FENURON IN THE MANAGEMENT OF WHITE PINE

by

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INTRODUCTION

During the early years of this country, timber was the most valuable and abundant natural resource. The forests were so extensive that thousands of acres of timber had to be removed and burned to provide room for our expanding population. This nation was also blessed with the greatest variety of species in the temperate zone of the world; tall white pines for masts of great sailing ships, chestnuts with their own "built-in" weather and pest resistance, and white oaks for tasks requiring strength. All of this was readily available to any enterprising individual with a saw. The American people assumed that the timber resources were unlimited; therefore, no concerted attempt was made to put the forests under proper management to conserve this valuable resource. Vast areas of prime timberland were soon converted to weed species, species with little or no economic value. Suddenly, two problems faced the nation; not only had the most valuable species been over cut, but there also was a deficit in forest volume, more timber was being cut than was being grown.

With the realization that the timber resources were not unlimited, and that continued abuse of the forests would result in a shortage of good timber, foresters began studying the problem of reclaiming vast areas of good timberland that had become weedy through neglect. The eventual goal of this gigantic reclamation project was, and still is, to establish on every forest site the most valuable species that can be grown successfully on that site.

In the Appalachian Mountains one of the most valuable species is white pine, Pinus strobus L. (25). At present, there are few sites with mature stands of white pine or even where white pine is established. Most of the old white pine sites are now covered with inferior species. If these idle sites are to become productive, an economical method must be found to convert these stands of weed species to white pine.

Before this problem can be solved, the conditions that exist must be considered. First, the site may be a good white pine site but may be barren of any white pine reproduction because of a lack of seed trees. In this case, the forester is faced with the task of site preparation and the planting of the area with white pine seedlings. Second, there may already be natural reproduction established on the site but, due to competition from other species, the white pine will never reach merchantable size. In this case, the forester is faced with the task of releasing the white pine by removing the competition of the weed species. In either case, an economical method must be found to remove the undesirable species.

White pine cannot be established on a site that has an existing hardwood canopy; it is intolerant to shade after the seedling stage (28). It cannot compete unless it receives relatively high intensity sunlight. If the plants do not receive high intensity sunlight, they will not produce enough carbohydrates to develop roots large enough to successfully compete for water and soil nutrients (15). As a result, the plant will eventually be eliminated from the forest community. Man can provide favorable conditions for white pine growth by eliminating the competition of other species. Not only must the crowns of offending trees be removed, but the competing root systems must be completely eliminated. Sprouts and suckers from these roots will grow fast, faster than a young pine seedling, and soon will dominate the seedlings. Nothing is accomplished unless the competing plants are completely eliminated.

Since the turn of the century much progress has been made on methods of removing competition from the forest. These methods fall in three categories:

1. Mechanical
2. Burning
3. Chemical

The earliest method of releasing pines was the cutting down or girdling of the competing trees (13). This method was satisfactory where there was a market for the logs but did not completely solve the problem. The stumps still had to be dealt with to prevent them from sprouting. Girdling would kill the crown of the tree, but the area below the girdle would often sprout prolifically. This practice was satisfactory where the pines were well established, because the pines would remain ahead of the competing sprouts.

Fire has been used extensively in the South to release longleaf pine but cannot be used in the management of white pine, for this species is very sensitive to fire.

In the search for a better method of removing competition, it was inevitable that chemical means would be investigated. Certainly this would be less expensive and less damaging than cutting down unmerchantable trees and hauling them out of the forest. Various chemicals have been investigated for this purpose and some found to be very effective tree killers. Sodium arsenite and ammonium sulfamate were two of the first successful herbicides used in forestry (5). A tremendous breakthrough came with the discovery of the translocated, systemic herbicides; 2,4-Dichlorophenoxyacetic acid (2,4-D) and 2,4,5-Trichlorophenoxyacetic acid (2,4,5-T). These herbicides were selective in nature, i.e., they would kill hardwoods and do relatively little damage to the conifers when applied at certain concentrations (14). They also gave a more complete kill than the herbicides previously used. In spite of the strides that have been made, the perfect herbicide is yet to be found. This hypothetical perfect herbicide must have the following characteristics; it must give complete kill with one application, be selective in nature, easy to apply, act quickly, and have no residual effect.

In 1951, a new family of herbicides, the substituted ureas, was introduced to the weed control industry (3). These herbicides are nonselective, of low toxicity to mammals, and are effective on a broad range of plants (16). They have been primarily used as soil sterilants. The ureas can be applied on the foliage as a spray or on the soil as either a wettable powder or as granules. It is believed that the foliage spray is not as effective as the ground application because sunlight may render the chemical biologically inactive (17, 27).

Herbicides applied to the soil are subject to a variety of factors that can reduce the effectiveness of the chemical. Some of the soil factors that affect the ureas are microbiological activity, structure, cation exchange capacity, moisture content, organic matter content, and the interactions of these factors (4, 8, 19, 21, 22, 26). Other environmental factors that effect the ureas are sunlight and rainfall. Microbiological activity is probably the single most important factor in inactivation of an herbicide (1, 19, 22). Some workers have found that certain soil microorganisms can use the ureas exclusively as a source of energy (11, 20).

There was little use of the ureas in forestry before the development of fenuron, 3-phenyl-1,1-dimethylurea. The earlier developed urea herbicides such as monuron either had too much residual effect to be used in forest management, or they were too insoluble to leach into the soil and kill deep rooted perennials. Fenuron is more susceptible to the action of soil microorganisms and is more water soluble than other urea herbicides; therefore, it has less residual effect. These characteristics make fenuron ideal for use on deep rooted perennials in soil that should not be tied up for long periods (9). It enters the plant through the roots and is translocated to the leaves where it acts by "causing to accumulate a phytotoxic material formed during the process of oxygen evolution in photosynthesis" (12).

Foresters have used fenuron primarily in site preparation projects. Several methods of applying the herbicide have been used; however, the two most common are (1) broadcast application and (2) treatment of individual stems. It has been reported that the individual stem treatment is more effective than the broadcast method (6). The rate seems to depend on the conditions present at any particular locality. It will suffice to say that it takes more fenuron to kill a tree on a heavy soil than on a light soil. Two of the most commonly used rates are 12 pounds per acre of active material for broadcast, and four grams per stem active material for the individual stem treatment. Time of treatment can influence the results obtained (6). Early spring has been reported as the best time for treatment and late summer as the poorest (10).

Foresters are always on the lookout for easier, quicker, more economical, and more effective methods of removing weed trees. Several characteristics of fenuron have attracted their attention. This chemical is extremely effective on trees, it requires no water or oil as a carrier, it requires no equipment for application, and it can be applied very rapidly. With this in mind, several experiments were performed to investigate possible uses of fenuron in management of white pine, and to determine what effect, if any, the fenuron has on the plant community.

METHODS AND MATERIALS

Experimental Area

The experimental area chosen for these experiments is located in Southwest Virginia on the north slope of Flattop Mountain, Nobusiness Creek watershed, Blacksburg District, Jefferson National Forest. The elevation is 3,000 feet. The soil type is a sandy clay loam which remains moist throughout the year except under the most severe drought conditions (Table 2). The site index is 80 for white pine (15).

There was a severe forest fire in the area in 1953, but since then there have been no natural disturbances of consequence. The forest as it is now composed represents a type 51 as defined by the Society of American Foresters and is uniform throughout the drainage area (23). It represents a forest of even age, about 28 years old, with hardwoods dominating the abundant white pine reproduction (Table 1). White pine is the species that will give the forester the highest economic return. The oaks and maples are of such quality that it would be uneconomical to manage for these species. The local market for hardwood pulpwood is limited; therefore, the district ranger has implemented a program of management for white pine. At present, the average number of stems per acre of all species is about 1700.

Table 1. Check list of trees found in the experimental area and abbreviations used in the test.

Common Name	Abbr.	Scientific Name
Black gum	BG	Nyssa sylvatica Marsh.
Black locust	BL	Robinia pseudoacacia L.
Cherry	Ch	Prunus serotina Ehrh.
Chestnut	C	Castanea dentata (Marsh.) Borkh.
Chestnut oak	CO	Quercus prinus L.
Cucumber	Cu	Magnolia acuminata L.
Dogwood	D	Cornus florida L.
Hemlock	He	Tsuga canadensis (L.) Carr.
Hickory	H	Carya tomentosa Nutt.
Pitch pine	PP	Pinus rigida Mill.
Red maple	RM	Acer rubrum L.
Red oak	RO	Quercus rubra L.
		Quercus velutina Lam.
		Quercus coccinea Muenchh.
Sassafras	S	Sassafras albidum (Nutt.) Nees
Serviceberry	Se	Amelanchier arborea (Michx.) Fern.
Sweet birch	SB	Betula lenta L.
Sourwood	So	Oxydendrum arboreum (L.) DC.
White oak	WO	Quercus alba L.
White pine	WP	Pinus strobus L.
Witch-hazel	WH	Hamamelis virginiana L.
Yellow-poplar	YP	Liriodendron tulipifera L.

Table 2. Soil analysis of two samples; number one from the first replicate of the white pine release site, and number two from the white pine establishment site.

	Sample	
	1	2
Percent sand	51.2	54
Percent silt	20	20
Percent clay	28.8	26
Soil type	Sandy clay loam	Sandy clay loam
pH	4.8	4.8
Calcium	Less than 1%	Less than 1%
Magnesium	Less than 1%	Less than 1%
Phosphoric acid	Less than 1%	Less than 1%
Potash	1-2%	1-2%
Organic matter	3.3%	3.3%

Materials

The herbicides used in this project were fenuron, 3-phenyl-1,1-dimethylurea, the granular form 25% active, sold under the commercial name of Dybar; and the butoxyethanol ester of 2,4,5-Trichlorophenoxyacetic acid (2,4,5-T), sold under the trade name of Trinoxol.

White Pine Release Experiment

The objectives of this experiment were to evaluate the effect of fenuron on white pine as well as upon the weed tree species when fenuron is applied at different seasons for release of white pine. Based on previous work, it was assumed that fenuron used in a white pine release program would kill many of the indigenous white pines along with the weed trees. The percentage kill would determine whether or not a forester could afford the use of fenuron. The size of the white pines on the site may determine whether this herbicide could be used if one size class is more susceptible to the fenuron than another size class. Most importantly, a forester would like to know if fenuron is effective against the particular weed tree species which he wants removed.

The design used in this experiment was a randomized block of four replications of three treatments. The replications were separated by a three chain width of untreated timber. In each replication, the treatments were separated by a one chain width of untreated timber. These buffer strips were designed to prevent any effects of one treatment appearing in another plot. This design fits well with a current management practice to release the white pine in strips that are as wide as the trees are high. The treated plots were one chain wide and three chains long with the long axis uphill.

The treatments were identical except for the time of treatment. Treatment A was applied on 18 May 1960, treatment B on 10 August 1960, and treatment C on 1 March 1961. Each hardwood stem over five feet tall was treated with four grams active ingredient of fenuron placed next to the base of the tree on the soil in a small concentrated pile. Only hardwoods that are commonly considered to reach tree size, 15 feet or over, were treated. When a white pine was growing within three feet of the stem to be treated, the chemical was placed on the side of the stem farthest from the pine.

At the time of treatment, a complete tally was made of all living hardwood stems over five feet tall. The white pines were counted and divided into three size classes; those less than two feet tall, those two feet to six feet tall, and those over six feet tall. The final tally of all species was made on 5 September 1961 for all treatments. At that time all of the original stems that had been treated but were still living were counted. A tree was considered living if it had any green leaves. The living white pines were tallied in the same manner as on the initial tally.

White Pine Establishment Experiment

The objectives of this experiment were to determine whether white pine seedlings could be planted one year after a site had been treated with fenuron, and to compare the relative susceptibility of the different hardwood species present to one gram active ingredient of fenuron. The existing canopy of hardwoods must be removed in order to provide growing conditions necessary for the survival of the white pine seedlings. Fenuron may have a residual effect that will prevent the planting of seedlings for several years.

The experiment consisted of three replications of one treatment and a check. The plots were one chain wide, three chains long, and separated by a one chain wide strip of untreated timber. The long axis was uphill.

Each hardwood stem over five feet tall was treated with one gram active ingredient of fenuron placed next to the base of the tree on the soil in a small concentrated pile. Only hardwoods that are commonly considered to reach tree size, 15 feet or over, were treated. Plot I was treated on 25 May 1960, plots II and III on 6 June 1960, and the check on 30 June 1960. It was desired to open up the canopy as much in the check as in the fenuron treated plots. This was done by treating all hardwood stems over 4" diameter at the base of the tree with 2,4,5-T at a rate of 40 pounds in 100 gallons of no. 2 fuel oil. The herbicide was applied with the aid of a Ruell tree injector. The injector was directed as near the root collar as possible. The blade was pushed into the living tissues and a small pocket opened by lowering the top of the tool. This pocket was filled to slightly overflowing with the herbicidal solution. The pockets were placed entirely around the stem slightly over-lapping.

On 21 March 1961, two hundred white pine seedlings were planted in each plot. The 1961 planting stock was of poor quality. To eliminate poor planting stock as a factor, two seedlings were placed in each hole. It was felt that if fenuron was a factor in causing death of the seedlings, both seedlings would be killed since their root systems were in such close proximity. The planting was done manually with the aid of a planting bar. The rows and holes were placed six feet apart. Each pair of seedlings was marked with a small white stake. The final count of surviving seedlings was made on 5 September 1961.

The first and second counts of the living hardwoods were accomplished in the same manner as the hardwood counts in the first experiment. The first count was made at the time of treatment, and the final count was made on 5 September 1961. Indigenous white pine was not tallied for this experiment.

Plant Community Investigation

The objective of the final experiment was to determine what effect the fenuron would have on the plant community. Fenuron usually effects the entire plant community. A forester would like to have some idea of the scope and desirability of this effect and whether it will be long term or temporary in nature.

The data was taken on subplots that were laid out in the release experiment, using the May treatments and the untreated strip of timber between the May treated plot and a neighboring plot. Sixteen sampling areas were established, eight in the four May treated plots and eight in four buffer strips. Two sampling areas were put in each plot and strip. One sampling area was placed one chain from the base of the plot and centered in the plot and the other area was placed two chains from the base of the plot and centered in the plot. The sampling areas were marked with a yellow stake driven into the ground.

The plots were circular and 100 square feet in area. On 10 September 1961 all living herbaceous plants in the area were recorded by species and the number of each present.

RESULTS AND DISCUSSION

White Pine Release Experiment

The results indicate that white pines over six feet tall may be more susceptible to the treatment of four grams of active ingredient than those under six feet tall (Figure 1). Through the use of a contingency table, it was determined that the survival of the pines of all size classes was independent of the time of treatment. An analysis of variance was used to determine the effect of fenuron on the hardwood species. Only those species that were found in each plot were used in the analysis. Before an analysis of variance could be used, the data had to be transformed. This was done in a manner suggested by Bartlett (2). Through the analysis it was found that results for the treatments and species were significantly different at the 1% level, and there was no interaction between species and treatments (Table 3). The Duncan Test was used to separate the treatment and specie means (Table 3). Results of the May treatment were significantly different at the 1% level from the August and March treatments. Red maple, red oak, and chestnut oak were more susceptible to fenuron than black locust, sassafras, and chestnut (Table 3).

The results obtained on the survival of the indigenous white pine need little clarification. White pine was as

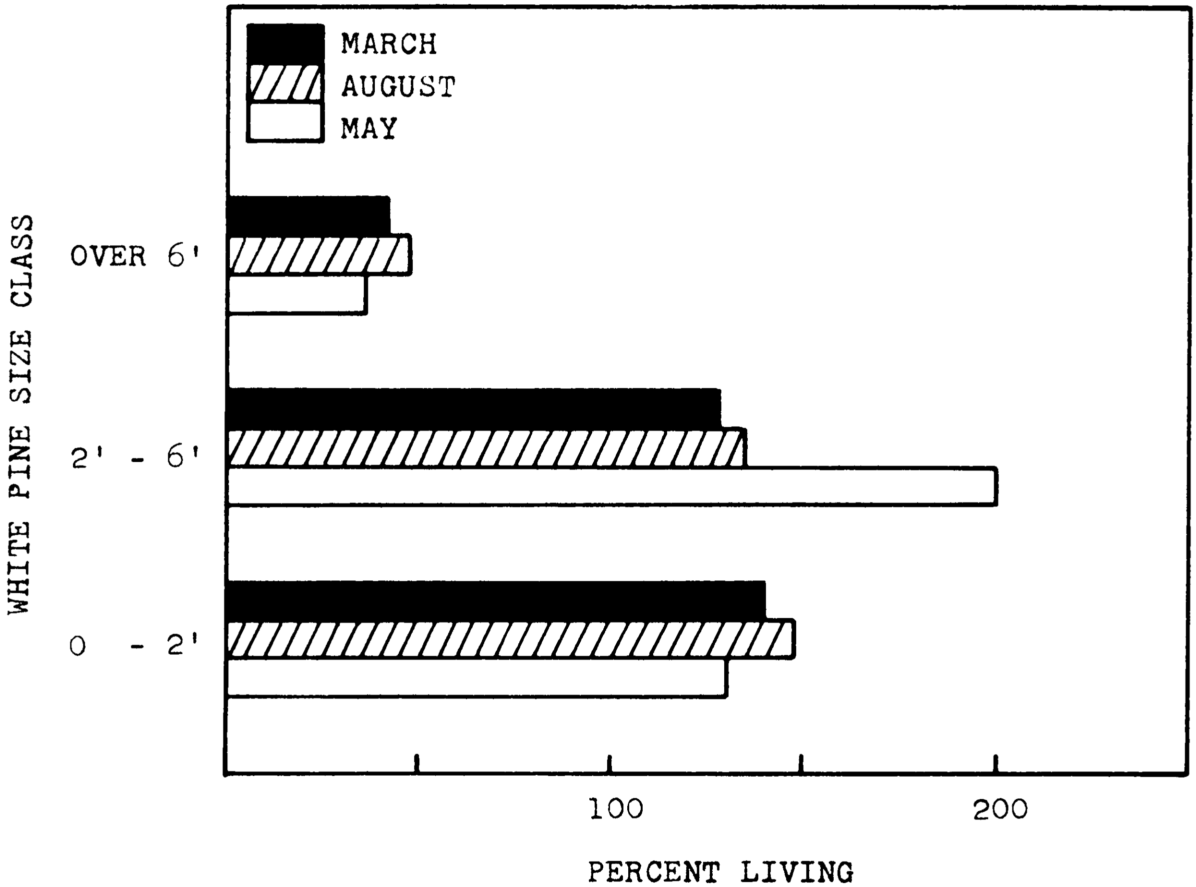

Figure 1. Average of three seasonal treatments with four grams active ingredient of granular fenuron.

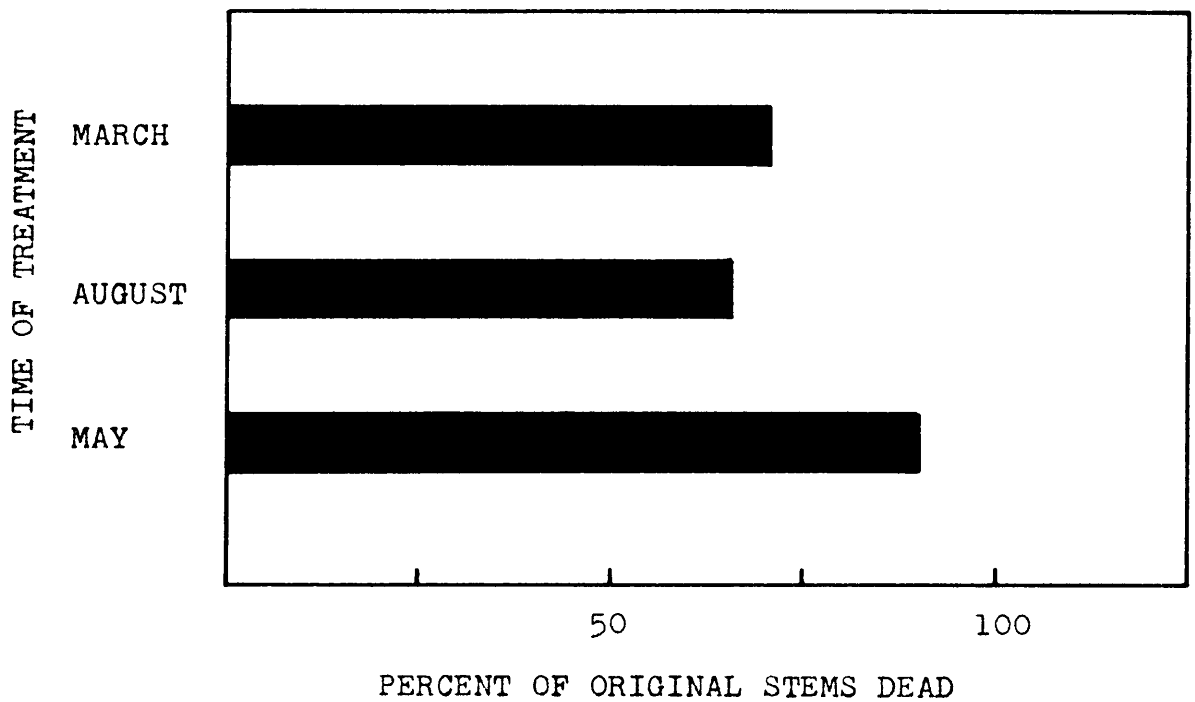

Figure 2. Original hardwood stems killed by four grams active ingredient of granular fenuron.

Table 3. Analysis of variance and separation of the means for the data in Table 4.

Source	df	SS	MS	F
Replicates	3	129.45	43.15	
Treatments	2	8,208.94	4,104.47	19.28**
Reps. x Treat.	6	1,277.32	212.89	
Species	6	11,726.81	1,954.47	15.47**
Species x Reps.	18	2,274.39	126.36	
Species x Treat.	12	2,112.94	176.08	1.53
Species x Treat. x Reps.	36	4,138.59	114.96	
Total	83	29,868.44		

** Significant at the 1% level.

Separation of the hardwood species means.*

RM	RO	CO	BG	BL	S	C
16.55	18.70	25.78	33.67	43.33	44.72	47.34***

Separation of the treatment means.*

May	March	August
19.18	37.27	42.16***

* Figures are the transformations of the percentage of original stems still living.

*** Note: Any two means not underscored by the same line are significantly different at the 1% level. Any two means underscored by the same line are not significanyly different.

Table 4. Results of the treatment of the hardwood species with fenuron in the white pine release plots.

	Time of treatment								
	May			August			March		
Species 1/	B 2/	A 3/	% 4/	B 2/	A 3/	% 4/	B 2/	A 3/	% 4/
BG*	178	11	6	109	48	44	65	26	40
BL*	68	11	16	35	16	46	49	29	59
C*	148	38	26	67	49	73	159	83	52
CO*	363	9	2	355	125	35	402	106	26
RM*	449	32	7	484	61	13	367	26	7
RO*	300	4	1	270	53	20	369	58	16
S*	303	62	20	181	134	74	192	111	58
Ch	0	0	0	0	0	0	0	0	0
Cu	7	4	57	18	15	83	11	6	55
D	0	0	0	0	0	0	7	0	0
He	3	0	0	0	0	0	1	0	0
H	7	1	14	23	13	57	17	8	47
PP	4	0	0	7	6	86	6	1	17
Se	14	1	7	9	5	56	12	4	33
So	172	30	17	69	35	51	97	63	65
WO	32	0	0	14	4	29	50	7	14
WH	1	1	100	26	7	27	2	0	0
Total	2049	204	10	1667	571	34	1807	528	29
WP 0 -2'	293	380	130	83	123	148	201	282	140
2'-6'	163	326	200	113	151	134	169	217	128
over 6'	371	133	36	227	109	48	257	111	43
Total	827	839	101	423	383	91	627	610	97

* Species used in analysis of variance and separation of means.

1/ See Table 1.

2/ Number of living stems present at time of treatment.

3/ Number of original stems still living at the time of the final tally.

4/ Percent of original stems still living.

susceptible to the treatment in May as in August and March; so it apparently makes no difference when the hardwoods are treated with fenuron as far as expected survival of the pines is concerned. The important fact is that there was not a large reduction in the white pine stand on the site as a result of treating the hardwoods with fenuron. There was an increase of 45% of pines under six feet tall and a reduction of 59% of pines over six feet tall. This is an odd result. There are two possible explanations for the apparent increase of smaller pines. First, at the time of the initial tally, some of the small seedlings were overlooked and not recorded. Second, in the course of the growing season, there was an actual increase in numbers of seedlings because the conditions for germination and growing were improved. It is felt that the reason the larger pines are apparently more susceptible to fenuron is due to the habit of the tree and the size of the root system and not due to a physiological factor. The root system of the white pine is fibrous and fans out in a circular pattern. The larger the tree, the larger the root system and the greater the possibility that some roots will be growing in an area that has received treatment. Apparently, fenuron can be used for white pine release; if the white pine stand is primarily under six feet in height; if the suppressed pines are over six feet in height, then fenuron probably should not be used.

The results obtained from the comparison of seasonal treatments on the hardwood species compare favorably with results other workers have obtained (6, 10, 18). Treatment in early spring gave a higher kill than the late summer and winter treatments (Figure 2). Why this is so is the major question to be answered. At present, it is believed that soil microorganisms are the major factor in reducing the biological activity of fenuron. This could lead us to believe that winter, when the activity of soil microorganisms is at a minimum, is the best season for treatment. The results, however, do not bear this out; so it is believed that a major factor to be considered when using fenuron is the physiological activity of the trees. In spring, just before bud break, the trees are more active than during the dormant season or in late summer when the dormant season is approaching. This activity should result in the tree taking in the fenuron more rapidly in the spring than in the other seasons. Possibly, during the late summer and the winter the fenuron is inactivated by the soil microorganisms before the tree accumulates a lethal dose. Since the final counts were made at different times in relation to the treatment dates, it is being assumed for this discussion that there will be no significant change in the percentage of original hardwood stems killed. There is a possibility, however, that the March treatment could have a higher percentage kill at the end of the summer of 1962.

This experiment has demonstrated that on this particular site some species of hardwoods appeared to be more susceptible to fenuron than other species. This could be due to different rates of absorption by the species. The more susceptible species absorb the fenuron faster, before the soil factors inactivate the fenuron. Another plausible explanation is the possibility that different species differ slightly in the chemistry of their physiological processes, and for that reason different quantities of fenuron are required to disrupt them. If the lethal doses were known for each species, a forester using fenuron in release work could treat each species according to the amount that would remove it. For example, red maple would require less fenuron to kill it than would sassafras. A forester should check his area to determine species composition and the percentage of each species. If there is a preponderance of hard-to-kill species, he would probably not want to use fenuron. Species composition is one of the factors to consider in cost-per-acre estimates.

An additional observation was made when making the final tally of the plots. It was noted that in the May treated plots that a large number of sprouts had appeared around the base of most of the trees. In most cases, these sprouts were small, weak, and appeared to be suffering from the effects of the fenuron. This was not the case with sassafras and cucumber tree; for these species there was a healthy sprout next to the original stem in almost every instance where the original stem had been killed. The cucumber tree appeared to be the species most resistant to fenuron in these experiments. It was observed on an earlier experimental area treated with higher rates of fenuron, that the treatments had resulted in a large increase in the number of sassafras stems on the site (24). It was observed that as many as 1000 sprouts and suckers of sassafras had developed on a one-fourth acre plot in which five grams active ingredient of fenuron per stem was used. Sassafras and cucumber tree are usually minor members of the forest community; it would be best not to treat these species with fenuron when releasing white pine.

Now that the experiment is completed, there are some postulations that can be offered. Fenuron may be used with comparative safety for white pine release in areas where the bulk of the white pine is under six feet tall. Fenuron was effective on most species commonly associated with white pine under the conditions of this experiment. Sassafras and cucumber tree appear to be the most resistant species to fenuron and should not be treated with this chemical in a management program. There is a possibility that by killing the original stems of sassafras there will be an increase of this species on the site as a result of sprouting. The most effective time for treatment with fenuron appears to be just prior to bud break in the spring. Since reaction to fenuron may vary under different conditions, it is suggested that before treating the entire area a trial should be made to determine whether the herbicide will be effective. This herbicide is ideal for use in areas where it is difficult to take equipment. One man with a knapsack of fenuron granules can treat a large area in a short time. A worker with no experience and a little training can apply this herbicide. Small landowners who do not want to invest money in equipment should find this herbicide to be a useful tool.

White Pine Establishment Experiment

In the white pine establishment experiment, 99.7% of the seedlings in the fenuron treated plots survived and there was 100% survival in the check. All seedlings had a healthy color and had added about 4" of growth in height at the end of the season. With an analysis of variance, it was found that there was significance at the 1% level in the percentage of kill between species of hardwoods. Only those species that were found in each plot were used in the analysis. Before an analysis of variance could be used, the data had to be transformed. This was done in a manner suggested by Bartlett (2). The Duncan Test was used to separate the means of the hardwood species. Red oak was found to be the most susceptible species and cucumber tree the least susceptible (Table 5).

The high survival rate obtained on the planted seedlings may have been due to several factors. Fenuron may have little long term residual effect; or if it does have long term residual effect, it is closely confined to its area of application. If it has a long term residual effect, and is not confined to its area of application, it moves to a depth where it will not contact the shallow roots of the pine seedlings. The latter is probably the most logical explanation since fenuron is quite soluble and moves out of the surface soil rapidly.

There is an indication in these plots that time of treatment may be very critical (Table 6). Plot I was treated just prior to bud break and the other two plots after bud break two weeks later. There are apparent differences between the May plot, plot I, and the June plots, plots II and III. First, better hardwood control seems to have been

Table 5. Analysis of variance and separation of the means for the data in Table 6.

Source	df	SS	MS	F
Replicates	2	1,001.21	500.61	
Species	10	6,797.31	679.73	4.77**
Error	20	2,850.30	142.52	
Total	32	10,648.82		

** Significant at the 1% level.

Separation of the hardwood species means.*

BO	WO	S	CO	RM	BG	C	H	BL	So	Cu
22.19	26.94	29.99	30.84	31.20	33.28	43.18	44.46	54.81	55.47	71.36***
						———	———	———	———	———
	———	———	———	———	———	———	———	———	———	
———	———	———	———	———	———	———	———			

* Figures are transformations of the percentage of original stems still living.

*** Note: Any two means not underscored by the same line are significantly different at the 1% level. Any two means underscored by the same line are not significantly different.

Table 6. Results of the treatment of the hardwood species with fenuron in the white pine establishment experiment.

	Time of treatment								
	May			June			June		
Species 1/	B 2/	A 3/	% 4/	B 2/	A 3/	% 4/	B 2/	A 3/	% 4/
BG*	42	7	17	29	13	45	26	8	31
BL*	18	13	72	5	4	80	13	6	46
C*	53	14	26	4	1	25	15	13	87
CO*	116	12	10	101	32	32	74	30	41
RM*	231	48	21	257	63	25	206	74	36
RO*	96	3	3	101	22	22	96	22	23
S*	84	23	27	95	18	19	86	25	29
Cu*	18	16	89	17	11	65	5	5	100
D	1	1	100	0	0	0	2	1	50
H*	14	4	29	16	11	69	4	2	50
PP	1	0	0	0	0	0	0	0	0
SB	0	0	0	0	0	0	5	0	0
Se	6	1	17	4	2	50	5	3	60
So*	28	10	36	29	19	66	66	62	94
WO*	20	7	35	16	1	6	4	1	25
WH	10	4	40	0	0	0	3	0	0
YP	1	0	0	0	0	0	0	0	0
Total	739	163	22	674	197	29	610	252	41

* Species used in the analysis of variance and separation of means.

1/ See Table 1.

2/ Number of living stems present at time of treatment.

3/ Number of original stems still living at the time of the final tally.

4/ Percent of original stems still living.

Table 7. Species found in the plant community investigation and the total number of each species found in the May treated plots and the buffer strips.

Species	Four g. fenuron/ stem	Untreated
Gaultheria procumbens L.	1,303	1,926
Epigaea repens L.	27	88
Panicum sp.	115	7
Solidago sp.	15	1
Erechtites hieracifolia (L.) Raf.	177	0
Phytolacca americana L.	12	0

achieved on plot I (Table 6). Second, there is a difference in the herbaceous vegetation found in the plots; more intolerant herbs are in plot I. The presence of the intolerant herbs could indicate that the canopy has been more effectively removed in plot I. These differences could also be explained by a possible difference in site and site conditions at the time of treatment.

This experiment demonstrates that under certain conditions good hardwood control can be obtained with small amounts of fenuron (Table 6).

This information suggests that it may be possible to treat an area and plant white pine immediately instead of making another trip back to plant a year later. From the information that has been obtained from the release and establishment experiments, it may be assumed that this could be done successfully; indeed, that it may be a superior practice (Figure 1). White pine is tolerant to shade during the seedling stage. During the first year after treatment the hardwood trees leaf out several times before they completely die. This results in a gradual opening of the canopy. The sprouts from the treated trees do not appear in large numbers until the second season after treatment. There will not be any competing annuals until the second growing season after treatment. The pine seedlings should have ideal conditions in which to become established with a gradual increase in light intensity, and little or no competition from sprouts and annuals. By the time competition appears, the seedlings are established as part of the community. This possibility should be further investigated.

Plant Community Investigation

In the third experiment, it was found that several species of plants occurred in abundance in the plots treated in May but were absent in the untreated buffer strips (Table 7). These were fireweed, Erechtites hieracifolia (L.) Raf., poke, Phytolacca americana L., and Panicum sp. (7).

There is only an indication of what may have happened. Only one count was made on the plots and this was made in the late summer. To accurately determine the composition of the community, counts should have been made throughout the growing season. The only real information available is that several late summer plants were abundant on the plots treated in May and not in the untreated buffer strips. These plants do give some indication of the conditions that prevailed in the plots, since they are species that are usually associated with freshly disturbed areas where there is high intensity sunlight. In the forest, they can be found along the roads and in clearings where the soil has been disturbed. These plants may be an indication of the amount of sunlight that has been admitted through the canopy to the forest floor, or that fenuron has altered the character of the soil medium. It was noted that these species are not present in the plots that have been treated for only one growing season, but appeared in great numbers in the treated plots after two growing seasons. This could indicate that maximum light and heat do not reach the forest floor until the second growing season after treatment, but this does not remove the possibility that the fenuron has changed the character of the soil medium. The same situation was observed on earlier experimental plots by this worker (24). The urea treated plots were characterized by an abundance of fireweed on them. The other plots, treated with different herbicides, were devoid of this plant.

The above situation is one that poses many questions. It is obvious that fenuron has had great impact on the area and that through some manner it either directly or indirectly altered the plant community. There is an indication that the practice of applying herbicides to the soil may become more general, and, therefore, it is imperative that information be gained as to the effect of each herbicide on the soil medium. These effects may be temporary or could have a long term residual effect that would permanently alter the plant community found on the site. Perhaps there is no effect on the soil and this is just a temporary condition that will revert to normal when the canopy closes and the normal light, moisture, and heat conditions are reestablished. These changes may be valuable from the forester's point of view. There is some indication that plots established with the urea herbicides are beneficial for wildlife (24). There is also the possibility that the application of these chemicals has been detrimental to the plant community and many years will be required to repair the damage.

SUMMARY

Experiments were conducted on the use of granular fenuron, 25% active, for white pine release and establishment, and its effect on the plant community was also investigated.

Studies included in the white pine release experiment were the effect of season of treatment on the kill of hardwoods, percentage survival of indigenous white pine, and the effectiveness of fenuron on various species of hardwoods. All hardwood stems over six feet tall were treated with four grams of active fenuron placed on the soil at the base of the tree. Treatments were made in May 1960, August 1960, and March 1961. The May treatment was most effective in the removal of the hardwoods. This could indicate that the physiological condition of the tree is a factor that can influence the results obtained. Just prior to bud break appears to be the best time for treatment. There was a small decrease in the stand of white pine on the area. There was a reduction of 59% of pines over six feet tall and an increase of 45% in the pines under six feet tall. The larger root systems of the trees over six feet tall extending into the areas that had been treated probably account for the higher percentage of kill in this size class. Red maple and the oaks were the species most susceptible to the treatment; whereas, chestnut, sassafras, and black locust were

the least susceptible. This could be due to different rates of absorption by the species or that more of the herbicide is needed to disrupt the life processes in some species.

In the white pine establishment experiment, studies on the residual effect of fenuron on white pine seedlings, and the effectiveness of a lower rate of fenuron on various hardwoods were investigated. Each hardwood stem over six feet tall was treated with one gram active ingredient in the spring of 1960. In March 1961, 100 seedlings were planted in each of three plots previously treated. Five months after planting there was 99% survival of the seedlings and all had a healthy color. This experiment has demonstrated that under favorable conditions good hardwood control can be obtained with relatively small amounts of fenuron. Red maple and the oaks were the most susceptible to the treatment; whereas, black locust, sourwood, and cucumber tree were the least susceptible.

Fenuron in some manner changed the composition of the plant community. Fireweed, poke, and several species of Panicum were present in the treated plots but were not present in the untreated buffer strips. This is probably a result of the changed light, moisture, and temperature conditions, but could be due to a change in the soil medium itself. It is unknown whether this change will be temporary or permanent. More research should be undertaken to determine whether this change is desirable or undesirable.

RECOMMENDATIONS

In one respect this study has been similar to every other study that has been undertaken; it poses more questions than it answers. There was only sufficient time to become thoroughly involved in the study and to receive some indications of the supplementary lines of investigation that should yield additional evidence. At this point, the author realized that it was time to record, analyze, and report the results of the work. With this in mind the author would like to put down some recommendations and thoughts for future research. The major problem of any future worker will be to define the limits of the investigation.

The white pine release experiment should be completely reevaluated at the end of the 1962 growing season and the results compared with the results that have been reported in this paper. A growth study could be initiated on this area to determine the effect of the release on the stand of white pine. The amount of hardwood sprouting and the effect of these sprouts on the white pines should be studied. To further strengthen our knowledge, another experiment identical to this one should be performed. In any future experiments of this nature, it is recommended that a better method of tallying the pines be developed.

In the white pine establishment experiment, the survival of the planted pines should be checked at the end of the 1962 growing season. The use of higher rates of fenuron for site preparation and the possibility of planting the pines at the time the weed species are treated should be investigated.

The herbicidal action of fenuron should be studied to determine whether the physiological condition of the tree can influence the action of fenuron and to determine whether some species are more susceptible than other species to this herbicide.

A more complete study of how fenuron affects the site is recommended. This should include a detailed investigation of the soil medium and should be a long term study, five years or more. More vegetation counts should be made during the growing season in order to have an accurate picture of the plant community. New experimental areas should be established to supplement the ones now in existence. The evaluation of these areas as wildlife clearings should be incorporated into the study.

An experiment should be set up to determine what the cost of using fenuron would be for the forester under actual field conditions.

Finally, it is recommended that fenuron be tested under a broad range of conditions on a variety of sites throughout the state of Virginia. Only through an extensive test program can a complete and accurate picture of the capabilities and limitations of this herbicide be obtained.

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ABSTRACT

Experiments were conducted on the use of granular fenuron, 25% active, for white pine release and establishment. The effect of fenuron on the plant community was also investigated.

Studies included in the white pine release experiment were the effect of season of treatment on the kill of hardwoods and percentage survival of indigenous white pine, and the effectiveness of fenuron on various species of hardwoods. All hardwood stems over six feet tall were treated with four grams of active fenuron placed on the soil at the base of the tree. Treatments were made in May 1960, August 1960, and March 1961. The May treatment was most effective in the removal of the hardwoods. There was a reduction of 59% of pines over six feet tall and an increase of 45% of pines less than six feet tall. Red maple and the oaks were the species most susceptible to the treatment; whereas, chestnut, sassafras, and black locust were the least susceptible.

In the white pine establishment experiment, the residual effect of fenuron on white pine seedlings, and its effectiveness at a lower rate on various hardwoods were investigated. Each hardwood stem over six feet tall was treated with one gram active fenuron in the spring of 1960. In March 1961, 100 white pine seedlings were planted in each

of three plots previously treated. Five months after planting there was 99% survival of the pine seedlings. The one-gram rate was effective against red maple and the oaks but had little effect on sassafras, cucumber tree, and chestnut.

Fenuron in some manner changed the composition of the plant community. Fireweed, poke, and several species of Panicum were present in the treated plots but were not present in the untreated buffer strips.