13) cited seven references, two of which are reported below. The general conclusions drawn by the authors, based on these references, were that slash generally increases the organic matter content of the soil, lessens moisture loss by evaporation, and favors the nutrient supply. Color of the foliage is improved and growth usually increased. They mentioned the promising results obtained on a sand plain in New York State, which is the work referred to in the introduction. Recent findings on this study are reviewed in the discussion on p. 16.

[1] Department of Soils. The writer is appreciative of the advice and cooperation of Mr. Henry Hicock, Head of the Department of Forestry, in the prosecution of this work.

Némec (14) studied the chemical properties of a heavy clay soil following certain treatments. He found that where logging slash was burned and the ashes scattered, the top 12 inches of soil contained more phosphoric acid and potash than did the unburned areas, even after seven years. Growth of spruce was slowest on the unburned areas.

More applicable to the present work is that reported by Fabricius (5). He mentioned the classical case of the private forest of Bärenthoren, near Berlin, where Scotch pine was growing on poor sandy soil under low annual rainfall conditions. After 50 years of "reisigdüngung" (twig manuring) in which all of the small lop and top material was left on the ground, the physical condition of the soil had been greatly improved.

In his own work, Fabricius found that a layer of spruce branches, applied as a mulch to completely suppress grass and other ground vegetation in a seven-year-old Norway spruce plantation, resulted in a definite increase in rate of growth, as compared with the control plots, ranging up to 20 per cent by the ninth year after treatment.

In another experiment located on a compact silty soil, a three-year-old plantation of Scotch pine and Norway spruce, was given the following treatments:

1. Check (no treatment).
2. All vegetation (mainly heather, with some *Juncus* and *Carex*) hoed or hacked off and removed.
3. All vegetation hoed or hacked off as in 2 but the cut material was left in place and the material removed from treatment 2 added.
4. Same as 2 but with cut material left in place.
5. Surface undisturbed, but with heather and other vegetation cut in the vicinity strewn thickly between the trees (15 pounds per square yard).

Total heights, in feet, after eight growing seasons were as follows:

Method	*Scotch pine*	*Norway spruce*
1. Check	6.15	3.00
2. Cut and removed	8.44	3.06
3. Cut material plus that from 2	8.65	2.96
4. Cut but not removed	7.48	3.72
5. Not cut, mulch added	10.52	8.28

According to Fabricius, the experiment showed that it was unnecessary to cut the existing ground vegetation; all that was needed was to cover the soil thickly with a mulch of cut vegetation obtained elsewhere. Other experiments with ash plantations gave similar results. The author pointed out, however, that beneficial results from such treatments appeared to be relatively independent of tree species or kind of soil. He was not in a position to explain the cause of the beneficial results, nor did he know why in some cases the treatments were not effective.

PLAN OF THE EXPERIMENTS

The Plantations

The Rainbow Forest Plantations, formerly owned by the Experiment Station, occupied about 120 acres of essentially level glacial outwash terrace land in northcentral Connecticut, some 12 miles north of Hartford (7). The annual precipitation averages 42.2 inches, usually well distributed throughout the year, but with occasional prolonged dry periods.

The soil is chiefly Merrimac loamy sand, with some variation in different parts of the area, ranging from sandy loam to coarse sand. The average profile in the area concerned bears the following general characteristics:

A_0 None to 1½ in. of needles and bits of twigs and bark, in varying stages of decomposition. Thickness depends on density and age of the stand. In character it varies from a rather poor Sand Mull[1] (organic matter admixture is result of previous plowing and some infiltration) to Thin Mor.[2]

A_1 0-5± in.—Dark brown (7.5YR 4/2)[3] to very dark grayish brown (10YR 3/2) loamy sand to sand (in localized areas the A_1 is very thin or absent).

B 5-24± in.—Strong brown (7.5YR 5/6) loamy sand to medium sand.

C_1 24-42± in.—Yellowish brown (10YR 5/4) to light brownish gray (10YR 6/2) coarse sand.

The A horizon possesses the following average characteristics:

pH	4.7	Moisture equivalent	7.7%
Loss on ignition	2.7%	Total sands	82.0%
Total nitrogen	0.05%	Silt	11.5%
Organic carbon	2.0%	Clay ($<$.002mm)	6.0%
Cation exchange capacity	4.6 m.e.[4]		

Description of Treatments

Work was done on four separate areas or blocks as follows:

1. "Clark Lot". Merrimac loamy sand. This was a stand of red pine (*Pinus resinosa* Ait.) averaging seven feet in height in 1939 at the time of applying slash. The original planting in 1933 was a 2′ by 2′ tree spacing on a one-tenth acre block divided into four equal plots. The experiment was designed to test out the carry-over effects of certain previous nursery fertilizer treatments, and to compare the response of the trees to fertilizer treatment in the field, applied to two of the plots. These field treatments were equivalent to the following grades, applied on the dates indicated, to plots 2 and 4.

7-10-5, 1000 pounds per acre, May, 1933
11-6-6, 400 pounds per acre, April, 1935
11-5-5, 425 pounds per acre, May, 1937

[1] Sand Mull—No H (humus) layer present; A_1 has a single grain structure and a low content of rather uniformly distributed organic matter.
[2] Thin Mor—H layer less than 1/2 inch thick; practically no mixing of organic matter with mineral soil; abrupt transition from surface organic matter to underlying horizon.
[3] Approximate color of moist soil according to the Committee Report on Soil Color, Soil Survey Division, Bureau of Plant Industry, Soils and Agricultural Engineering, U.S. Dept. of Agriculture, Beltsville, Md. May 27, 1948 (mimeographed).
[4] Milliequivalents per 100 g soil.

In May, 1939, the planting was thinned to 6′ by 6′ (leaving 32 trees per plot), and the cut trees from all four plots constituted the "slash" which was spread between the rows on plots 1 and 2. In 1941 the trees were measured and soil samples collected.

2. Block 45. Merrimac loamy sand to sand. In June, 1939, green white pine slash from another part of the plantation with slightly better soil was scattered on several small plots of white pine (*P. strobus* L.) spaced 6′ by 6′, and averaging four feet in height. Growth measurements were made periodically over a period of four years.

3. Block 59. Manchester sandy loam. This 37-38 year old, 8′ by 10′-spaced white pine stand, completely destroyed by the 1938 hurricane, was cleared and divided into five plots. In 1939 two of the plots were covered with 8 to 16 inches of white pine slash (Figure 1); on a third the added slash was burned in the early part of 1940 and 1941, and two plots were kept clear. All were then planted in April, 1942, to white pine spaced 7′ by 7′ and interplanted with Norway spruce [*Picea Abies* (L.) Karst. (*P. excelsa* Link)]. Each spruce was centered between four white pines. Both species were 2-1 stock.

Figure 1. Planting pine and spruce (2-1 stock) on one of the slash plots on block 59,—Manchester sandy loam. April 1942. (Compare with Figure 4).

4. Block 64. Merrimac loamy sand (Figure 2). This block was formerly an 8′ by 8′ Scotch pine (*P. sylvestris* L.) stand 30 years old. Following

destruction of the stand, the block was divided into 12 plots. Treatments were applied in 1939, 1940 and 1941 simultaneously with and identical to those on block 59 but using Scotch pine slash from the preexisting stand. This was the only block on which it was feasible to provide an adequate replication of treatments suitable for statistical analysis. The treatments were as follows:

Plots 1, 4, 7, 10 clear
Plots 5, 6, 8, 9 slash spread
Plots 2, 3, 11, 12 slash spread, then burned

The plots were planted to white pine and Norway spruce at the same time and in the same manner as those on block 59.

Figure 2. General view of block 64, Merrimac loamy sand, at time of planting,—April 1942.

Measurements on blocks 59 and 64 consisted of periodical survival counts, and total height and growth rates in 1941 and 1947. The soils in blocks 45 and 64 were sampled in 1941 and 1947; that on block 59 in 1947 only.

RESULTS

Tree Survival and Growth

The data on total growth over a given period of time on two of the areas are given in Table 1, while Table 2 shows the survival and total growth on the other two blocks. Figure 3 gives the average annual growth on all four blocks.

TABLE 1. EFFECT OF SLASH ON THE GROWTH OF RED AND WHITE PINE

MERRIMAC LOAMY SAND

A. Clark Lot. Total growth of red pine, 1939-41 (3 years). Av. per tree[1] in feet.

	Clear	Slash
Unfertilized	4.90	4.32
Fertilized[2]	4.96	4.46
	4.93	4.39

B. Block 45. Total growth of white pine, 1939-44 (6 years). Av. per tree[3] in feet.

	Clear	Slash
Replicate plots	8.07	9.16
	7.82	8.74
	....	8.89
Average	7.94	8.93

[1] Data based on 28 to 31 trees in each treatment. Planted in 1933, the trees averaged 7 ft. tall when slash was applied 1939.
[2] Field treatments equivalent to the following rates per acre:
1000 lbs. of 7-10-5 in May, 1933
400 lbs. of 11-6-6 in April, 1935
425 lbs. of 11-5-5 in May, 1937
[3] Data based on 16 to 20 trees in each treatment. Trees were about 4 ft. tall when slash was applied in 1939.

TABLE 2. SURVIVAL AND GROWTH OF WHITE PINE AND NORWAY SPRUCE PLANTED 1942

Block No. and Soil	Series	White Pine			Norway Spruce		
		Clear	Slash	Burned	Clear	Slash	Burned
Survival at end of first season, per cent							
59[1]		94	91	88	96	74	94
(Manchester sandy loam)		93	93	....	93	74	....
Av.		93.5	92.0	....	94.5	74.0	....
64[2]	(a)	96	85	100	97	92	98
(Merrimac	(b)	98	93	100	98	98	98
loamy sand)	(c)	86	95	96	95	90	95
	(d)	86	96	89	97	95	93
Av.		91.5	92.3	96.3 NS[3]	96.7	93.7	96.0 NS
Total growth, 1943-47, inclusive. Av. per tree, in cm.[5]							
59[1]		111	117	121	69	77	74
(Manchester sandy loam)		104	115	....	72	82	....
Av.		102.5	116	....	70.5	79.3	....
64[2]	(a)	100	90	122	31	37	41
(Merrimac	(b)	90	87	96	35	38	33
loamy sand)	(c)	83	82	109	34	35	41
	(d)	92	92	101	51	44	38
Av.		91.3	87.7	107 Sig.[4]	37.7	38.5	38.3 NS

[1] Data based on 22-69 trees in each treatment. Duplicate clear and slash plots.
[2] Data based on 28-51 trees in each treatment. Quadruplicate plots.
[3] NS—Differences not significant.
[4] Sig.—Differences significant at 5% point.
[5] Measured in cm. instead of feet because of their small size.

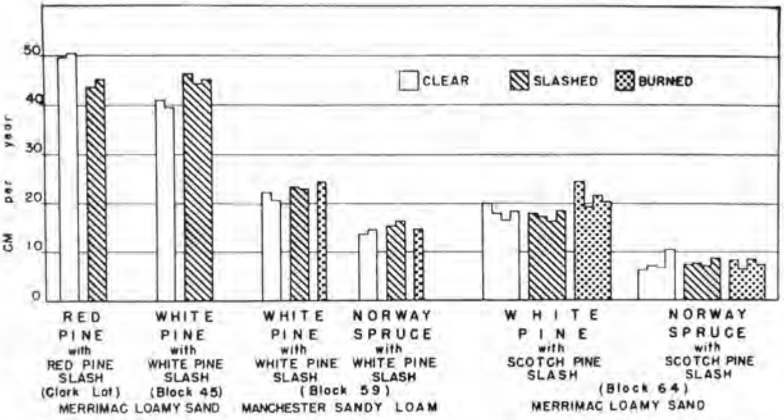

Figure 3. The average annual growth of trees in the four slash experiments at the Rainbow Plantation.

Survival

The first part of Table 2 shows that the only effect of slash was to reduce survival of Norway spruce on block 59 by about 20 per cent. On some portions of these plots planting was made unusually difficult by the thick layer of slash (Figure 1), and it may be that poor planting affected spruce more than it did pine. Burning had no measurable effect on either species. A recent study by Bruce (2) on longleaf pine showed no survival benefit through burning. He attributed any unfavorable effect from burning to direct injury to the trees by fire.

Growth

The effect of treatment on growth varied somewhat on the different blocks. Table 1 shows that on the Clark Lot, red pine slash appeared to have had a slightly unfavorable effect on growth of red pine, but on block 45 white pine slash was beneficial to white pine trees. In the second portion of Table 2 it is seen that, although white pine slash seemed to favor growth of both white pine and Norway spruce on block 59, Scotch pine slash had no effect on these same two species on block 64. Burning caused a significantly higher (17.5%) growth rate of the pine but had no such effect on spruce. This favorable effect of burning is in keeping with findings in another experiment with red pine (11).

Two other items of interest are shown in Table 2 and Figure 3. One is the markedly faster rate of growth of white pine as compared with Norway spruce; the other, the differences in growth rate between blocks 59 and 64, particularly in the case of Norway spruce. These differences can be accounted for in the character of the two soils, as will be discussed in the next section.

Effect of Treatment on the Soil

The first set of soil samples, collected in May, 1941, were tested for pH.

for the usual quick tests (NO_3-N, NH_3-N, P, K, Ca, Mg and Mn) (12), for available P and K extracted by 1 per cent citric acid, and for total soluble salts. Only those data showing treatment response are presented.

The only effect of slash was to cause an increase in available potassium and total soluble salts, as shown in Table 3. The burned plots in block 64 showed markedly higher K and total soluble salt contents, as would be expected. Also the pH was raised slightly (Table 4).

TABLE 3. EFFECT OF SLASH AND BURNING ON THE SOIL MAY 5, 1941, SAMPLING[1]

Block	Available potassium						Total soluble salts		
	Quick tests Approx. lbs./A.			Citric acid soluble m.e.[2]			ppm		
	Clear	Slash	Burn	Clear	Slash	Burn	Clear	Slash	Burn
Clark Lot	112	150	......[3]	0.049	0.077	......	214	170	......
(Red pine slash)	107	205	......	.049	.115	......	150	208	......
Block 45	75	115	......	.027	.121	......	155	170	......
(White pine slash)	90	105	......	.030	.044	......	160	160	......
Block 64	75	140	......	.025	.063	......	160	180	......
(Scotch pine slash)	75	75	200	.044	.019	.137	155	170	385

[1] Data on duplicate samples except on burned treatment.
[2] Milliequivalents per 100 g. of air-dry soil, soluble in 1% citric acid. The average exchangeable K content, replaced by N/1 ammonium acetate, in another portion of the plantation was 0.046 m.e. or 18 ppm.
[3] No burned plots on the first two blocks.

Quick tests on the October, 1941, sampling showed no response to treatment aside from a slight but significant increase in pH as a result of burning. The latter data are shown in Table 4.

TABLE 4. EFFECT OF BURNING ON THE pH OF THE SOIL ON BLOCK 64 1941 DATA

Time of Sampling	Clear	Slash	Burn
May[1]	4.72	4.71	5.00
October[2]	4.55	4.60	4.73

[1] Readings on composite samples from about 18 borings.
[2] Means of four replicas. These differences are significant at the 5% point. Each sample was a composite from about 18 borings.

Samples from the October sampling were incubated at room temperature and optimum moisture for two months, then analyzed for ammonia and nitrate nitrogen content. The data on the first two blocks, given in Table 5, show that there was a loss in ammonia and a gain in nitrates in the clear (no slash) plots, and a gain in both ammonia and nitrates in the slash-treated soils.

Comparing unfertilized with fertilized soil in the Clark Lot, it appears that in the clear treatments less NO_3-N was formed in the soil samples from the fertilized plots, while in the slash treatments more NH_3-N was produced in the fertilized soils. In the absence of further confirming data, the significance of these results is not clear.

The nitrogen transformation data for block 64 are not given in the table owing to the absence of differences as a result of treatment. It is sufficient to state that there was a small but rather uniform loss of ammonia (1 to 3 ppm) under all three treatments, viz., check, slash, and burned; and at the same time a fairly uniform gain in nitrates (clear averaged 13.1 ppm, slash 14.3 and burned 10.1). These differences are not statistically significant.

TABLE 5. NITROGEN TRANSFORMATION IN THE SOIL FROM TWO OF THE BLOCKS, AFTER TWO MONTHS INCUBATION OCTOBER, 1941, SAMPLING[1]

Block		Clear			Slash		
		Start	End	Gain or Loss	Start	End	Gain or Loss
				NH_3–N ppm			
Clark Lot	No	3.5	0.5	−3.0	2.2	3.0	+0.8
(Red pine slash)	Fert.	3.5	1.0	−2.5	2.2	4.0	+1.8
	Fert.[2]	3.4	0.0	−3.4	4.2	15.8	+11.6
		3.4	1.0	−2.4	4.2	16.8	+12.6
Block 45		15.0	4.6	−10.4	7.2	19.2	+12.0
(White pine slash)		7.0	17.8	+10.8	9.0	19.8	+10.8
				NO_3–N ppm			
Clark Lot	No	0.5	30.0	+29.5	0.5	20.6	+20.1
(Red pine slash)	Fert.	.5	38.5	+38.0	.5	18.1	+17.6
	Fert.	.5	17.2	+16.7	.7	23.0	+22.3
		.5	16.0	+15.5	.7	22.3	+21.6
Block 45		0.5	8.8	+8.3	0.4	1.1	+0.7
(White pine slash)		.5	1.0	+0.5	.4	1.6	+1.2

[1] Duplicate samples. Each sample, consisting of a composite of 12 or more borings, was incubated in duplicate.
[2] See Table 1 for details.

Final sampling was done in October and December, 1947, omitting the Clark Lot. Tests for pH and moisture equivalent[1] were run on the October samples. The samples were then incubated for four weeks, after which soil tests were made by a modification of the Wolf method (16), and total soluble salts determined. On the December samples moisture equivalent, mechanical analyses by the Bouyoucos hydrometer method (1) and loss-on-ignition determinations were made.

Table 6 gives the pH, loss-on-ignition and moisture equivalent of the soils as collected, and the available P content and total soluble salt content after incubation. It is seen that the pH of the soils on the burned plots tended

[1] Moisture-holding capacity of the soil when it is subjected to a force 1,000 times gravity.

to be slightly higher than those on the other two treatments. Likewise, the burned plots on block 64 were slightly higher in P content, and very slightly lower in loss-on-ignition and total salts, but in no case are the differences significant.

TABLE 6. EFFECT OF SLASH AND BURNING ON CERTAIN PROPERTIES OF THE SOIL 1947 SAMPLING, REPLICATED PLOTS

Block	Series	pH			Loss-on-Ignition per cent			Moisture Equivalent per cent			Available P After Incubation ppm			Total Soluble Salts After Incubation ppm		
		Clear	Slash	Burn	Clear	Slash	Burn	Clear	Slash	Burn	Clear	Slash	Burn	Clear	Slash	Burn
Block 45		4.55	4.50	......[1]	2.87	2.23	......	7.48	6.22	......	3.85	3.64	......	160	160	......
(White pine		4.62	4.60	......	2.67	2.52	......	7.93	6.97	......	3.58	3.82	......	200	160	......
slash)		......	4.70	......	......	2.57	......	......	7.36	......	......	3.60	......	......	150	......
Block 59		4.78	4.80	4.92	2.63	2.81	2.92	7.89	7.95	7.93	4.08	6.02	5.61	150	150	190
(White pine slash)		4.89	4.82	......	2.65	2.47	......	6.96	8.24	......	6.31	5.80	......	150	170	......
Av. of 45 + 59		4.71	4.68	......	2.71	2.52	......	7.57	7.35	......	4.45	4.58	......	165	158	......
Block 64	(a)	4.80	4.74	4.95	2.87	1.94	2.30	6.92	5.23	6.32	4.54	4.12	5.22	240	150	150
(Scotch	(b)	4.72	4.68	4.70	2.65	2.53	2.43	7.34	6.35	6.24	3.99	3.91	4.12	145	160	145
pine	(c)	4.71	4.73	4.80	2.57	2.60	1.97	6.10	6.17	5.09	5.39	5.74	7.35	155	145	145
slash)	(d)	4.65	4.65	4.75	2.25	3.49	2.10	5.92	7.73	5.65	4.35	4.16	4.31	150	150	145
Av. Blk. 64[2]		4.72	4.70	4.80	2.59	2.64	2.20	6.57	6.37	5.83	4.57	4.48	5.25	172	151	146
Over-all Average[2]		4.71	4.69	4.82	2.65	2.68	2.34	7.07	6.91	6.25	4.51	4.53	5.32	169	155	155

[1] Blank spaces indicate no data available.
[2] Differences between treatments are not statistically significant.

The strikingly higher growth rate of the trees on block 59 as compared with those on block 64 warranted further consideration of the soil in the two areas. The difference in texture estimated in the field was confirmed by mechanical analysis of the surface soil (Table 7), and moisture equivalent determination of surface and subsoil (Table 8). The soil on block 59 was lower in sand content and higher in silt, clay, total colloids and moisture equivalent than was the soil on block 64. It was evident from field inspection that similar analysis of the B and C horizons would have shown corresponding differences between the two areas.

TABLE 7. MECHANICAL ANALYSIS[1] OF SURFACE SOILS (0-6 in. ±) QUADRUPLICATE SAMPLES—IN PER CENT

Block		Total Sands	Silt	Fine Clay <.002 mm	"Total Colloids" (Bouyoucos) <.05 mm
Block 45 (Merrimac loamy sand)		81.2	12.4	4.6	8.0
		84.2	9.6	5.5	8.1
		82.0	11.8	6.2	11.2
		80.4	13.4	6.2	9.6
	Av.	81.9	11.8	5.6	9.2
Block 59 (Manchester sandy loam)		73.8	19.5	7.7	10.4
		77.4	16.4	6.2	9.4
		79.4	14.0	6.2	8.8
		74.8	19.0	6.2	12.2
	Av.	76.3	17.2	6.6	10.2
Block 64 (Merrimac loamy sand)		84.2	10.8	5.0	8.5
		83.4	11.8	4.8	8.6
		83.2	11.8	5.0	9.3
		83.4	11.6	5.0	7.6
	Av.	83.5	11.5	4.9	8.5

[1] Bouyoucos Hydrometer method (1).

TABLE 8. COMPARISON OF THE AVAILABLE NUTRIENT CONTENT AND MOISTURE EQUIVALENT IN THE SUBSOILS OF MANCHESTER SANDY LOAM AND MERRIMAC LOAMY SAND

Depth	Block	Soil	NO_3-N ppm	P ppm	K m.e.[1]	Total Soluble Salts ppm	Moisture Equivalent per cent
6-12 in.	59	Manchester sl	4.5	6.6	0.85	250	7.6
	64	Merrimac ls	0.6	5.5	0.83	145	5.7
12-18 in.	59	Manchester sl	3.0	6.3	0.95	290	6.9
	64	Merrimac ls	0.6	3.4	0.65	145	5.6

[1] Milliequivalents per 100 g. of soil.

These physical differences are supported by certain chemical tests made on the 6 to 12-inch and 12 to 18-inch depths, as shown in Table 8. Here it is seen that NO_3-N, P, K and total salts are all noticeably higher in the soils on block 59 than in those on block 64.

Aside from these soil differences, several factors of an ecological character may have contributed to the variation in growth: first, the difference in the species and age of the pre-hurricane stands as indicated in the description of treatments and the greater accumulation of litter on block 59 and, secondly, the proximity of a locust stand adjoining block 59. Although prevailing winds probably tended to blow most of the locust litter away from 59, the possibility of a beneficial effect from such litter cannot be ignored.

DISCUSSION

The limited growth response to slash treatment is in striking contrast to the results obtained in the previously mentioned Pack Forest investigation. It indicates a probable difference in soil characteristics and, perhaps, in other environmental factors that have not been apparent. Some of their recent findings (6) help to explain the variable results obtained at Rainbow. In their work Heiberg and White found that the response of trees to slash was due, not to better moisture relations or other physical improvement of the soil, but rather to potassium released by the slash. Only the slash from productive stands was effective, however. That grown on the same poor site had very little effect. They also tried fertilizers and found that only those supplying K (60 to 180 lbs. of K_2O per acre) were significantly effective. Nitrogen caused but mild response. Red pine tree needles on the plots receiving potash fertilizer, or good slash, or humus, analyzed 0.45 to 0.74 per cent K, while those not so treated usually contained less than 0.30 per cent.

In referring to the growth data, Figure 3, it is observed, first, that slash was not beneficial to red pine on the Clark Lot. Two factors are probably responsible, viz., (a) growth on this lot was generally more satisfactory than on the other three blocks, due to a finer textured subsoil and shallow water table (7), and (b) the slash was produced on the same area. The fact that half of the trees used as slash had previously been fertilized did not seem to alter the picture. A third factor may have a bearing, namely, the species involved. In this case both the slash and trees under which it was placed were red pine. This species and Scotch pine (the latter referred to below) are two of the less exacting species, and the ash analysis of their wood is lower than that of white pine and Norway spruce (3, 9).

A second observation is that growth of white pine on block 45 was benefited by *white pine* slash that was *produced in another area* of somewhat better soil—two factors which make for improved growth.

A third observation helps to explain the differences in slash effect on blocks 59 and 64. In both cases the slash used had been grown on the site. However, that on 59 was white pine and, as revealed by the soil studies, the soil was better than average for the plantation. The slash on 64 was Scotch pine, and the soil average or below that of the plantation as a whole. Had white pine slash from 59 been carted over to 64, and vice versa, the differences reported in Table 2 would possibly have been reversed.

Although the field work of this experiment was terminated in 1947 and the land has passed out of the hands of the Station, some of the plots had undergone little or no disturbance by the early spring of 1951. Observations at that time indicated that the breakdown of the slash had been fairly complete, as shown in Figure 4.

Figure 4. The same slash plot on block 59 as that shown in Figure 1, but photographed 9 years later. Note the small amount of slash left on the ground. March 1951.

The favorable effect of "reisigdüngung" on the physical condition of the soil, as reported by Fabricius (5), was the result of 50 years of such treatment. What the effect was on the chemical composition and tree nutrition is not known. His best treatment in the shrub removal experiment was obtained where he added material produced on another area. To what extent the better results were due to the character and source of this added material can only be surmised from the information available.

With respect to soil fertility and nutrient intake in this slash study at Rainbow, direct application of fertilizers was not tried (aside from the ineffective previous treatments on part of the Clark Lot). However, in a nutrition experiment[1] in another part of the plantation, on similar soil, an attempt had been made some years back to increase growth rate of red pines (spaced 6′ by 12′) by treating individual trees, 6 to 8 feet in height, with various fertilizer combinations. The potassium treatment consisted of muriate of potash applied at the rate of about 118 pounds of K_2O per acre (based on a 6′ by 6′ spacing), in conjunction with nitrogen (NK), nitrogen and phosphorus (NPK), or the same with lime (LNPK).

Measurements over the seven-year period showed that in most instances only the treatments containing potassium were beneficial; but in all cases the increases were small, not exceeding 11 per cent in height, or 12 per cent in

[1] Unpublished except for brief mention in the Director's Report (4).

DBH. The inclusion of a peat moss mulch with one of the NPK treatments favored diameter growth slightly.

Analysis of the needles on two separate samplings indicated a modest but significantly higher K content wherever a potash fertilizer was included.

This is shown in the following data:

	K in % of dry matter		*K in % of ash*	
Treatments	*Current needles*	*1 year old needles*	*Current needles*	*1 year old needles*
Without P or K	Av. 0.30	0.24	17.4	12.3
NP, NPK, LNPK, or NPK plus peat moss	Av. .40	.31	23.0	16.7

These differences are less than those reported by Heiberg and White (6).

Soil analyses of the A horizon on untreated plots, obtained on other occasions in the Rainbow Plantation, showed an exchangeable K content (displaced by ammonium acetate), averaging 18 ppm (0.046 m.e. per 100 g. of soil), which is somewhat higher than in the untreated Pack Forest plantation soil (6). In the later work untreated plots averaged about 14 ppm of K, and those receiving K fertilizer or good slash about 22 ppm. Thus, the poor response to slash at Rainbow can be ascribed to two known factors: (a) better growing conditions due to the somewhat higher content of available K in the soil and a slightly higher rainfall (42 inches cf. 39 in Pack Forest); and (b) the difference in source of slash. Had slash been obtained from a better soil it is possible that the results would have been different.

The beneficial effect of burning on growth of white pine in this work and on red pine in another study (11) confirms similar findings by others (2, 15). These investigators have found that the beneficial effect is probably due to the increase in available nutrient content of the soil as a result of burning. On the other hand, Bruce's (2) findings that growth was greater on burned plots were attributed by him, not to any differences in soil as a result of burning, but rather to the control of brown spot needle blight [*Scirrhia acicola* (Dearn.) Siggers]. His study showed no significant differences in growth obtained on two soil types.

It is the experience, no doubt, of all foresters and forest soils investigators that in some situations forest trees, particularly pines, are very unresponsive to differences in fertility level. In other situations the same species respond relatively well (9). In certain studies carried on in southern New England (8, 10), soil has had seemingly less effect than have other factors of the environment, particularly moisture supply (in those instances where better moisture conditions are not reflected in the soil type, or at best only slightly so). In the present study the subsoil and substratum of the Manchester sandy loam were definitely more moist as well as being of heavier texture than were those of the Merrimac loamy sand. Bruce (2) states that in his studies in Mississippi and in Florida ". . . differences in soil conditions may outrank all other influences on longleaf height growth".

Just as response to slash mulch may be uncertain, likewise it is not always possible to predict growth rate on different soils or on the same soils with variable treatment. Obviously, where all other conditions are equal, the growth rate will be governed by soil fertility and/or soil moisture or certain other soil characteristics. Soil fertility is seldom independent of moisture, organic matter content, microbiological activity, soil structure and consistence, for example. Likewise, variations in other environmental factors, such as light, temperature, competition and so on, have a definite effect on the soil environment, and their evaluation in terms of tree growth can be very difficult. Nothing short of the complete picture, including knowledge of the source of plant stock, will suffice in any attempt to evaluate a given site.

SUMMARY AND CONCLUSIONS

This work was done on the sandy soils (Merrimac loamy sand and one block of Manchester sandy loam) in the Rainbow Plantation. On one block a mulch consisting of freshly cut 7-foot trees thinned from a red pine plantation was placed between and under the remaining trees. On another block green white pine slash obtained from another part of the plantation was spread between four-foot white pine trees. On a third block dead white pine slash and on a fourth, dead Scotch pine slash, each used on the land on which it was produced, were added to certain plots and burned on other plots prior to planting with white pine and Norway spruce. Survival counts (on the new plantings), tree growth and several soil studies were made over a period of three to six years. No provision was made for direct comparisons between green and dead slash.

1. Survival of white pine and Norway spruce was essentially unaffected by treatment, although in one case Norway spruce survival was reduced about 20 per cent by slash.

2. The effect of slash on growth appeared to be dependent upon kind and source of slash, and species so treated.

   a. Red pine slash produced on the same site was not beneficial to a red pine stand.

   b. White pine slash introduced from a nearby area increased growth of white pine trees about 13 per cent over a 6-year period.

   c. On the Manchester sandy loam block, white pine slash applied to the land on which it was produced resulted in about a 13 per cent increase in growth of white pine and Norway spruce in 5 years.

   d. Scotch pine slash applied to the land on which it was produced (Merrimac loamy sand) had no effect on white pine and Norway spruce growth.

The probable explanation of the foregoing results is as follows: (a) red pine is less exacting than either white pine or Norway spruce; (b) red pine and Scotch pine slash, being lower in nutrient content because of the lower requirements of those species as compared with white pine and spruce, add less nutrients; and (c) slash produced on poor soil and on the same area is less effective than that grown on another area of more fertile soil.

3. Burning the slash before planting favored white pine growth by 17 to 18 per cent, but not Norway spruce.

4. The growth rate of white pine greatly exceeded that of spruce.

5. Norway spruce trees on Manchester sandy loam grew about twice as fast as those on Merrimac loamy sand, due to differences in soil type and associated properties.

6. Soil tests indicated that available potassium and total soluble salt contents were slightly higher under slash and considerably higher where slash was burned. When the soils were incubated, slash favored ammonification somewhat, and burning increased available phosphorus slightly.

This work confirms findings elsewhere that on this kind of soil and in this climate, benefits from a slash mulch are chiefly nutritional rather than physical, and that the kind and source of the slash has an important bearing on its effectiveness. These results and those of other experiments on Merrimac soil point to potassium as the element largely responsible for increased tree growth.

The rather modest benefits of slash mulches at the Rainbow Plantation were in striking contrast to the pronounced growth increases in the Pack Forest experiment in New York State, previously mentioned. Growth records and soil tests indicated that the Rainbow soil was not as deficient in plant nutrients, particularly potassium, as was the Pack Forest soil. Differences in source of slash, in rainfall, and possibly in previous land use are other contributing factors.

There is evidence that burning of slash has a favorable effect on growth, at least temporarily.

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