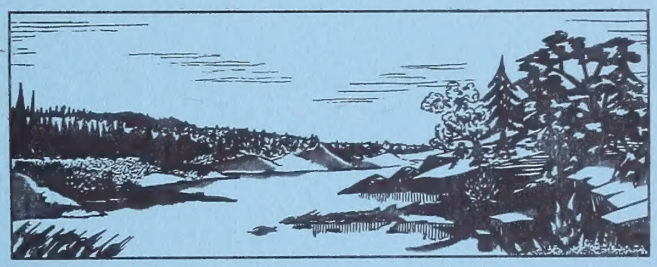
STATION PAPER NO. 17 MAY 1949

CONTROL OF WEEDS IN CONIFER NURSERIES BY MINERAL SPIRITS

J. H. STOECKELER



DIVISION OF FOREST MANAGEMENT

LAKE STATES FOREST EXPERIMENT STATION

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U. S. Department of Agriculture, Forest Service
Lake States Forest Experiment Station 1/

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INTRODUCTION

Weeding in forest nurseries is an expensive operation, especially in first-year conifer seedbeds where mechanical cultivation equipment is not very practical until the tender seedlings are about 1.0 to 1.5 inches high and have developed fairly tough stems. It may cost over $150 per acre for one early-season hand weeding, while the same job can be accomplished for $20 to $25 per acre by use of "mineral spirit" 4/ sprays which can kill weeds without killing the coniferous trees. Most broadleaf tree species, however, are reported to be injured or killed by the mineral spirits.

Previously, stove oil had been used as a selective herbicide in crops of carrots (1) and with some success in guayule seedbeds (8) and in conifer nurseries. The chief drawback seemed to be the wide variation in weed-killing ability of different batches or brands of stove oil.

Within the past few seasons, experimental work has shown that mineral spirits give good weed control in conifer nurseries (3, 2, 6). A number of different mineral spirits have been used. In many cases the products are very similar chemically and about equal in weed-controlling ability. Among such products reported successful are those known to the trade as Stoddard Solvent, Sovasol No. 5, Stanisol, Varsol, and Sohio Weed Killer. Others may be as effective. The important consideration seems to be uniform aromatic content of at least 10 percent and preferably 15 to 20 percent.

1/ Maintained at University Farm, St. Paul, Minnesota, in cooperation with the University of Minnesota.

2/ Credit is due E. R. Stoltz and M. L. Heinselman of the Lake States Forest Experiment Station for aid in collecting and summarizing the field data.

3/ Forester, Northern Lakes Forest Research Center, Lake States Forest Experiment Station, Rhinelander, Wisconsin.

4/ The mineral spirits are of napthenic origin and usually have an aromatic content of 10 to 20 percent. They were first used by truck farmers about 5 or 6 years ago as sprays in fields of carrots, parsnips, and other crop species of the carrot family (5). Recently they have been used as selective herbicides in Wisconsin cranberry marshes.

U. S. Department of Agriculture, Forest Service
Lake States Forest Experiment Station 1/

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CONTROL OF WEEDS IN CONIFER NURSERIES BY MINERAL SPIRITS 2/

J. E. Schoenicker 3/

INTRODUCTION

Weeding in forest nurseries is an expensive operation, especially in first-year conifer seedbeds where mechanical cultivation equipment is not very practical until the conifer seedlings are about 1.0 to 1.5 inches high and have developed fairly tough stems. It may cost over $100 per acre for one early-season hand weeding, while the same job can be accomplished for $40 to $55 per acre by use of "mineral spirits" 4/ sprays which can kill weeds without killing the conifer stems. Most broadleaf trees species, however, are reported to be injured or killed by the mineral spirits.

Previously, stove oil had been used as a selective herbicide in crops of carrots (1) and with some success in growing meadows (2) and in conifer nurseries. The chief drawback seemed to be the wide variation in weed-killing ability of different batches, or brands of stove oil.

Within the past few seasons, experimental work has shown that mineral spirits give good weed control in conifer nurseries (3, 5, 6). A number of different mineral spirits have been used. In many cases the products are very similar chemically and about equal in weed-controlling ability. Among such products reported successful are those known to the trade as Stoddard Solvent, Mineral No. 5, Stanisol, Varsol, and Sohio Weed Killer. Others may be as effective. The impurity concentration seems to be uniform aromatic content of at least 10 percent and preferably 15 to 20 percent.

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EXPERIMENTS IN WISCONSIN NURSERIES

To test several weed killers in nursery beds of different species, a number of experiments were run in Wisconsin nurseries during 1947 and 1948.

Results of 1947 Tests

In 1947, a preliminary trial was made at the Hugo Sauer Nursery, Rhinelander, Wisconsin, to test the effectiveness of such products as No. 1 burner oil, Stoddard Solvent, Sovasol No. 5[5], Weedone[6], and Esteron 44[6]. Burner oil gave rather poor weed control at full concentration or emulsified at a ratio of 1 to 3 with water, whereas Weedone and Esteron 44 caused moderate to severe mortality of the trees. With dosages as low as 70 to 80 gallons per acre (7), the two mineral spirit products, Stoddard Solvent and Sovasol No. 5, killed slightly over 90 percent of the weeds on beds of first- and second-year red pine and third-year white spruce. These materials were applied full strength with a 3-gallon continuous-pressure garden sprayer.

The weed kill was better where weeds were small. The weeds began to droop slightly and changed color within two or three hours after treatment. After 24 hours, most of the thin-leaved, succulent weeds had turned gray to light brown in color and were dead. In hot weather the reaction was more rapid. Some of the more persistent weeds lasted as much as a week before dying. Some species, notably Canada thistle, purslane, and rye (when large), and quack grass were killed only partially (5 to 30 percent or less) or not at all.

Dosages of over 120 gallons per acre injured second-year red pine by causing a pink and later a brown discoloration near the base of the needles, just above the leaf sheath, apparently due to collection of small droplets of the weed killer at that point. By the end of the year the injury had largely disappeared, without causing any detectable difference in seedling survival or size.

Observations in April 1948 in red pine beds treated the previous summer as 1-0 stock showed very deleterious effects of the 2, 4-D products on both stand and seedling size (treatments 2 and 3 in table 1). The burner oil was not harmful to the trees, but was rather ineffective in weed control. The mineral spirits (treatments 5 and 6) caused only minor needle damage.

Second-year red pine beds similarly treated showed considerable mortality from Esteron, but only minor losses from the other three treatments. The Weedone, however, stunted growth of the pine. In April 1948, the percent of needles showing basal lesions caused by Stoddard Solvent and Sovasol was 18 and 30 percent respectively for dosages of 144 and 216 gallons per acre of the two treatments. By the fall of 1948, these trees had largely recovered.

5/ Mineral spirits.
6/ 2, 4-D products.

EXPERIMENTS IN WOOD KILL WEATHERING

To test several wood killers in nursery beds of different species, a number of experiments were run in Wisconsin nurseries during 1947 and 1948.

Results of Last Tests

In 1947, a preliminary trial was made at the Hugo Sauer Nursery, Kinglander, Wisconsin, to test the effectiveness of such products as No. 1 burner oil, Stoddard solvent, Sovasol No. 5[1], Woodsage[2], and Esteron 44[2]. Burner oil gave rather poor weed control at full concentration or emulsified at a ratio of 1 to 3 with water, whereas Woodsage and Esteron 44 caused moderate to severe mortality of the stems. With dosages as low as 70 to 80 gallons per acre (V), the two mineral spirit products, Stoddard Solvent and Sovasol No. 5, killed slightly over 90 percent of the weeds on beds of first- and second-year red pine and third-year white spruce. These materials were applied full strength with a 3-gallon continuous-pressure garden sprayer.

The weed kill was better where weeds were small. The weeds began to droop all dirty and changed color within two or three hours after treatment. After 24 hours, most of the thin-leaved, succulent weeds had turned gray to light brown in color and were dead. In hot weather the reaction was more rapid. Some of the more persistent weeds lasted as much as a week before dying. Some species, notably Canada thistle, pursiane, and rye (wild large), and quack grass were killed only partially (5 to 30 percent or less) or not at all.

Dosages of over 120 gallons per acre injured second-year red pine by causing a pink and later a brown discoloration near the base of the needles, just above the leaf sheath, apparently due to collection of small droplets of the weed killer at that point. By the end of the year the injury had largely disappeared, without causing any noticeable difference in resulting survival or size.

Observations in April 1948 in red pine beds treated the previous summer as 1-0 stock showed very deleterious effects of the 2, 4-D products on both stand and seedling size (treatments 2 and 3 in table 1). The burner oil was not harmful to the trees, but was rather ineffective in weed control. The mineral spirits (treatments 5 and 8) caused only minor needle damage.

Second-year red pine beds similarly treated showed noticeable mortality from Esteron, but only minor losses from the other three treatments. The Woodsage, however, stunted growth of the pine. In April 1948, the percent of needles showing basal lesions caused by stoddard solvent and sovasol was 12 and 30 percent respectively for dosages of 144 and 216 gallons per acre of the two treatments. By the fall of 1948, these trees had largely recovered.

1/ Mineral spirits.
2/ 2, 4-D products.

Table 1.--Comparative damage caused by various weed killers in beds of first-year red pine, and effect on size as 2-0 stock 1/

Treatment	Needles showing damage	Trees killed by treatment	Total weight of 100 2-0 trees	Remarks
	Percent	Percent	Ounces	
1. Check.....	0.0	0.0	9.35	
2. Weedone.....	92.0	27.0	4.70	Not suitable
3. Esteron 44.....	100.0	40.0	2.25	Not suitable
4. No. 1 Burner Oil	0.6	0.0	8.15	Tree damage very light, but weed kill was poor.
5. Stoddard Solvent	3.2	0.0	8.85	Treatment appears promising.
6. Sovasol No. 5....	3.4	0.0	10.40	Treatment appears promising.

1/ Treated July 17, 1947. Observations for injury and mortality are for April 28, 1948. Weight data was recorded in October 1948.

Third-year spruce treated the same way showed more resistance than red pine to injury by Weedone and Esteron and practically no injury from the mineral spirits which were applied at the rate of 120 or more gallons per acre.

A lot of red pine given the same treatments as 2-0 stock showed a marked reduction in tree stand by the fall of 1948. Sizes of surviving trees were reduced 26 and 43 percent respectively by Weedone and Esteron. The average size of the 3-0 trees treated with Stoddard Solvent and Sovasol No. 5 was slightly better than in the check plots, but not significantly so.

Experiments in 1948

In 1948 more detailed experiments were run at Hugo Sauer Nursery and Griffith State Nursery in Wisconsin. They were designed to test more accurately the toxicity of mineral spirits in relation to species and age class of trees and season, weather conditions, watering, and shade. These tests included several experiments, each of which contained 4 to 7 treatments, usually replicated four times. Weed counts were made before treatment and usually about a week after treatment. Tree counts were also made before treatment and about 10 to 30 days after treatment so that possible adverse effects of the mineral spirits would have time to show up. Notes were made at frequent intervals to observe progress of tree damage or recovery.

Accurate experimental control was deemed desirable because much of the work done to date with mineral spirits in forest nurseries has been of an observational or empirical nature. Past experience with several thousand nursery

Table 1.--Comparative injury caused by various wood killers in beds of first-year red pine, and effect on mice in 2-0 stock 1/

Treatment	Medium showing damage	Trees killed by treatment	Total weight of 100 2-0 trees	Remarks
	Percent	Percent	Grams	
1. Check.....	0.0	0.0	8.35	
2. Woodtone.....	98.0	87.0	4.70	Not suitable
3. Esteron 44.....	100.0	40.0	3.55	Not suitable
4. No. 1 Burner Oil	3.6	0.0	8.15	Trees damage very light, but weed kill was poor.
5. Stoddard solvent	3.3	0.0	8.55	Treatment appears promising.
6. Soresol No. 5....	3.4	0.0	10.40	Treatment appears promising.

1/ Treated July 17, 1947. Observations for injury and mortality are for April 28, 1948. Weight data was recorded in October 1948.

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A lot of red pine given the same treatments as 2-0 stock showed a marked reduction in tree stand by the fall of 1948. Size of surviving trees were reduced 35 and 45 percent respectively by Woodtone and Esteron. The weight size of the 2-0 trees treated with stoddard solvent and Soresol No. 5 was slightly better than in the check plots, but not significantly so.

Experiments in 1948

In 1948 more detailed experiments were run at Mapo Sheet Nursery and Griffith Co. Nursery in Alexandria. They were designed to test more accurately the toxicity of mineral spirits in relation to species and age class of trees and season, weather conditions, watering, and shade. These tests included several experiments, each of which consisted of 4 to 7 treatments, usually replicated four times. Good results were made before treatment was usually about a week after treatment. Tree counts were made before treatment and about 10 to 30 days after treatment to test possible adverse effects of the mineral spirits would have time to show up. Notes were made at frequent intervals to observe progress of tree injury or recovery.

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experimental plots had shown the difficulty of defecting rather uniformly distributed losses of 10 to 20 percent in stand, particularly from treatments designed as soil amendments or weed or seed control, in trees just starting to emerge from the soil, unless one relies on counts rather than observation. A nursery seedling crop usually has a value of $3,000 to $8,000 per acre, and a shrinkage in production of as low as 5 to 10 percent obviously represents a serious loss.

In the 1948 trials the sprays were accurately measured out with a graduate to the nearest cubic centimeter and applied quite uniformly as a fine mist with a 2-quart hand sprayer.

The spray material used was Stoddard Solvent containing 10.8 percent of aromatic hydrocarbons, with an initial boiling point of 314° F., an end point of 389°F., A.P.I. gravity of 48.9, and specific gravity of 0.784.

At the time of spraying, the individual plots were shielded with cloth barriers to prevent drifting of the spray onto adjoining plots.

Effect of Sprays on Weeds

From May 19 to 21, 1948, four sets of experiments were conducted at Hugo Sauer Nursery to compare weed kill and tree species reaction in (1) first-year red pine; (2) first-year white spruce, (3) second-year white spruce, and (4) white spruce transplants age 3-1. Before spraying there were about 5 weeds per square foot.

The weed kill in these four separate tests was quite variable, depending on weed species and size (table 2). Larger weeds and grass-like plants proved relatively difficult to kill.

In trial 1, weeds were about 60 percent rye, averaging 4 inches high, with other weeds only about 1 inch high. The rye proved rather hard to kill with light dosages.

In trial 2, about 38 percent of the weeds were rye, averaging 4 inches high. Nongrass weeds averaging 0.8 inch high were killed readily by low dosages.

In trial 3, the weeds were practically all rye, averaging perhaps 3 to 5 inches high.

In trial 4, weeds were practically all nongrasses, averaging 2 inches high.

Subsequent tests at Griffith State Nursery on June 15 and 16, 1948, showed a much greater kill on weeds usually under 1 inch in size, with the intermediate range of treatments (table 3). Spraying 50 gallons per acre of Stoddard Solvent reduced the weed stand 90 percent. A similar dosage on larger weeds reduced them by only 44 percent.

Later experiments repeatedly verified the results of these trials as regards kill in relation to size of weeds. It seems safe to say that spraying with mineral spirits kills 90 to 95 percent of the common weeds found in Wisconsin nurseries if applied when the weeds are less than 1 inch in height or spread.

Table 2.--Effect of Stoddard Solvent on weeds in four trials made May 19 to 21, 1948, at Hugo Sauer Nursery, Wisconsin

Stoddard Solvent applied per acre	Increase or decrease in weed stand after one week				
	Trial 1	Trial 2	Trial 3	Trial 4	Average
Gallons	Percent	Percent	Percent	Percent	Percent
0	+12	+ 8	+15	+ 4	1/ + 10
50	-24	-67	-45	-38	- 44
75	-36	-76	-64	-57	- 58
100	-48	-80	-83	-70	- 70
125	-64	-84	-78	-84	- 78
150	-74	-89	-85	-86	- 84

1/ Note increase in weed stand in check plots. Weed stand before treatment averaged about 4, 6, 3, and 7 weeds per square foot respectively in trials 1, 2, 3, and 4.

Table 3.--Reduction in weeds where average height was less than 1 inch. Sprayed with Stoddard Solvent. Griffith State Nursery, Wisconsin. Sprayed June 15-16, 1948.

Treatment per acre	Increase or decrease in weed stand after one week
Gallons	Percent
0	1/ +190
40	- 77
50	- 90
75	- 95
100	- 95

1/ Note marked increase in weed stand in check plots. These results of the test indicate a pre-emergent kill of sprouting weed seeds.

Tree Species and Age Class Reaction to Mineral Spirits

The adverse effects of oil sprays based on tree counts were rated by two major categories, i.e., (1) mortality or decrease in stand, and (2) injury as exhibited by needle burning. The latter usually comprised all injury, including that deemed recoverable. In instances where one-third or more of the needle area had been killed or where the tree had been severely set back in growth, injury was classed as severe. Treatments with mortality over 5 percent are particularly suspect because this represents an irretrievable loss, whereas slightly injured trees have considerable chance of recovery.

The 1948 experiments showed conclusively that some species, notably white spruce, were more subject to injury than jack or red pine. The damage on white spruce was especially noticeable in first-year seedbeds sprayed late in May. Both the stand and the size of trees were affected adversely by the oil sprays. Here actual tree mortality ranged from 19 to 62 percent, depending on dosage level (table 4). Based on counts before and after spraying, about 32 percent of the seedlings in the four heavier treatments died the first week because of the oil spray. Losses in the 50-gallon treatment did not occur so quickly.

Three other age classes of trees (1-0 red pine, 2-0 red pine, and 3-1 white spruce) sprayed at the same time as the first-year white spruce on May 19 to 21 showed no significant loss. However, some trees were injured, especially in the heaviest treatment of 150 gallons per acre.

On first-year red pine treated with the 150-gallon dosage, no mortality was attributable to the oil sprays. The percent of the trees which showed injury, largely as lesions on the tender stems or reddish spots on the cotyledons, were 0.2, 0.5, 3.3, 3.4, and 5.3 percent respectively for the 50, 75, 100, 125, and 150-gallon-per-acre treatments. These recovered almost completely by the end of the season.

Results on second-year white spruce and 3-1 white spruce were not quite so regular in trend, but indications are that treatments of about 75 gallons per acre will give good weed control with negligible injury--usually 2 or 3 percent or less of the trees. In the case of white spruce, the injury with heavier treatments showed up in the terminal buds which were either inhibited from forming or if already formed, turned dark brown and died in some 5 to 10 percent of the plants. New growth was more sensitive to oil burning than older needles.

On treatments of jack and red pine made in mid-June or later, heavier treatments (over 100 gallons per acre) usually caused the foliage to turn yellowish green. Severely damaged needles later turned brown and died.

Jack pine treated with about 100 gallons per acre of Stoddard Solvent often turned light green, indicating some interference with normal metabolism. After 3 to 4 weeks the normal green color returned, with apparently no adverse effect on size of trees.

First-year white pine, balsam fir, and white spruce sometimes reacted somewhat like jack pine in color change, although not so strikingly because of their lesser foliage growth. The new growth on conifers seems to be especially susceptible to damage from the sprays. Older needles show less injury than new ones.

Table 4.--Stand and survival in beds of first-year white spruce treated with various amounts of Stoddard Solvent on May 21, 1948 1/

Treatment per acre	Trees per square foot on June 28	Stand compared with check plot
Gallons	Number	Percent
0	58.5	100.0
50	47.5	81.0
75	41.5	71.0
100	37.2	64.0
125	26.0	44.0
150	22.4	38.0

1/ Trees averaged 0.5 inch high and germination was about 75 percent complete. The day was bright and sunny, with air temperature in the shade about 70° F.

First-year white pine and balsam fir are subject to injury with dosages of 75 gallons or more per acre, especially before the true needles have formed and where beds are unshaded.

As the season progresses, some tree species become more resistant to the action of Stoddard Solvent. For instance, first-year beds of white spruce sprayed on June 25 showed practically no mortality from dosages of 50 to 125 gallons per acre. However, the 150-gallon-per-acre treatment caused 7.6 percent mortality. First-year red pine sprayed on June 14 was uninjured by sprays of 50 or 75 gallons per acre, and only 0.5 percent were injured by dosages of 100 to 150 gallons per acre.

All these results indicate that less damage is incurred in first-year beds from spraying in summer rather than in late May when the plants are quite succulent or just emerging from the soil.

Other species on which oil sprays were tried included first-year mugho pine, Austrian pine, Scotch pine, eastern white pine, balsam fir, and blue spruce. Dosages of 50 to 75 gallons per acre were generally quite successful except on blue spruce, which showed some late-season mortality when treated with 40 gallons per acre.[7]

Of all the species and age classes tested in 1948, two spruces (white and blue) were particularly subject to injury or death from the mineral spirit sprays applied in the first half of the growing season on first-year beds, especially when the seedlings were just emerging from the ground. Nurserymen should, therefore, proceed with utmost caution in use of oil sprays on spruces at this period of their development. Dosages as low as 25 to 35 gallons per acre may be necessary. Some additional precautions will be mentioned later.

Effect of Repeated Sprayings

Previous results had shown repeatedly that satisfactory weed control could be obtained with use of Stoddard Solvent, but there was some question as to possible harm to trees from repeated use of mineral spirits. No tests were made in these experiments on residual effects on the soil. However, according to W. H. Lachman,[8] Assistant Research Professor at Massachusetts State College, no damage or harmful residual effects were observable after five years' use of mineral spirits in experiments with carrots and parsnips.

Low-grade oils of a higher viscosity and with fairly high asphaltic residue have been used for 20 years in citrus groves in California without ill effects, according to W. A. Harvey of the Division of Botany, University of California.[9] Apparently with lighter oils, such as furnace oil, stove oil, or mineral spirits which volatilize readily and leave very little residue, chances of residual bad effects are negligible and no adverse soil effects are anticipated from use of mineral spirits in forest nurseries.

7/ According to observations by Howard Anderson, Nursery Superintendent at the Nekoosa-Edwards Paper Company nursery.
8/ Information via correspondence.
9/ Personal correspondence.

No experiment at Hugo Sauer Nursery included more than three sprayings with Stoddard Solvent. First-year red pine and 3-1 white spruce successfully withstood three treatments without apparent loss. In the first-year red pine, the initial spray was applied on May 19, when the stand usually had from 10 to 12 trees per square foot and was still germinating vigorously. The seed coats were still adhering to the cotyledons. Eight days later the stand had increased to about 40 trees per square foot with no apparent mortality (table 5). The beds were again sprayed on June 14 and July 29. By the end of the season the loss in stand from June 14 to October 15 ranged from 2.6 to 3.1 trees per square foot for sprayed plots while the check plots had a loss of 2.9 percent. No adverse effect on tree size was noted at the end of the season. In fact, the treated pines were slightly larger than those in check plots.

Among first-year white spruce, on the other hand, losses were heavy, especially from the early applications (table 6). Almost 40 percent mortality occurred in plots receiving 75 gallons or more of Stoddard Solvent per acre. Mortality caused by the second application was negligible, indicating a marked increase in resistance to the oil by that time. The "normal" mortality from factors other than mineral spirits was about 10 trees per square foot on the check plots. The loss in the 50-gallon-per-acre treatment was a little more. Losses in the beds treated with 75 gallons or more per acre were two to three times as high as in the check plots, indicating that dosages of 75 gallons per acre are too high, at least for the May sprayings.

Average size of the 1-0 spruce trees was reduced by as much as 30 percent, and all oil treatments of 50 gallons per acre or over caused a marked reduction in weight of the trees. This contrasts with first-year red pine which was actually improved in size by the oil sprays.

The mortality of 3-1 white spruce transplants sprayed on May 20, July 13, and September 2 was 0.5, 0.5, 1.4, 0.4, and 0.5 trees per square foot for the 50, 75, 100, 125, and 150-gallon per-acre treatments, respectively. The mortality in check plots was 0.8 tree per square foot on spruce transplants, but the problem in connection with spraying is not tree mortality, but bud injury, especially with treatments of more than 75 gallons per acre. Size of trees in sprayed plots at any level of spray treatment was as good as or better than that in check plots.

There was no undue mortality in second-year white spruce seedlings sprayed on May 21 and July 13. With this age class the chief problem is avoidance of injury, especially a temporary chlorotic condition in the new needles on the leader. Dosages of 75 gallons or less per acre did not cause any appreciable chlorosis, and no reduction in size was noted with dosages of 125 gallons or less per acre.

First-year jack pine sprayed on June 14 and June 24, respectively, showed no consistent mortality from oil spray from dosages up to 150 gallons per acre. Size of trees in sprayed plots was equal or superior to that in check plots.

In two repeat sprayings made June 11 and July 29, on first-year red pine, there was no appreciable difference in mortality with dosages in the range of 50 to 150 gallons of Stoddard Solvent per acre, and tree injury was negligible in treatments of 100 gallons per acre or less. Trees in sprayed plots were larger than those in check plots.

Table 5.--Stand of first-year red pine before and after three separate applications of Stoddard Solvent 1/

Dosage per acre	First spraying			Second spraying			Third spraying			Loss in stand per sq.ft. since germination was complete 2/	Average fresh weight of 100 trees
	Stand per sq. ft.		Increase or decrease	Stand per sq. ft.		Increase or decrease	Stand per sq. ft.		Increase or decrease		
	Before spray	After spray		Before spray	After spray		Before spray	After spray			
Gallons	Number	Number	Percent	Number	Number	Percent	Number	Number	Percent	Number	Ounces
0	10.9	43.7	+301.9	39.9	38.7	- 3.0	38.7	37.0	- 4.4	2.9	2.40
50	11.8	39.7	+236.4	38.7	37.7	- 2.6	37.7	35.7	- 5.3	3.0	2.80
75	16.2	45.8	+282.7	42.5	40.7	- 4.2	40.7	39.5	- 3.0	3.0	2.55
100	12.7	37.1	+192.1	38.5	37.0	- 3.9	37.0	35.9	- 3.0	2.6	2.80
125	9.7	45.7	+371.1	38.8	37.3	- 3.9	37.3	36.2	- 3.0	2.6	2.80
150	10.4	36.9	+254.8	37.6	36.3	- 3.5	36.3	34.5	- 4.9	3.1	3.15

1/ Sprayed on May 19, June 14, and July 29. Counts were made on May 19 and May 27; June 14 and June 25; July 29 and October 15 respectively for the three sprayings; first spraying data based on one replication and for other two sprayings on all four replications.

2/ Comparing counts of June 14 and October 15.

Table 6.--Effect of two Stoddard Solvent treatments on first-year white spruce

Dosage per acre	Tree mortality per square foot			Average fresh weight of 100 trees
	First spraying May 21	Second spraying June 25	Total	
Gallons	Number	Number	Number	Grams
0	3.8	5.9	9.7	28.6
50	2.2	10.7	12.9	21.0
75	15.7	6.3	22.0	23.6
100	17.5	10.7	28.2	21.0
125	17.6	5.0	22.6	22.3
150	13.5	6.9	20.4	19.9

Repeat sprayings of 2-1 red pine made on June 11 and July 14 with 50 to 150 gallons per acre showed no significant tree mortality in any dosages. In the two heaviest treatments (125 and 150 gallons) some browning of the tips of the needles occurred and about 5 percent of the trees had dead terminal buds. By September 7, however, about 95 percent of the damaged trees had again formed new terminal buds.

No cumulative losses were incurred by any tree species in six or more tests where two to three repeat sprayings were made. White spruce alone showed considerable mortality largely due to an early spraying of May 21, when trees were just emerging from the soil. In this latter case, the size of trees at end of the growing season was considerably smaller in sprayed plots than in check plots. On practically all other tests, trees in oil-sprayed plots were equal or superior to those in check plots.

Repeat sprayings have the advantage that fewer weeds come up after spraying than in hand-weeded plots, thus leaving beds progressively cleaner as the season advances.

Pre-emergent Kill of Weeds and Weed Seed

As a check on possible pre-emergent kill of their seeds or newly germinated plants, all the weeds were removed by hand from a series of first-year jack pine beds on June 24, 1948. The beds were sprayed with Stoddard Solvent the next day, and weed counts were made on July 12 and again on July 27.

The results showed that mineral spirits, especially if applied in fairly heavy dosages (which give deeper penetration into the soil) kill a very high percentage of the more permeable weed seeds or newly germinated seeds which have not yet pushed through the soil. Dosages of 150 gallons per acre caused a reduction of 98.8 percent in weed stand (table 7), with the effects carried over for a full month. This also explains why repeat sprayings tend to leave progressively cleaner beds where oil spraying is used rather than hand weeding.

The results of this test indicate that mineral spirits can be applied profitably before there is an extensive visible stand of weeds. Properly leveled seedbeds, at least in late spring seedings, can be treated to advantage with heavy dosages of mineral spirits (perhaps 150 or more gallons per acre) several days before planting the conifer seed. In this way it appears possible to control weeds fairly well during the first month or so without risk of oil injury to the trees. After spraying, there should be little or no soil disturbance by leveling or raking in order to prevent bringing to the surface, soil from depths below the level of treatment penetration. Such soil still contains viable weed seeds.

Table 7.--Stand of weeds 32 days after treatment of hand-weeded seedbeds. Treated on June 25, 1948 with Stoddard Solvent.

Treatment per acre	Average weed stand per 4'x4' bed	Weed stand in relation to check plot
Gallons	Number	Percent
0	16.25	100.0
50	2.25	13.8
75	1.75	10.8
100	1.25	7.7
125	0.50	3.1
150	0.20	1.2

Effect of Overhead Irrigation on Reaction of Mineral Spirits

Since some damage to tree seedlings and transplants occurred at higher dosages, it was deemed desirable to determine how such damage might be minimized. One method which was investigated was the use of water on the beds before and after spraying with mineral spirits.

The first trial of watering of first-year jack pine immediately before application of 150 gallons per acre of mineral spirits caused maximum reduction in tree damage. The percent of trees injured was only 4.2, as compared with 21.4 percent where watering was done 1 to 2 hours in advance of the mineral spirit spray (table 8). The latter water application was apparently ineffective because of evaporation of the water before the oil spray was applied. Watering done just after the application of the weed killer was less effective than that done before spraying. Since most nurseries have overhead irrigation available, this may offer a way to minimize damage on sensitive tree species. It is apparent, however, that weed kill was not quite as good where watering was done before instead of after application of the weed killer.

Table 8.--Comparative damage by mineral spirits (Stoddard Solvent) in first-year jack pine treated on July 13, 1948, counted July 19, 1948

Treatment per acre	Time of water application	Effect on trees		Effect on weeds
		Injured per sq. ft.	Injured	Increase or decrease in stand after 6 days
Gallons		Number	Percent	Percent
150	Two hours before treatment	1/ 3.8	2/ 21.4	-71
150	One hour before treatment	5.1	21.4	-93
150	Just before treatment	0.7	4.2	-83
150	Just after treatment	2.3	12.1	-100
150	One hour after treatment	3.1	11.0	-100
150	Two hours after treatment	1.9	14.5	-100
0	Watered but not treated	...	....	+87

1/ Based on count of entire bed of 16 square feet replicated four times in each treatment.
2/ Based on counts of 2 square feet in each of four replications in each treatment.

A second test of the "cooling" principle was tried on first-year white spruce, on August 9. There was a reduction in tree mortality with dosages of 75 and 150 gallons, but it was not as contrasting as in the first-year jack pine beds.

A third trial, made on August 9, 1948, on first-year jack pine, indicated that watering just before application of Stoddard Solvent did not appreciably affect weed kill. Tree mortality was negligible in all cases. However, there was a very marked and consistent reduction in injury to the pine by watering just before treatment, there being usually only half as much damage as in unwatered beds (table 9). About half of the trees rated as damaged on September 7 still

showed injury as exhibited by foliage browning as late as October 4, 1948. Oil sprays of 150 gallons or less per acre showed no adverse effects on seedling size.

Table 9.--Effect of watering just before application of Stoddard Solvent on first-year jack pine. Treated August 20, 1948, counted September 7, 1948

Treatment per acre	All trees injured		Trees severely injured	
	Not watered	Watered	Not watered	Watered
Gallons	Percent	Percent	Percent	Percent
0	0	0	0	0
75	4.4	3.2	0.8	0.3
150	27.7	9.1	6.0	2.2
225	40.9	20.4	12.3	4.6

Effect of Shading and Low Light Intensity on Toxicity of Mineral Spirits

Does shading of beds reduce oil damage? To help solve this question, half of an area of first-year white spruce seedbeds was protected with half shade and a double layer of coarsely woven cotton cloth, and half was left unshaded. The beds were sprayed on July 14, 1948. Shading reduced oil injury to the trees (exhibited by foliage yellowing or browning and needle curling) from 29 to 80 percent for unshaded beds down to 2 percent or less for shaded beds (table 10). The mortality was slightly, but consistently lower in the shaded beds. Weed kill was practically complete in all treatments. No untreated plots were included in this test, so it is not known whether the 7.2 percent mortality in the 75-gallon-per-acre treatment (shaded) was partly attributable to normal or average mortality such as often occurs even in untreated beds. The important thing is that the value of shading in reducing oil injury is definitely established, even though the degree of shade used in the experiment was somewhat heavier than with the usual slat-wire snow fence used for half shade in large-scale operations.[10/] Excessive shade caused a reduction in fresh weight of trees, ranging from 32 to 53 percent. Since shading is a normal nursery practice on first-year seedbeds of white spruce, it therefore has additional merit in reducing oil injury.

10/ The shade used in this experiment was considerably heavier than the usual half shade used for spruce beds and more nearly simulated light conditions on a day with very heavy overcast or when raining. The average light intensity (Weston Meter) based on 8 readings at breast height under shade was only 16.0 percent of that in the open. Based on light as reflected from the soil, it was 15.6 percent.

Table 10.--Effect of shade on reaction of mineral spirits in first-year beds of white spruce, sprayed July 14, 1948

Treatment per acre	Mortality in trees 1/		Trees injured but still alive 2/		Weed kill 3/	
	Shaded	Not shaded	Shaded	Not shaded	Shaded	Not shaded
Gallons	Percent	Percent	Percent	Percent	Percent	Percent
75	7.2	9.4	2.1	39.7	100.0	99.3
150	2.4	10.6	0.0	29.1	100.0	100.0
225	9.7	10.8	2.1	80.3	100.0	100.0

1/ Counted July 12 and again on September 30, 1948.
2/ Counted July 12 and again on July 27, 1948.
3/ Counted July 12 and again on July 19, 1948.

Temperature and Other Weather Conditions as Factors in Toxicity of Mineral Spirits

So-called "oil burning" of the tree crop from use of mineral spirits appeared to be less prevalent on cool than on warm days. A bed of first-year jack pine consisting of 24 4x4-foot plots was sprayed on July 12 and 14 respectively, a warm and a cool day. The average air temperatures in the shade at instrument shelter height was 84° F. on July 12 and 77°F. on July 14. The former was an overcast day, and the latter was bright and sunny.

The percent of trees showing oil injury was strikingly and consistently higher on the warmer day (table 11). The actual tree mortality was rather negligible and had no apparent significance. Nor did any significant differences show up in weed kill as between the two days. However, the weed kill with only 50 gallons per acre (as was the case in some other tests) was rather mediocre.

Table 11.--Comparison of reaction of mineral spirits on trees and weeds on cool and moderately warm day. Trees were first-year jack pine, sprayed July 12 to 14, 1948.

Treatment per acre	Trees showing oil injury		Increase or decrease in tree stand		Decrease in weeds	
	Cool day	Warm day	Cool day	Warm day	Cool day	Warm day
Gallons	Percent	Percent	Percent	Percent	Percent	Percent
50	2.7	6.6	-0.7	-2.1	-43.0	-32.0
100	2.2	23.7	+0.4	-3.0	-94.0	-93.0
150	2.1	51.5	-1.7	-0.3	-67.0	-86.0

The air temperature in the open at a height of one inch above ground was 91° F. and 84°F. respectively on the warm and cool days. It is rather surprising that differences were so contrasting in tree injury. No adverse effect was observed in seedling weight at end of the season from oil treatments of 100 gallons or less per acre.

Results of a second trial made on first-year jack pine, attempting to appraise temperature as a factor, did not result in sharp differences, and there was some indication that intensity of sunlight, humidity, and the hour of spraying may have affected the rate of penetration or of evaporation of the mineral spirits and its resulting injury.

Comparison of Results in Day Versus Night Spraying

The effect of day versus night application of mineral spirits was the subject of tests run on August 20, 1948, in first-year jack pine beds. The air temperature was 80° F. in the day, and 70°F. in the evening.

The results showed a very marked and consistent reduction in needle browning with night spraying. In the 150-gallon-per-acre treatments, the percent of trees showing injury was 22.2 percent and 1.3 percent respectively for day and night spraying. At a 75-gallon-per-acre treatment it was 4.6 and 0.6

percent respectively (table 12). The total weed kill was almost identical in the day and night sprayings, but there were so few weeds as to make results in weed kill inconclusive.

Table 12.--Comparative injury and mortality in first-year jack pine beds treated with mineral spirits on August 20, 1948

Treatment per acre	Trees injured by oil spray				Increase or decrease in tree stand	
	All injury		Severe injury		Day	Night
	Day	Night	Day	Night		
Gallons	Percent	Percent	Percent	Percent	Percent	Percent
0	0.0	0.0	0.0	0.0	-2.0	-3.5
75	4.6	0.6	0.6	0.3	-2.3	0.0
150	22.2	1.3	5.2	0.3	-1.2	-1.2

Tree mortality, amounting to only a few percent, showed no consistent differences between day and night spraying. Mortality was about equal in check plots and in treated plots, indicating that in midsummer of the first year, jack pine is very resistant to kill even from a rather high dosage of 150 gallons per acre of mineral spirits.

Jack pine was used extensively as an "indicator" plant in experimental work because of its quick changes in color, showing effects of oil injury in the form of needle browning.

Apparent Safe Dosages of Mineral Spirits

As a guide to nurserymen, the best available information as to apparently safe levels of treatment of species commonly grown in the Lake States nurseries has been assembled (table 13). Generally the lower level of the range is advisable especially during the germination period. Where special precaution is used, such as spraying beds with overhead sprinkling or spraying on cool nights, the upper level of the range should be quite safe and probably could even be exceeded by as much as 25 percent without incurring undue injury.

Indications are that in the germination period, dosages of 25 to 75 gallons per acre are safe, with some variation by genera -- the pines being more oil resistant than the spruces or fir. After July 1, when germination is generally complete and the trees have hardened up somewhat, the effective and yet safe dosages are in the range of 50 to 90 gallons per acre, with pines usually able to take heavier treatment than spruces or fir.

These dosages incorporate a safety factor of about 10 gallons per acre for the germination period and around 20 gallons per acre thereafter. In other words, the upper limits stated could be exceeded by those amounts without appreciable nonrecoverable damage or tree mortality. In any large-scale operation, it is difficult or impossible to put on an exact prescribed dosage, and such a safety factor thus gives nurserymen some "margin for error."

Table 13.--Apparent safe dosages of mineral spirits on conifer nursery beds

Genera and species 1/	Application per acre of mineral spirits 2/	
	During germination period up to July 1 of first-year seedbeds	After July 1 on first-year beds and at anytime on any age classes older than one year
	Gallons	Gallons
Pines, jack and red.....	40 - 75	75 - 90
Spruces, white, Colorado blue and Norway...	25 - 40	50 - 75
Firs (balsam fir).....	35 - 50	50 - 75

1/ See text, page 19, for reaction of other species.
2/ Where weeds are small, the lower level of the range in treatment will give satisfactory results with a minimum of risk. Additional precautions include watering beds just before application of the mineral spirits, or spraying on cool days or at night when air temperatures are around or under 75° F. With such precautions, the upper limit of treatment would appear safe, or could even be exceeded somewhat.

As an added precaution, it is recommended that nurserymen try out the mineral spirits on a small scale before undertaking large-scale spraying operations. With species for which there is rather limited information, small-scale trials are especially necessary. These may indicate that with the preliminary sprinkling with overhead systems, the first-year species can take considerably heavier oil treatment with resulting better weed kill.

The results of two years' experimentation in Wisconsin give no basis as yet for fine distinctions in prescribed dosages for individual species of pine. The variations observed in oil resistance (first-year red pine being outstandingly resistant) have not warranted compilation of a complicated set of prescriptions. A simple set of recommendations seems sufficient (table 13).

More significant may be the fact that species which usually require half shade in the first-year seedbeds (generally climax or near-climax species ecologically), such as spruces and balsam fir, will not tolerate dosages of mineral spirits as high as those species usually grown in full sunlight in the first-year seedbeds.

Some information was obtained for other species not listed in the general recommendations. Austrian, Mugho, and Scotch pines, as first-year trees, were uninjured by sprays of 50 gallons per acre, and first-year white pine was not damaged by 75-gallon-per-acre applications. Whether the dosages are safe on older age classes was not determined. Eliason (3) reports second-year Scotch pine as being damaged by heavier dosages of mineral spirits and that larches are so susceptible to damage that they should not be sprayed with this herbicide. It is reported that Douglas-fir can withstand dosages about as given for balsam fir. Northern white-cedar is rather sensitive and appears to rank with white spruce in oil resistance. Robbins (6) observations on first-year ponderosa pine appear to place it in about the same resistance category as red pine. Cossitt (2) indicates that longleaf, loblolly, and shortleaf pines can be treated with dosages at least as heavy as shown for the spruces. He indicates that dosages of 40 to 50 gallons are a maximum required in southern pine nurseries and that often very light treatments of about 25 gallons per acre will give excellent weed control, provided spraying is done when the weeds are very small. He mentions spraying eastern redcedar successfully, apparently with the same general level of treatment as for the pines.

Methods of Application of the Mineral Spirits

The method of applying mineral spirits will vary by purposes of the spraying. For investigation of reaction on tree species or age classes for which no information is available, the most satisfactory device for spray application is a hand-operated piston type spray gun of 0.5 to 2.0-quart capacity. With these, precise levels of application on small plots of 10 to 16 square feet in area, replicated four to five times, will give good experimental results within a minimum space and with the fewest number of seedlings damaged or killed. Counts or estimates of weed kill are necessary. Exact counts of tree stand, before and after spraying either on the entire bed or specified interior drills (for instance 3 out of 7 or 10) will aid in a more exact evaluation of treatment. Counts of damaged trees help in rounding out the picture.

In small nurseries or where a small area of seedbeds or transplants is to be sprayed but where there is a fair knowledge of safe dosages, a satisfactory outfit is a 3-gallon continuous-pressure garden sprayer, either slung on the shoulder or mounted on a garden cultivator with a small boom 6 to 8 feet or less in length and equipped with fan-type nozzles spaced 12 to 24 inches apart. Such a device was successfully used by Hammer and Tukey (4) in applying 2, 4-D in rather light dosages and is equally adaptable to oil spraying in forest nurseries.

A surprising amount of area can be covered with the ordinary 3-gallon sprayers. At Griffith State Nursery near Wisconsin Rapids, Wisconsin, one man with this type of sprayer was able to spray 500 seedbeds 4 by 12 feet in size in an 8-hour day, using a 75-gallon-per-acre treatment.[11]

For larger scale operations, a tractor-drawn spray rig is ideal. Several of these are described by Eliason (3) and Cossitt (2). At Hugo Sauer Nursery, Rhinelander, Wisconsin, Nursery Superintendent E. F. Biebesheimer and staff adapted a Meyers Orchard Sprayer for application of Stoddard Solvent. The sprayer was mounted on a trailer and had 12 Meyers fan-type nozzles spaced 18 inches apart, mounted on a 3-section boom 20 inches above the ground and connected by rubber hoses to the power sprayer. This rig sprays three 4-foot beds at a time at a pressure of up to 200 pounds per square inch.[12] The tank holds about 100 gallons. With the usual seedbed setup of ten 4-foot beds between pipe lines, 9 beds are covered in 3 runs. The tenth bed is covered on the fourth trip with the two sections of the boom on either side shut off and swung in back of the center section of the boom. The spray rig was pulled by an Allis-Chalmers Model B rubber-tired tractor.

It is necessary to compute in terms of gallons per acre the rate of discharge per minute at a given pressure of the sprayer used. This, in turn, is translated into terms of tractor speed. At Hugo Sauer Nursery, for instance, with the rig used there, a speed of 162 feet per minute applies about 64 gallons per acre at a pressure of 200 pounds.

A table of forward speeds with the tractor in a certain gear ratio and with throttle set in specific notches is very useful when worked out in terms of a range of applications, say for 30, 50, 70, and 90 gallons per acre.

It is best to have valves, gaskets, hoses, etc., on the spray rig, which come in contact with the mineral spirits, made of neoprene or other oil-resistant synthetic. Natural rubber quickly disintegrates from the chemical action of the spray.

A number of precautions should be taken when using mineral spirit sprays. None of the material should be dropped or spilled on the beds, since it is likely to cause mortality or severe burning of foliage. The highly inflammable mineral spirits should be kept away from engine exhaust pipes, and no smoking should be allowed near the operation. No spraying should be

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11/ According to Nursery Superintendent, W. H. Brener.

12/ Some authorities have recommended the use of pressures of 50 to 75 pounds (3, 6), but the 200-pound pressure caused no ill effects in these trials.

done on windy days because of increased hazard from drift and uneven coverage. Grounding of the spray rig with a short piece of dragging chain would appear desirable. Mineral spirits should not be stored in nursery buildings where equipment or valuable records are kept, but should be kept in barrels or large tanks away from buildings.

Savings by Use of Mineral Spirits

The savings in use of mineral spirits compared with hand weeding have run from 53 to 76 percent in several time-and-cost studies run by E. F. Biebesheimer, Superintendent of Hugo Sauer Nursery. The lower range was in a lot of transplants where considerable hand weeding was necessary as a "mop up" operation after the spraying. The higher figure was for some seedbeds where weed kill was quite complete. Here the comparative costs were $75.87 for hand weeding and $18.22 per acre for oil spraying.

The mineral spirits in this section of the Lake States cost about 25 cents per gallon, and the labor cost of applying sprays amounted to $2.22 per acre in actual test. Labor now costs about 80 cents per hour.

The use of sprays does not always eliminate hand labor entirely, since in some instances from 5 to 15 man-hours per acre of labor may be required in "mop up" several days after oil spraying to get rid of the larger or more oil-resistant weeds which escaped.

Weeding done entirely by hand often requires about 100 hours per acre, and sometimes much more. A time study run at Hugo Sauer Nursery in seedbeds with different densities of weeds which averaged one inch high (range 1/2 to 2 inches) indicated that a stand averaging 10 weeds per square foot would require about 172 man-hours per acre, for the hand weeding (table 14). It is, therefore, understandable that some nurserymen have claimed an 80 to 90 percent saving in weeding costs by use of sprays under conditions where weeds are rather dense and where the bulk of the weeding would have to be done by hand.

In Lake States forest-tree nurseries, seedbeds are sown with 7 to 10 drills running the long way of the 4-foot-wide beds, with a space of 4.5 to 6.0 inches between drills. This makes possible the use of hand tools as well as mechanical cultivation and reduces costs of picking the weeds. Therefore, in Lake States nurseries, a more conservative estimate of savings by weeding with mineral spirits is in the range of 50 to 60 percent.

Table 14.--Man-hours required to hand weed nursery plots of different weed density

Weeds per square foot	Time per gross acre of seedbed 1/
Number	Man-Hours
1	33
2	63
3	87
4	103
5	123
6	135
7	147
8	156
9	165
10	172
11	178
12	184
13	188
14	195
15	200
16	205
17	210
18	214
19	218
20	222

1/ Calculated on basis of 32,000 square feet per gross nursery acre actually being devoted to seedbeds, and remainder to paths and turn areas. Cost of mechanical weeding of paths, end of beds, and other unseeded areas is not included.

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