B. Mr. Ray Boyd, U.S. Forest Service, Intermountain Forest and Range Experiment Station, Moscow, Idaho. Subject: Soil Fumigation and Weed Control in Forest Nurseries.

1. Mr. Boyd was asked if all chemicals used were tarped. He answered that all were tarped except Vapam.

SOIL FUMIGATION STUDIES AT THE COEUR D'LENE AND SAVENAC NURSERIES 1/

by
R. J. Boyd:, Research Forester
Forestry Sciences Laboratory
Intermountain Forest and Range Experiment Station
Moscow, Idaho

INTRODUCTION

Although my assigned subject is "Soil Fumigation for Weed Control in Forest Nurseries," I feel that I must include some of our observations on disease control and growth effects to give you a well-balanced picture of our experiences. While our initial work on fumigants was prompted more by our weed problem than by diseases, we have attempted to obtain at least a gross evaluation of the effects of fumigation on disease losses and on seedling growth.

Some preliminary trials prior to 1961 by Jim Augenstein at Savenac Coeur d'Alene had shown that western white pine and ponderosa pine growth was enhanced by soil fumigation with methyl bromide and by various combinations of methyl bromide, chloropicrin, and propargyl bromide. However, no records were kept on weed control, germination, nursery survival and seedling growth.

Formal studies, designed to give us an evaluation of fumigation based on measured results, started in the fall of 1961.

1/ Studies conducted in cooperation with the Dow Chemical Company and Stauffer Chemical Company.

METHODS

Our fumigation studies include the following tests:

1. Fall fumigation with. Brozone2/ at 25 and 50 gallons/acre and with Trizone at 1•0 and 200 lbs/acre at the Coeur d'Alene nursery in 1961. Fumigated beds were sown to white pine, Douglas fir, Engelmann spruce and ponderosa pine in the spring of 1962. Two replications of the four fumigations plus checks.

2. Spring fumigation in 1963 at Coeur d'Alene with the following:

   a. Brozone at 110, 170, and 340 pounds/acre. (tarped)

   b. Trizone at 140 and 200 pounds/acre. (tarped)

2/ Use of proprietary names does not constitute endorsement.

c. MC-33 at 170 and 300 pounds/acre. (tarped)

d. Vidden D at 50 gallons/acre. (untarped)

e. M-2441 at 50 gallons/acre. (untarped)

f. M-2467 at 50 gallons/acre. (untarped)

g. Vapam at 40 and 80 gallons/acre. (untarped)

These fumigated beds were spring-sown to Ponderosa pine, Douglas fir, Engelmann spruce, and grand fir. Three replications of the 12 fumigation treatment plus checks.

3. Fall fumigation in 1963 at Savenac and Coeur d'Alene using the same chemicals and rates as in the spring 1963 fumigations (Table 1). White pine was both spring- and fall•sown in fumigated beds. Ponderosa pine, Douglas fir, and Engelmann spruce were spring-sown. At Coeur d'Alene, White pine, Douglas fir and Engelmann spruce were spring transplanted into fumigated soils.

Table 1. Chemical Composition of Fumigants and Company Supplying Material and Advice.

Trade Name	Active Chemical Components	Company Cooperating in Test Program
Trizone	61% Methyl Bromide (wt.) 30% Chloropicrin (wt.) 9% Propargyl Bromide (wt.)	Dow
Brozone	68.6% Methyl Bromide (wt.) 1.4% Chloropicrin (wt.)	Dow
MC-33	66.7% Methyl Bromide (wt.) 33.3% Chloropicrin (wt.)	Dow
Vidden D	1, 3-dichloropropene) 1, 2-dichloropropane) 100% + related chlorinated) hydrocarbons	Dow
M-2441	80% Vidden D 20% Chloropicrin	Dow
M-2467	90% Vidden D (wt.) 10% Propargyl Bromide (wt.)	Dow
Vapam (SMDC)	Sodium N-methyldithiocarbamate	Stauffer

RESULTS

The analysis of our results is by no means complete. None of the seedlings grown in fumigated soils have been field-planted to test survival and growth potentials. Our largest and most highly controlled test has only gone through one-half of a growing season. Yet the results in terms of weed and disease control, and the visible, though as yet unmeasured, growth effects are quite dramatic. The following data have been selected as representative examples of the results of our fumigation studies. None of the data has been subjected to statistical analysis, so small differences in treatment effects should be largely overlooked.

Weed Control. Throughout the series of fumigation trials, weed control has been an outstanding, readily visible feature of the fumigation benefits. As an example, consider the sample weed-counts in early June for Savenac and Coeur d'Alene as shown in Figure 1. At Savenac there was an average of 80 weeds per square foot on unfumigated soils at counting time. All of the fumigants with the possible exception of Vapam at 40 gallons/acre reduced the weed population. The largest reductions in weeds occurred on soils fumigated with Brozone at 170 pounds/acre or greater; Vapam at 80 gallons/acre, Trizone at 200 pounds/acre, and MC-33 at 170 and 300 pounds/acre. There is probably little if any significant difference in weed control effectiveness among these treatments. At Coeur d'Alene the magnitude of weed reduction was not as great as at Savenac, but the relative effectiveness of various fumigants was much the same.

Working the soil after fumigation and prior to sowing probably resulted in some mutual contamination. This would tend to make the estimates of weed control effectiveness conservative.

In order to estimate the long-range weed control benefits from fumigation, soil samples were taken in selected plots to a depth of 6 inches. The surface 1 inch was discarded to eliminate weed seed which had accrued since the beds were prepared. Soil samples were then spread on containers in the greenhouse, and the germinating weeds counted. On thirty-seven samples from fumigated soils a total of 6 weeds germinated while 33 samples from unfumigated soils supported a total weed population of 425. Thus, the fumigation has virtually eliminated viable residual weed seed to a depth of at least 6 inches.

However, weed counts in themselves may be deceptive. If the only other alternative weed control measure were hand-weeding, there would be no question about the economy of fumigation at $400-500 per acre to control weeds. Hand-weeding time studies indicate roughly that a reduction of 11 weeds per square foot will reduce hand--weeding cost by $400 per acre. Figure 1 shows many fumigation treatments which provide this much reduction in weed population or more.

Hand-weeding is not the only other alternative to weed control, however. Many herbidical treatments, including the old standby aromatic oils, may accomplish the job at less cost. Even when fumigation reduces the weed population to very low levels, it has no influence on weeds from seed blown in after fumigation and very little control of perennials. With the criteria of absolute weed control, even 10 weeds per square foot is 10 weeds too many, and they must be removed. Assuming that they can be controlled with aromatic oils

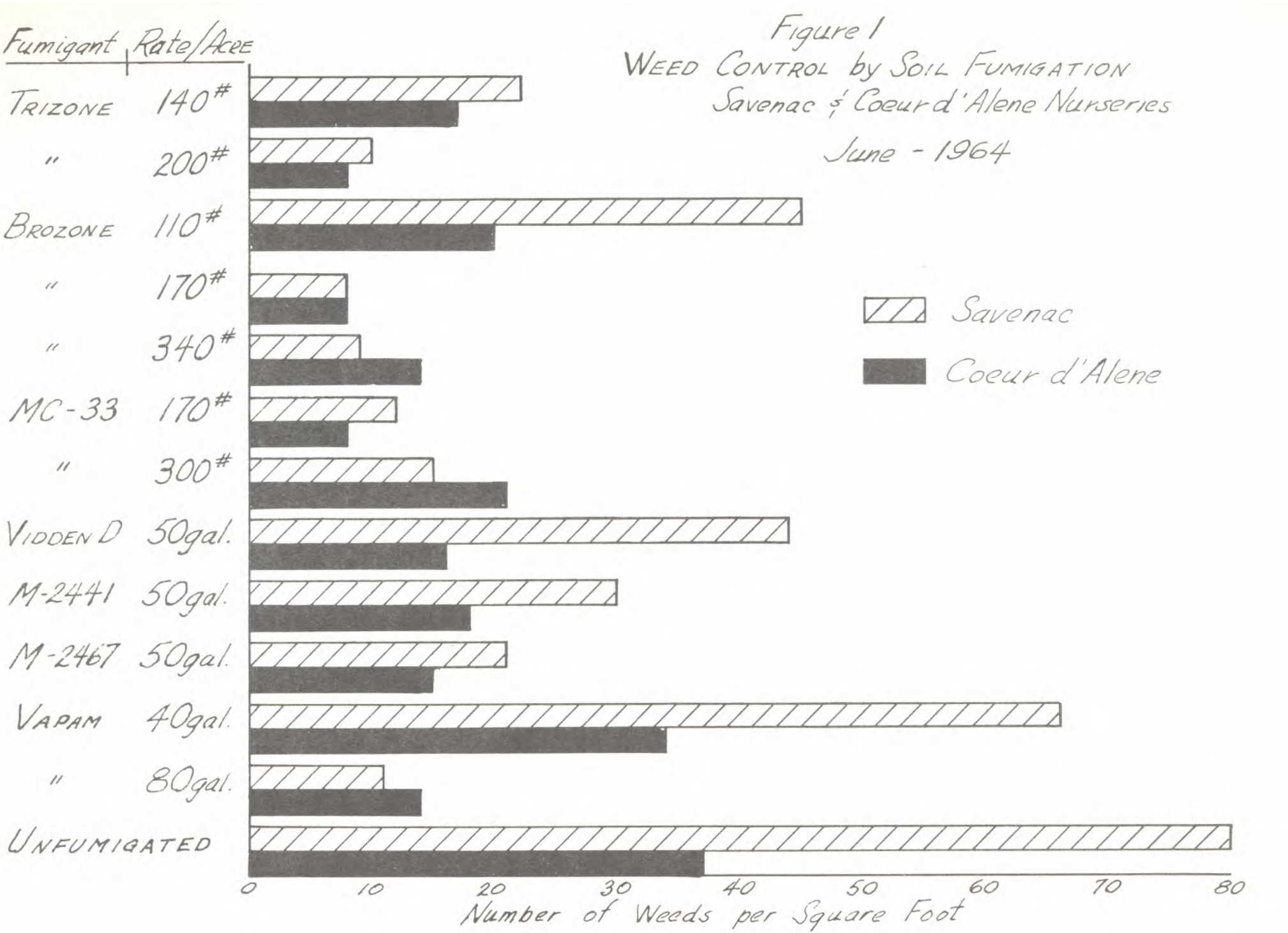
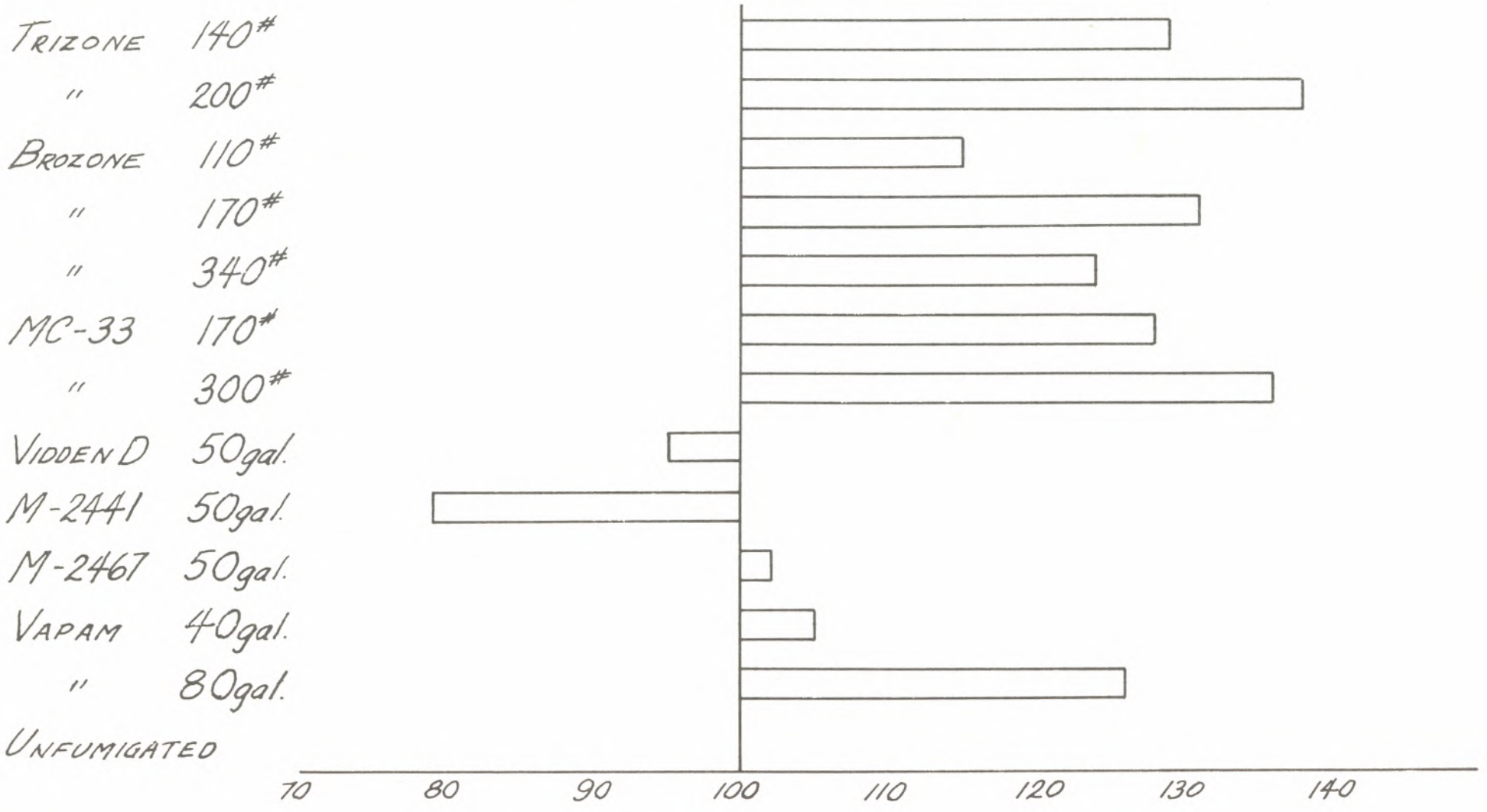


Figure 1
WEED CONTROL by SOIL FUMIGATION
Savenac & Coeur d'Alene Nurseries
June - 1964

Figure 2

AVERAGE PLANT COUNT as a % of UNFUMIGATED
Coeur d'Alene & Savenac Nurseries
All Species - 1964



or some other selective herbicide, it will cost just as much to kill the 10 per square foot as it would 100 per square foot in the unfumigated soil, since, in the application of selective herbicides the amount of chemical needed is a function of the area rather than the weed density.

While our studies have not been completed, it would appear that soil fumigation as a weed control measure is of marginal economic benefit. A situation with extremely high residual weed seed population, or a high component of weeds resistant to selective herbicides such as the aromatic oils, might economically justify fumigation for weed control. Fumigation to control weeds might also be justified where there is no known selective herbicide. (For instance, lodgepole pine and western larch which are apparently very sensitive to aromatic oils at any stage of development.)

Although fumigation as a weed control measure may be economically marginal, one must look at other fumigation benefits before he decides for or against the practice. In our studies, the other benefits have been far more impressive from a hard•nosed, economic approach than the weed control aspects. However, the same Questions of alternative approaches still plague us.

Disease Control. The evaluation of disease control in our fumigation tests has been Quite gross, with little information on the specific pathogens which we are controlling. Sample plots within the fumigation test areas were sown with counted seeds, and their fate has been followed. These counted-- seed sowings have been supplemented with regular nursery inventory data and periodic counts of dead and dying seedlings.

Figure 2 shows the gross effects of each fumigant on plant-percent as compared to the same seed lots sown in unfumigated soils. For instance, for each 100 -plant yield on unfumigated soil we grew 136 plants on soils fumigated with MC•33 at 300 pounds/acre and 79 plants on soil fumigated with M-2441, at 50 gallons/acre. In this gross appraisal there is probably little basis for choosing between Trizone at 140 and 200, Brozone at 170 and 3i-0, MC-33 at 170 and 300, and Vapam at 80. The remainder are definitely inferior in producing the desired results.

The performance of individual species on soils treated with various fumigants is often different than the general averages shown above. Data for white pine, ponderosa pine, Douglas fir and Engelmann spruce are shown in Table 2.

(Table 2 on following page)

Table 2. Average Plant-Count as a Percentage of Count in Unfumigated Soil, Coeur d'Alene and Savenac

Fumigant	Rate of App.	Species			
		Spruce	White Pine	Douglas Fir	Ponderosa Pine
Trizone	140#/acre	152	131	126	118
	200#/acre	152	151	148	124
Brozone	110#/acre	129	105	106	112
	170#/acre	105	151	144	124
	340#/acre	100	146	132	110
MC-33	170#/acre	114	167	139	105
	300#/acre	169	158	100	129
Vidden D	50 gal./acre	76	107	68	108
M-2441	50 gal./acre	93	81	88	70
M-2467	50 gal./acre	121	105	74	109
Vapam	40 gal./acre	100	147	86	96
Vapam	80 gal./acre	150	167	150	91

Of all the species sown, ponderosa pine benefited least from fumigant control of diseases. The average response of ponderosa pine to fumigants, other than those containing 1,3-dichloropropene (Vidden D, M-2441, and M-2467), was 113 percent. By comparison, Douglas fir had the next highest response (126 percent), followed closely by spruce with 130 percent. White pine benefited most from disease control by fumigation with a yield of 147 seedlings in treated beds for every 100 produced in unfumigated soils.

Compounds containing 1,3-dichloropropene (Vidden D, M-2441 and M-2467) did not control diseases -- or were in many cases detrimental to the seedling stand. Vapam, which proved highly effective with white pine, Douglas fir and Engelmann spruce, was slightly detrimental to ponderosa pine.

Growth. Some workers in the field of soil fumigation have reported fumigant-induced stimulation of plant growth beyond that which can be attributed to disease and weed control. While we have had some outstanding growth on fumigated soils as compared to the controls, our information is not sufficient to determine the cause of this growth. response. I suspect that the response which we observe is more a matter of control of sub--lethal diseases which reduce seedling vigor and growth, but do not necessarily kill.

In our 1961 studies, we thought that we could see differences in seedling size, but measurements indicated that fumigation had no effect on size. Spring-fumigation followed by spring-sowing reduced seedling size. In our large 1963 fall-fumigation test we have observed some outstanding differences, and suspect other, more subtle effects. Growth differences have not been measured yet, and observations are subject to illusions. For instance, it is easy to imagine that seedlings in a dense bed are larger and more vigorous

than equivalent seedlings in a sparse bed. As a corollary to this, the measurement of growth effects can be complicated by the effects of fumigation on density and the subsequent effects of density on growth. Seedlings in dense beds tend to be taller than those in sparse beds whether fumigated or not. Wherever possible, we have attempted to eliminate this confounding by thinning small plots of fumigated and unfumigated beds to a constant density for future evaluation of the effects of fumigation on growth.

I hesitate to say more about growth response, since we have so few measurements with which to quantify these responses. However, some responses have been so obvious that I would be remiss not to report them. They are as follows:

1. A 1960 fumigation with Trizone at Savenac produced white pine approximately twice as large as those grown in unfumigated soils. They were transplanted as 1•0 and shipped as 1-1.

2. The 1963 spring-fumigation at Coeur d'Alene,already referred to, produced seedlings equal to or smaller than those from unfumigated soils.

3. In our 1963 fall-fumigation series, the fall-sown white pine has been particularly sensitive to fumigation in terms of growth responses.

At Savenac, and to a lesser extent at Coeur d'Alene, seedlings grown in soils fumigated with 80 gallons of Vapam per acre are considerably larger than their checks. An obvious bronzing of the foliage is also characteristic of the seedlings from the Vapam-treated soils, but it does not seem to affect their growth. Phosphorus availability, according to soil tests, has not been affected by fumigation. Other fumigants which have apparently increased growth in the fall•sown white pine are MC-33 at 300 pounds/acre, Trizone at 200 pounds/acre and Brozone at 170 and 340 pounds/acre. Growth differences in other species were either too subtle, or the seedlings too small (spruce) to report on an observational basis.

Observations on Season of Fumigation. While there is probably some advantage to sowing, or transplanting, as soon after fumigation as possible, we have had poor luck with spring-fumigation in preparation for sowing the same spring. We cannot depend upon soil temperatures being high enough for effective fumigation until mid-May. Allowing 1-2 weeks for the fumigants to do their work and dissipate from the soils, then sowing or transplanting cannot be done until late May or early June. I would imagine that most northern nurseries would find this a limiting factor. In addition to these shortcomings, seedlings grown in spring-fumigated beds were often stunted and chlrotic. Jim Augenstein summed it up quite well as he walked through the study area when he said, "We should use this stuff called 'check,' only more of it.'"

On the other hand, we have had consistently good results with fall-fumigation followed by fall-sowing of white pine. All the other species have been spring-sown in fall-fumigated beds. If fumigation is done in late August or early September before soil temperatures fall below optimum I can see no reason why seeds could not be sown in late October or early November.

SUMMARY

While some of the soil fumigants tested have provided considerable weed control, the cost of this control in view of cheaper alternatives makes fumigation for weed control economically marginal. On the other hand, fumigation control of diseases with its attendant savings in seed cost and better seedling vigor has made fumigation profitable at the Coeur d'Alene and Savenac nurseries. Fall fumigation followed by fall or spring sowing has been superior to spring fumigation followed by spring sowing. Fumigants containing dichloropropenes were generally inferior to other fumigants. Other fumigants provided good weed and disease control, usually at the higher rates of application. All of the results reported are based on nursery evaluation. None of the seedlings have been tested for field survival and growth performance.