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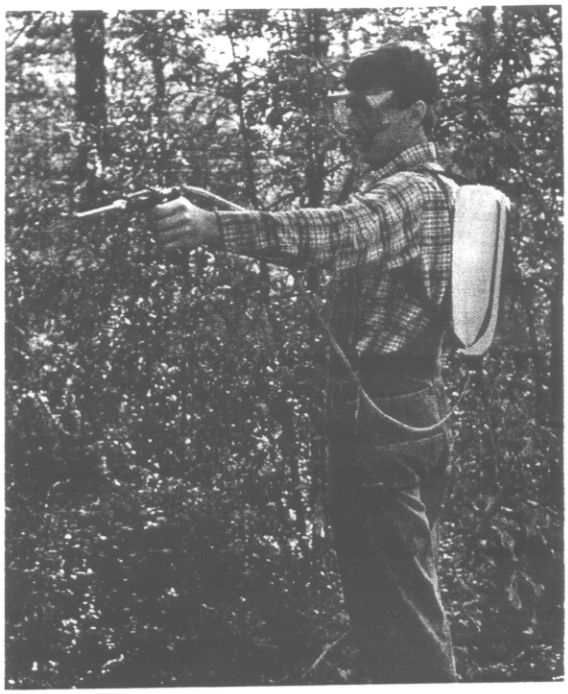
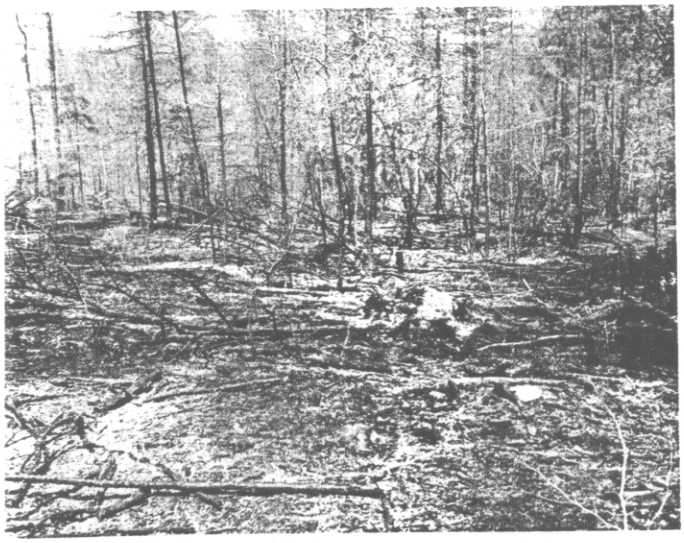




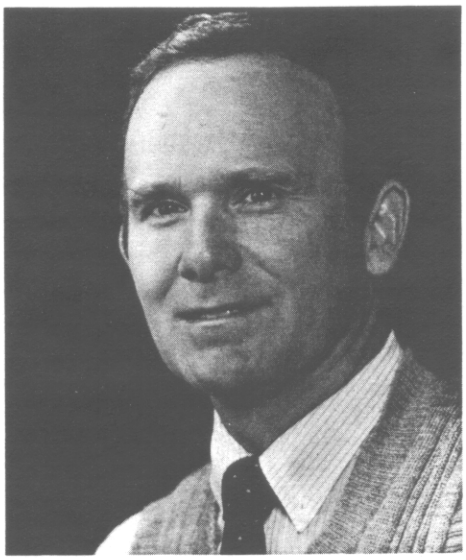
DEVELOPMENT AND EVALUATION OF LOW-COST SYSTEMS FOR ARTIFICIAL REGENERATION OF PINES

By:
Michael S. Golden

RESEARCH DIVISION

GEORGIA FORESTRY COMMISSION

About The Author



Michael S. Golden is an Associate Professor of Forestry at Auburn University and a staff member of the Alabama Agricultural Experiment Station. He received his M.S. in Forest Ecology at Auburn University and a Ph. D. in Plant Ecology at the University of Tennessee. He has been teaching and conducting research in silviculture and ecology at Auburn since 1975.

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Development And Evaluation Of Low-Cost Systems For Artificial Regeneration Of Pines

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INTRODUCTION

A series of studies was initiated to explore potential lower-cost alternatives for establishment of pines on cutover forest lands in the southern Piedmont and hilly Coastal Plain. In particular, the individual forest landowner with a modest or small-sized tract needs reasonable alternatives to the expensive, highly intensive techniques involving heavy machinery and land clearing. Systems were sought which would avoid the requirements of large, expensive, or highly specialized equipment and which could cost substantially less than the typical $150-$200 per acre now common for loblolly pine plantation establishment on cutover sites.

Generally, the two most important objectives in site preparation on upland sites are to control competition and to facilitate planting of seedlings. The latter objective is accomplished through removal or reduction of stumps and debris and is most crucial where machine planting is planned. However, this removal process, when conducted with large machinery, often has negative side effects, such as removal of topsoil, increased erosion, and stream sedimentation. Besides being quite sensitive to surface roughness and the presence of obstacles, machine planting efficiency is affected by tract size .The small acreages typically involved for individual landowners are often economically impractical for machine planting. Handplanting is much less sensitive to residual stumps and debris, as well as tract size, although efficiency and thoroughness will suffer as the amount of obstacles increases.

However, the more intractable problem in pine establishment on cutover sites is competition. The shade intolerance of southern pines and the profuse sprouting ability of most hardwoods combine to result in inadequate pine establishment on most cutover sites where no action is taken to reduce competing vegetation. The only apparent alternatives to mechanical removal are fire and herbicides. Burning is much cheaper than mechanical treatment and can consume much of the vegetative impedances to planting. However, its effectiveness when used alone is questionable, since many hardwoods are not killed and sprout quickly and profusely after being topkilled.

Herbicides are registered and commercially available which will, according to their manufacturers, kill most of the competing hardwood species when applied at recommended rates and with certain application techniques. However,most of the recommended rates and application techniques result in site preparation costs similar to those of intensive mechanical approaches and typically require use of aircraft or large sprayers. Much more information is needed on more selective application techniques and lower per acre rates. Additionally, herbicide use in combination with burning needs further study.

The studies which are the subject of this report were initiated to add information relative to the use of fire and herbicides in the context of small land holdings. These studies were designed to be exploratory rather than definitive in nature. The major goal was to determine whether certain potentially workable burning/herbicide systems could be reasonably effective for pine establishment and still remain cost-effective.

PROCEDURES

Five different studies were installed, involving various combinations of sites, herbicides, applications, and burn/herbicide timing. All five included broadcast burning, but varied in the season of burn and the timing relative to the application of herbicide (Table 1). The assumption was made that burning would normally be the minimum site preparation treatment that a landowner should consider for pine establishment on cutover land.

Randomized complete-block designs with 5 to 7 blocks having 1/4 acre treatment and 1/8 acre measurement plots were used for the first three studies (Piedmont burn-first, Piedmont comparison, and Coastal Plain comparison). The Piedmont tagged rootstock study employed a completely random design of 1/40 acre treatment and 1/100 acre measurement plots, with 7 or 8 replications of each treatment.

Each of the study sites had been recently cut over, with all merchantable trees removed. Residual hardwood trees and rootstocks were abundant on each however, so that poor pine plantation success would be expected without some competition control treatment.

Study Sites

The sites for four of the studies (Piedmont burn-first, Piedmont comparison, and the two tagged rootstock studies) are located near the southern terminus of the Piedmont Physiographic Province, in Lee County, Alabama. Hodgkins et al. (1979) classified this area as part of the Opelika Plateau Forest Habitat Region. It is typified by gently to somewhat steeply rolling topography, underlain primarily by granites and gneisses. It is typical of a large acreage in east-central Alabama and central Georgia. The soils are predominantly Gwinnett sandy loams (clayey, kaolinitic, thermic Typic Rhodudult) and Pacolet sandy loams (clayey, kaolinitic, thermic Typic Hapludult).

As with most of the southern Piedmont, these areas were farmed at one time, and terraces are still evident on hillsides. Before harvest, they were covered primarily by variably stocked second-growth stands of shortleaf and loblolly pines,with a mixture of oaks, hickories, and other hardwoods (principally sweetgum, yellow-poplar, dogwood, and red maple). All commercially valuable timber, both sawtimber and pulpwood, was harvested within a year prior to treatments.

The Coastal Plain comparison study site is located in the Loam Hills Region of the Hilly Coastal Plain Province (Hodgkins et al. 1979) in Macon County, Alabama. The terrain is rolling to moderately hilly, with quite variable surface soils, ranging from sandy clay loam to loamy sand. Slopes within the study plots were gentle, ranging from about 2% to 8%.

Treatments

Hexazinone, in a liquid formulation marketed by DuPont under the trade name "Velpar L", was applied using a "spot gun" in three of the studies and applied with a hand-

Table 1. Characteristics of five studies involving effects of burning and hand-applied herbicides on pine establishment.

Study Name	Time of herbicide application	Timing of burn	Treatments tested
Piedmont burn-first	after burning	late winter	burn-only burn + Velpar L[1]/
Piedmont comparison (Velpar-Tordon)	before burning	fall	burn + Velpar L burn+Tordon 10K[2]/
Coastal Plain comparison (Velpar-Tordon)	before burning	fall	burn only burn + Velpar L burn + Tordon 10K
Piedmont tagged rootstocks	after burning	winter	burn + Velpar-L burn + Tordon 101M[3]/ burn + Garlon 4 [4]/
Piedmont tagged rootstocks	after burning	spring	burn + Velpar-L burn + Tordon 101M burn + Garlon 4

[1]/Hexazinone [2]/Picloram in granules.
[3]/Picloram and 2,4-D mixture. [4]/Triclopyr ester.

pumped backpack sprayer in the two tagged rootstock studies. Picloram, in a granular formulation marketed by Dow under the trade name "Tordon 10K", was applied with measuring spoons by hand in two of the studies. It was applied as a liquid mixture with 2,4-D (marketed as "Tordon 101M") by backpack sprayer in the tagged rootstock studies. Triclopyr (marketed as "Garlon 4") was also applied by backpack sprayer in the two tagged rootstock studies.

In the spot gun applications used here, the Velpar L product was diluted 50% with water and applied with a spot gun set to deliver three ml per trigger squeeze. Six milliliters of solution per one inch of stump or base diameter were applied to the ground near the base of each live rootstock on the treatment plots. Heavy patches of woody vines, such as Japanese honeysuckle or grape, were treated on a grid basis, with spots three feet apart.

In the tagged rootstock studies, the herbicides were also diluted with water. The Velpar L was applied as a 7% solution, the Tordon 101M as a 10% solution, and the Garlon 4 as a 4% solution.

Loblolly pine seedlings were hand planted at an 8X8 ft spacing in three of the studies. One of the studies, the "Piedmont burn-first", examined the application of Velpar in late spring following planting of pine seedlings after a winter burn. In contrast, seedlings were planted in the late winter following herbicide treatment and burning in the "Piedmont comparison" and "Coastal Plain comparison" studies.

Data Collection and Analysis

For each study, data were taken on vegetation present in late winter just before treatments were applied, then at some point during the growing season following the burn, and then at least one time during or following the growing season after the herbicide was applied. All woody stems were inventoried by species or species group within a measurement plot or subplot. Additionally, in the two tagged rootstock studies, 5 to 14 rootstocks each of sweetgum and oaks in each plot were marked with aluminum tags to allow monitoring of survival and growth.

In the three studies where pine seedling data were taken (Table 1), these measurements were taken immediately after planting to establish initial densities and heights, then again during November or December to determine growth and survival.

Data summarization and analyses were performed using procedures of the Statistical Analysis System (SAS, Freund and Littell 1982). General linear model and simple analysis of variance, analysis of covariance, Duncan's New Multiple Range test, Scheffe's test, and t-tests were performed where appropriate to test for differences among treatment results.

RESULTS

Piedmont Burn-First Study

This study examined the application of a hot winter burn, hand planting soon after, then application of Velpar L by spot gun in late spring. This was directly compared to burning and planting with no herbicide treatment.

Basal areas for woody competing vegetation for pretreatment and during the second and third growing seasons are shown on Table 2. The spot gun treatment significantly reduced the total woody competition basal area and that of several individual species. Red oak, sweetgum, maple, dogwood, *Prunus*, hickory, sumac, and yellow-poplar were all significantly reduced during the second growing season. By midsummer of the third season, the gap had narrowed between the burn-only and

Table 2. Mean basal area (ft²) per acre of woody non-pine vegetation, by treatment, Piedmont Burn-first study. All significant comparisons are shown.

	Pretreatment 1982		June 1983		June 1984	
Species	BO[1]/	Velpar	BO	Velpar	BO	Velpar
All combined	19.99	14.12	50.89	16.63**[2]/	26.72	11.31**
Red oak	1.76	1.86	7.10	3.13**	5.03	1.92*
Sweetgum	1.92	2.07	9.95	1.84**	5.16	1.34**
Maple	1.51	0.10	1.83	0.91*	1.03	0.41**
Prunus spp	1.11	0.64	2.79	0.36**	1.13	0.20**
Dogwood	0.76	0.91	3.69	0.83**	1.45	0.60
Hickory	0.03	0.10	0.72	0.27**	0.22	0.20
Sumac	0.07	0.02	8.06	1.87**	2.25	0.94*
Yellow-poplar	1.09	0.36	1.09	0.50*	0.67	0.49
Eastern redbud	1.91	1.11	5.43	2.20	2.43	0.94*

[1]/BO is the burn only treatment.
[2]/*=significant at the 0.05 level.
**=significantly different at the 0.01 level.

spot gun treatments such that the differences were no longer significant for hickory, dogwood, or yellow-poplar.

Analysis of the data on numbers of live rootstocks in the third growing season produced similar results, although some of the sensitive species changed. Total live rootstocks were almost 3000 lower per acre on the Velpar-treated plots than on the burn-over plots (4961 vs. 7891). Sassafras and winged elm exhibited significant rootstock death in response to Velpar, along with sweetgum, red oaks, Prunus, and sumac.

The exception to this was yellow-poplar. Although its basal area was reduced on the spot gun plots relative to the burn-over plots, its number of live rootstocks was actually higher (237 vs. 97 per acre) on the spot gun plots in 1984. This appears to reflect an increase in seedlings on the spot gun plots, but a decrease in larger stems. American beautyberry rootstocks also showed an increase on the spot gun plots (190 vs. 27 per acre). The yellow-poplar and beautyberry appear to be responding to reduced competition on the spot gun plots. Both seed in rapidly in a burned area, and since the Velpar had greatly reduced both woody and herbaceous competition, establishment and survival of new seedlings of these species was greater than on the burn-only plots.

Although yellow-poplar, maple, and dogwood are reported to be "hard-to-kill" species for Velpar, basal area was significantly reduced during the second season for all three with the spot gun applications used here. This may indicate that specific targeting of stems, such as is accomplished in spot gun application, may give improved kill for difficult species over the typical broadcast applications.

For the pine seedlings, after two growing seasons heights and survival still did not differ significantly (Table 3) between the Velpar-treated and the burn-only control plots. Thus, the Velar spot gun treatment did not result in any statistically significant increase or decrease in either survival or height growth after two growing seasons.

First-year planted seedlings survival was somewhat low on both burn-only and the herbicide-treated plots, 60% for the treated plots and 58% for the controls. The soil was quite dry at planting, and the summer of 1982 had an extended drought period, which may have contributed to high mortality. Otherwise, the explanation for such low survival is not apparent. Very little additional mortality occurred during the second year.

Most relevant to this study, however, is the result that survival on the spot gun-treated plots was not lower than on the burn-only plots. It was possible to apply the liquid Velpar using the spot gun, get effective reduction of competing vegetation, and avoid killing a significant number of pine seedlings.

Some tip moth damage and deer browsing resulted in a high degree of variation among the heights of individual trees within treatments. This variation would tend to mask any differences in treatment effects. Despite the lack of detectable difference in heights at two years, a possible trend toward increasingly taller heights in the Velpar-treated plots is indicated (Table 3).

The Velpar treatments did result in a significantly larger average seedling ground line diameter (GLD) (Table 3). This probably reflects the reduced competition from both woody and herbaceous vegetation.

Piedmont Comparison Study

This study differed from that just described in two major ways. First, it approached the competition problem by the more conventional approach of applying herbicides before burning and before planting rather than after. Secondly, it compared two different herbicides to each other, but not to burning alone. Consequently, this study was designed to determine only whether the two herbicides (Velpar L and Tordon 10K), applied by hand, differed in their effectiveness in suppressing competing vegetation and in increasing pine seedling early survival and growth.

When compared across all sizes and species, woody competition during the second growing season did not differ significantly in basal area between the two treatments (Table 4). However, Velpar was more effective in suppressing basal area of hickory and both red and white oaks. Although untreated plots were not available for direct comparison, it is apparent that both herbicide treatments reduced the amount of competing vegetation that

Table 3. Pine seedling survival, heights,and ground-line diameters (GLD) at the Piedmont burn-first study site, by treatment.

	Pretreatment Jan. 1982		Fall 1982		Fall 1983	
Variable	BO[1]/	Velpar	BO	Velpar	BO	Velpar
Survival (%)	--	--	58	60	56	57
Height (in.)	9.0	8.7	13.9	14.9	29.5	30.9
Height growth (in.)	--	--	5.1	5.6	20.7	21.6
GLD (in.)	--	--	--	--	0.4	0.6[2]/

[1]/Burn only
[2]/Significantly different at the 0.05 level.

Table 4. Mean basal area (ft²) for woody non-pine vegetation, by time and treatment, Piedmont Velpar-Tordon comparison study, all diameter classes. All significant comparisons are shown.

	Pretreatment April 1982		Summer 1983		Summer 1984	
Species	Tordon	Velpar	Tordon	Velpar	Tordon	Velpar
All combined	77.57	65.64	70.59	57.76	50.87	42.37
Hickory	5.71	6.73	4.78	1.28**	4.94	0.74*
Red oak	22.14	15.02	16.32	2.27*	12.09	2.09*
White oak	3.28	1.39	3.16	0.69*	3.39	0.44*
Prunus spp	1.28	2.53	3.54	1.76*	2.50	0.94
Sweetgum	15.52	17.12	14.73	11.18	9.03	4.90

*Significant at 0.05 level.
**Significant at 0.01 level.

would have been present during the second growing season without herbicide treatment. This is indicated by the considerably lower basal areas present in 1984 than were present at planting. Normally, without more than a burn, the competition basal areas tend to be higher by the second season than they were before treatment, as was indicated in Table 2 from the burn-first study.

For pine seedlings, there was no difference in survival between the two herbicide treatments, 88.6% and 86.7% for the Tordon and Velpar plots, respectively (Table 5). Although neither the total height nor GLD were different, the amount of height growth on the Velpar-treated plots was significantly higher, 8.1 in. vs 7.3 in. (Table 5).

Coastal Plain Comparison Study

A third study was installed on a Coastal plain site in which the same two herbicide treatments were compared to each other and to burning alone. In this study, the broadcast burn was applied in October 1982, after the herbicide treatments had been applied the previous April. The pine seedlings were hand-planted during the following January, 1983.

Both herbicides reduced overall plot competition basal area compared to that of burning alone after two growing seasons (Table 6). This reduction was due not only to the death of large stems, but also due not only to the death of large stems, but also due to reduced sprouting. The reduction in basal area by Velpar was significant for five individual species or genera: southern bayberry, hickory, sweetgum, hawthorn, and winged elm (Table 6). Individual species significantly reduced by Tordon (compared to burning) were southern bayberry, and *Vaccinium*.

Compared to the burn-only plots, American beautyberry actually increased on both types of herbicide treatments, and significantly more so on the Velpar plots. American beautyberry is a rapid invasion species which apparently was able to take advantage of the reduced vegetation levels on the treated plots.

First-year seedling survival exceeded 90% for all treatments. The seedling heights were not significantly different. GLD's averaged 0.03 in. greater on the Velpar-treated plots than on either the burn-only or Tordon-treated plots, which were the same (Table 7). Although this difference was statistically significant, it is so small that it is of dubious importance at this young age.

Piedmont Tagged Rootstock Studies

It was desirable to look more closely at the effects of application of herbicides following burning. There is little information available regarding this sequence, in contrast to the conventional application before burning. Additionally, our experience with and the results from the previously described burn-after spot gun study were encouraging. The application was so conspicuously easier and faster than the

Table 5. Pine seedling survival, height growth, and groundline diameters (GLD), by time and treatment, Piedmont Velpar-Tordon comparison study.

	Pretreatment Jan. 1983		December 1984	
Variable	Tordon	Velpar	Tordon	Velpar
Survival (%)	--	--	88.6	86.7
Height (in.)	7.9	7.9	15.2	16.0
Height growth (in.)	--	--	7.3	8.1*
GLD (in.)	--	--	0.2	0.2

*Significantly different at the 0.05 level.

Table 6. Basal areas (ft²) per acre for woody non-pine vegetation, by time and treatment, Coastal Plain comparison study. All significant comparisons are shown. Values in a row group with the same letter or no letter are not significantly different at the 0.05 level using Scheffe's test.

	April 1982 Pretreatment			August 1983			August 1984		
	BO	Velpar	Tordon	BO	Velpar	Tordon	BO	Velpar	Tordon
All combined	64.6	67.6	66.4	71.9a	36.9b	44.2ab	51.9a	29.5ab	18.9b
Bayberry	5.0	4.5	4.2	6.5a	2.8b	3.1b	3.4a	1.6b	1.6b
Hickory	0.6	1.6	1.4	1.7a	0.5 b	0.8ab	0.7a	0.3b	0.5ab
Sweetgum	17.3	16.5	19.7	22.4a	8.1b	8.4b	20.3a	3.6b	4.2b
Hawthorn	1.7	1.0	1.6	3.6a	0.4b	1.4ab	2.1a	0.3b	0.9ab
Winged elm	0.5	0.2	0.2	0.7a	0.1b	0.2b	0.3a	0.1b	0.1ab
Beautyberry	0.0	0.0	0.0	0.1a	1.2a	0.4a	0.1b	0.8a	0.3ab
Vaccinium spp	3.7	2.3	1.9	8.8a	7.0a	2.5b	6.0a	4.0a	1.8b

case where the site was unburned that this approach should have more appeal to the persons who have to accomplish the work. Effectiveness remained a major question.

Where appropriate, herbicide treatments were applied on each area after the surviving rootstocks had fully leafed out following the burn. This was on June 11 for the winter burn, but was not until July 1 for the spring burn. On these plots, all woody vegetation within reach (to approximately 8 ft. above the ground) was sprayed to wetting over the entire leaf area. For all hardwoods over 8 ft. tall, each herbicide was also applied as a basal spray until the base was thoroughly wetted.

A comparison of the numbers of live tagged rootstocks before burning, soon after burning, and during the second growing season after treatment is presented for both the winter and spring burn studies in Fig. 1.

In the burning alone treatments, the spring burn was obviously more effective than the winter burn, for both sweetgum and oaks. The winter burn resulted in only a 6% kill of rootstocks (no resprouting observed) for each species, whereas the spring burn killed 10% of the sweetgums and 24% of the oaks (Fig 1).

All three herbicide treatments very clearly and significantly reduced both the number of live rootstocks (Fig 1) and number of stems in comparison to burning alone. The reduction for sweetgum was less in every case than for the oaks, indicating that it is more resistant than oaks to all three herbicides. The effectiveness of the three herbicide treatments was similar, although the Garlon treatment in most cases had higher kill percentages.

The herbicide treatments were also effective in reducing the height of the sweetgum and oak sprouts. This is, of course, quite important in affecting the overtopping of the pine seedlings by these competing sprouts. Again the spring burn was more effective, the oaks were more strongly suppressed than the sweetgums, and Garlon appeared to be slightly more effective than the other two herbicides.

Application of herbicide with a spot gun.

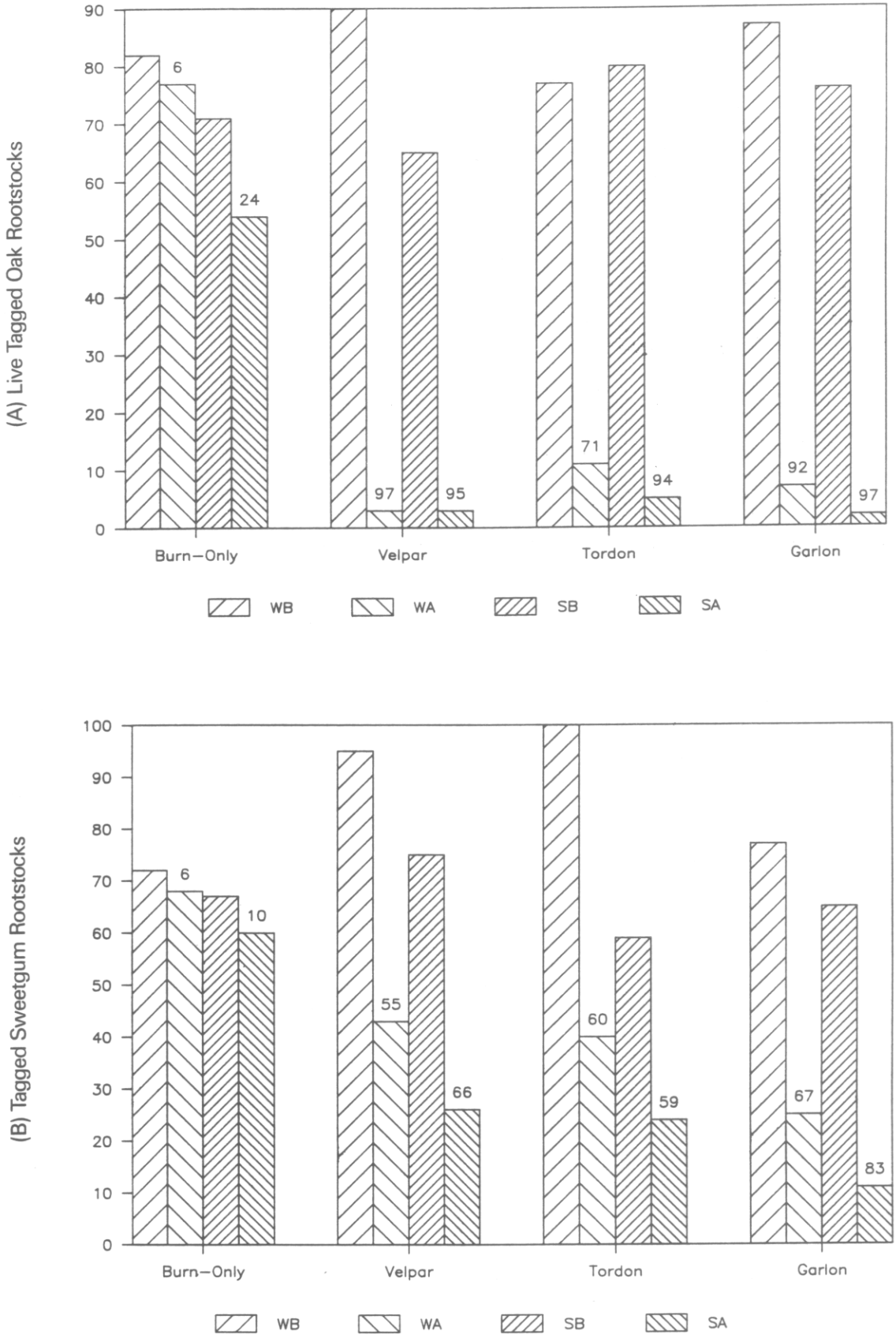

Figure 1. *Piedmont tagged rootstock studies: number of living tagged rootstocks, by herbicide treatment, for before the winter burn (WB), the second summer after the winter burn (WA), before the spring burn (SB), and the second summer after the spring burn (SA). Numbers above the "after" treatment bars reflect the percent reduction in living rootstocks resulting from the treatment.* ***Part A*** is for oaks, **part B** for sweetgum.

SUMMARY AND CONCLUSIONS

In every case and situation tested, the herbicide treatment along with burning was significantly more effective in reducing non-pine woody vegetation than the burning alone. Velpar L applied with a "spot gun" and Tordon 10K pellets applied by hand significantly reduced the non-pine vegetation on both Piedmont and Coastal Plain sites. The two herbicide treatments were similar in their effectiveness, although the Velpar was generally more effective for oaks and hickory.

It was determined that burning the site first, then applying herbicide to the resprouting vegetation was effective on two different Piedmont sites, using both winter and sring burns. For one of these, application of Velpar L by spot guns afer the pines were planted also approved to be feasible, in that no increased seedling mortality was detected. Application of Velpar L, Tordon 101M, and Garlon 4 by backpack sprayer after both winter and spring burning proved effective in reducing oaks and sweetgum. The spring burn treatments were, however, more effective than the winter burns.

The application rates and approximate current chemical costs of the herbicide treatments are shown in Table 8. The chemical costs on the less dense sites with the burn-first applications are consistently around $60 per acre. The chemical costs on the denser sites, which used burn-after applications, range from about $71 to about $84 per acre. The two studies using the pelletized herbicide, Tordon 10K, are quite close in rates applied, just over 20 lbs/acre, which reaches the label-recommended broadcast rate range of 20 to 60 lbs per acre.

The applications of liquid Velpar varied significantly, differing by more than 1/2 gallon/acre between extremes. The rate applied on the Coastal Plain study barely reached the label-recommended broadcast application range of 2 to 4 gallons per acre. The Piedmont burn-first spot gun and backpack spray applications of Velpar L fell at least 1/2 gallon below the minimum label-recommended broadcast rates.

The two sites which had the higher chemical rates, the Piedmont comparison site and the Coastal Plain comparison site, had considerably higher basal areas and rootstock densities than the other two sites which used the burn-first treatment. A strong relationship between competition density and application rates should be expected, since, where possible, the chemical was directed only toward living rootstocks rather than being broadcast without regard to vegetation density.

The backpack spray rate for the Tordon 101M application, 2.16 gallons per acre, falls within the label-recommended broadcast rate range of 1 to 4 gallons. The Garlon 4 backpack spray application of 0.87 gallons per acre falls slightly below the label-recommended broadcast rate range of 1 to 2 gallons.

Subjective observation of the vegetative response to the backpack spraying treatments left the distinct impression that the applications were heavier than necessary. It appears quite possible that less spray applied to each sprout may have been just as effective, thus reducing the total amount of chemical applied. They were sprayed until runoff, but perhaps thorough wetting without reaching the point of runoff would have been sufficient. The application rates, in other words, could use futher refinement to achieve greater cost-effectiveness.

Thus it is quite possible that the chemical cost for one of the burn-first spray treatments where competition densities are modest (less than 5000 rootstocks/acre) might be reducible.

Average actual application time for the studies ranged from 2.14 to 2.75 hours per acre for the spot gun applications and from 2.10 to 2.35 hours per acre for the Tordon 10K

Table 7. Pine seedling survival, height growth, and ground line diameter (GLD),by time and treatment, Coastal Plain Velpar-Tordon comparison study. Values in a row group with the same letter are not significantly different at the 0.05 level.

	Pretreatment Jan. 1983			December 1983		
Variable	BO	Velpar	Tordon	BO	Velpar	Tordon
Survival (%)	--	--	--	95a	92a	95a
Height (in.)	8.4a	8.0ab	7.7 b	15.5a	16.7a	15.7a
Height growth (in.)	--	--	--	7.6a	8.7a	7.8a
(GLD) (in.)	--	--	--	0.20 b	0.23a	0.20 b

Table 8. Herbicide product application rates and approximate chemical costs [1]/ for the four study sites.

	Tordon 10K		Velpar		Tordon 101M		Garlon 4	
Study	1b./A	$/A	gal/A	$/A	gal/A	$/A	gal/A	$/A
Piedmont burn-first	--	--	1.43	60.17	--	--	--	--
Piedmont comparison	20.2	79.99	1.71	71.84	--	--	--	--
Coastal Plain comparison	21.32	84.43	2.01	84.42	--	--	--	--
Piedmont Tagged Rootstocks	--	--	1.51	63.59	2.16	61.78	0.87	59.30

[1]/Costs used are low - volume quotes from Resource Management Inc. in February, 1986: Tordon 10K @ $3.96/lb, Velpar-L @ $42.00/gal, Tordon 101M @ $28.56/gal, and Garlon 4 @ $68.56/gal.

pellet applications.

Average application time for the backpack spraying studies was much longer. The actual spraying time on these small research plots averaged in excess of 4 hours per acre. The person who conducted these applications was quite methodical and meticulous. It is quite clear that, operationally,this time could be reduced substantially. On larger contiguous areas, with less wasted time on research-related details and with more opportunity for improvement through practice, it may be possible to reduce this by 25 to 50%. This is especially true if herbicide efficacy could be maintained with less thorough wetting, as seems likely. Obviously, the density of vegetation will also affect these times. It seems reasonable then to estimate operational labor rates in the range of 2 to 3 hours per acre, with density of vegetation and experience of the applicator being major influential factors. At $5/hour for labor, this would add $10 to $15 per acre to the treatment costs.

To get a more complete picture of the approximate costs of the type of treatments studied here, the cost of burning has to be added. This cost will depend somewhat on whether the landowner contracts part or all of the burning tasks, or is able to accomplish them himself. Normally, firebreaks must be plowed, except in instances where the site is surrounded by roads, streams, or plowed fields. Where contracted, prescribed burning costs typically vary somewhat with the size of the parcel to be burned. Taking all of these possible factors into consideration, the costs of burning are likely to fall in a range of $3 to $8 per acre.

When the likely ranges of chemical costs, labor costs, and burning costs are combined, one arrives at a range of roughly $70 to $105 per acre for the site preparation expenses. At the upper end, this is somewhat comparable to mechanical site preparation costs and reaches or exceeds broadcast contracted chemical site preparation costs. At or near the lower end, this represents a savings of possibly $10 to $50 per acre.

Hence, without further refinement, these individual stem treatment approaches save substantial costs only where hardwood rootstock densities are at moderate to low levels. At high densities, the application rates and labor times will be essentially the same as for broadcast application of herbicides.

Where they are feasible, the burn-first approaches such as those studied here appear to be potentially effective, and they have some distinct advantages over the burn-after herbicide treatment approaches. They are definitely much easier for the herbicide applicator. This could affect the availability and perhaps the cost of labor, as well as speed of work. The data of these studies suggest that, where this approach is feasible, less chemical may be required for effective competition control. This makes sense, since there is less non-target material to absorb the herbicide, some of the competing vegetation will have been killed by the fire and not require treatment, and that still alive will be in a weaker condition with lower food reserves.

Of course, burning first is not practical in many situations. Sufficient suitable fuel must be present. The most applicable case is following clearcutting of a stand which had a significant, well distributed pine component. This will provide pine litter and slash, which serves as very good fuel under proper weather conditions. A pure or almost pure hardwood stand will not usually be suitable for the burn-first approach. Hardwood litter and slash rarely provide adequate fuel for an effective burn for top-killing most of the sapling vegetation, which is necessary for this approach to be successful.

The burn-after applications used here probably represent reasonable situations where the burn-first treatment would be marginal or inadequately effective. Preharvest pine densities were lower and hardwood densities were higher on these two sites. It would have been much more difficult to get an adequate burn without the herbicide activity.

Although these studies examined only late winter and spring burning for the burn-first approach, it seems reasonable that any time from late summer to mid-spring should be possible. The spring timing will likely be most effective of any of this period, since food reserves in the rootstocks will be at their lowest levels.

One timing precaution seems advisable for the burn-first approach. The resprouting vegetation (after burning) should be allowed to approach or reach the full leaf stage before the herbicide is applied for the spray applications. This will provide more absorptive leaf surface for foliar uptake, and the root systems will also be more active than earlier, thus increasing the uptake of soil active material. This makes the timing most difficult for spring burning followed by Velpar L. If conditions delay a spring burn until late in the season, the vegetation may not sprout and refoliate adequately until past midsummer. Since the hexazinone in Velpar is primarily taken up from the soil by roots, rainfall during the late summer alone may be insufficient for good soil activity, and thus might result in less effective rootstock kill. Although it is less clear, the Tordon 101M treatment may also suffer some sensitivity to this timing problem, since much of picloram's activity is through soil uptake.

Thus, it seems sensible to recommend the triclopyr (Garlon 4) treatment for burn-first applications whenever a mid-to-late spring burn is used. This is especially appropriate in light of its generally superior kill and suppression of competing vegetation in the Piedmont Tagged Rootstocks study.

In conclusion, the herbicide-burning combination treatments examined in these studies were sufficiently effective to obtain reasonable pine plantation establishment in the situations involved. For certain conditions, these approaches can entail substantial savings in expense when compared to applicable mechanical site preparation or broadcast herbicide application. Where conditions are suitable for a hot site preparation burn, the approach of burning first then applying herbicide when topkilled vegetation approaches full refoliation appears to show promise for a simpler, easier, perhaps cheaper method than to apply the herbicide before burning. It is highly desirable that further studies attempt to gain more definitive information on the minimum effective application rates, most effective chemicals, optimal timing, and range of suitable conditions for the burn-first approach.

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