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Miller, J.H.; Glover, G.R.

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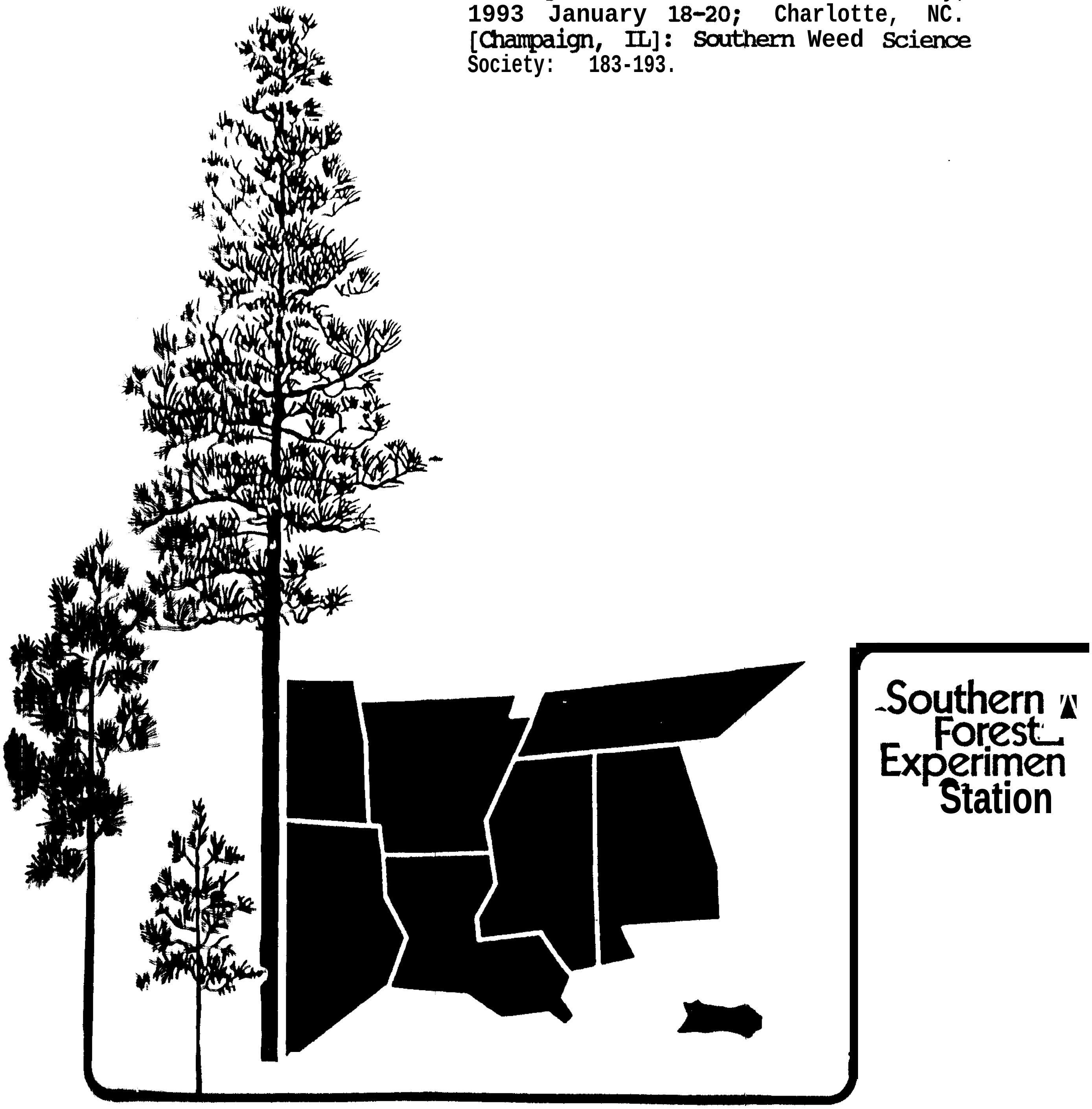

WORKER PRODUCTIVITY AND HERBICIDE USAGE FOR PINE RELEASE WITH MANUAL APPLICATION METHODS.

J.H. Miller and G.R. Glover, USDA Forest Service and School of Forestry, Auburn University, AL 36849.

ABSTRACT

Productivity, herbicide usage, and costs of manually-applied pine release treatments were examined with linear regression analysis and compared. Data came from a replicated study in a 3-year-old loblolly pine plantation in Alabama's Piedmont. Brushsawing had the highest labor costs but lowest total treatment costs. While of the herbicide treatments, the lowest costs were directed foliar sprays when rootstocks exceeded 4,100 per acre and streamlining only around pines in the dormant season when below this density. Spotgun applications in a grid pattern had the lowest labor costs when rootstocks exceeded 2,800 per acre, which could be cost-competitive with directed foliar sprays on low hexazinone rate sites. Streamline basal sprays applied in the dormant season were less costly and more labor efficient than growing season streamlining. Prediction equations are provided, but the cost-return of these. treatments can only be judged after future pine response are evaluated.

INTRODUCTION

Manually-applied pine release treatments with herbicides have increased in use over the past 10 years in southern U.S. forests- Industrial, non-industrial, and especially public land managers have increasingly employed individual stem treatments using directed foliar sprays and basal sprays. innovations in the standard application methods using lower volumes, modified nozzle setups, and improved backpack sprayers have apparently increased worker productivity, but with little documentation. The more recently registered herbicides do provide wider spectrums of control and wider application windows (2,3,5). These improvements also have aspects of enhanced applicator and environmental safety. Another treatment option, spotgun applications with liquid hexazinone (Velpar L) in grid patterns, has been used since 1981 (6). Selection of the best release method from these options-has been hindered by the lack of information on the relationships of labor and herbicide costs as affected by target stem densities.

A comprehensive comparative examination of the newer herbicides and modified application methods for pine release has not been reported to date for control efficacy, crop response, and productivity-costs relative to rootstock densities. Such a study was initiated in 1987 through cooperation among investigators with the Auburn University Silvicultural Herbicide Cooperative and the Southern Forest Experiment Station (USDA Forest Service), with partial

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funding provided by the Georgia Forestry Commission (1,7,8). Two innovative options. brushsawing with and without herbicide stump treatments, also were included in the study. This report focuses on the worker productivity and herbicide usage phase of the investigation along with additional data from added treatment plots.

METHODS

The study was established on a rolling Piedmont site in east-central Alabama using a randomized complete block design with four replications, with blocking by rootstock density. Loblolly pines (*Pinus taeda* L.) had been machine planted on a 6- x IO-ft spacing after windrowing. Crop pines were beginning their third growing season at study establishment. Treatment plots, 0.2 ac in size, were located between windrows, with a 0. 1-ac pine measurement plot encompassing two 8- x 50-ft competition measurement plots (CMP's). CMP's yielded a 9% sample of all woody plants over 2 ft tall. Heights and groundline diameters (gld's) were measured at establishment of both rootstock groupings and individual woody stems.

The original study compared the following treatments:

a. No release treatment (check).
b. Directed foliar spray with imazapyr as Arsenal AC at 0.5%.
c. Directed foliar spray with triclopyr as Garlon 4 at 2.5%.
d. Streamline basal spray with imazapyr as Chopper at 6%.
e. Streamline basal spray with triclopyr as Garlon 4 at 20%.
f. Brushsaw.
g. Brushsaw and stump treatment with picloram + 2,4-D amine as undiluted Pathway.

These treatments were applied in May, 1987, after full leaf-out. Only woody competition greater than 2 ft tall was treated or cut. The brushsaw treatment used a Shindaiwa B-45 Brush Cutter fitted with a P.J. Brush Blade that had chainsaw teeth. The brushsaw plus herbicide treatment will not be discussed further, because of limited observations for productivity comparisons.

A Solo 425 backpack sprayer was used to apply the herbicides. For directed foliar sprays, a 65" flat-fan spray tip (0.3 gpm @ 40 psi) was used with a 24-inch extension to the standard spray wand and a pressure regulator to maintain 15 psi. The surfactant Ortho X-77 at 0.25% was added to the herbicide-water solutions. Equal cost spray mixtures were tested, with 1992 costs being $2.05 per gallon. Application was made as spray-to-wet (no leaf drip) to the entire hardwood crown from one side for smaller hardwoods and from two sides for larger hardwoods (4). Two male applicators with moderate experience were used, with one applicator per plot. An applicator progressed back and forth across a plot treating between two or three pine rows per pass, depending upon stand density.

For basal streamline applications, sprayers were equipped with Model 30 Gunjet sprayguns and straight stream tips (0.2 gpm @ 40 psi) and operated at 30 psi. The spray stream was aimed at smooth juvenile bark to the lower 24 inches of target woody stems (4). Stems were treated on two sides when larger than l-inch gld or in sprouting clumps. Most stems less than l-inch gld were treated on one side. Single stems were treated with an up-and-down band about 4 inches long and multiple stemmed-rootstocks were treated with a back-and-forth motion that produced about a 4-inch wide band on all stems (4). Since plants were in full foliage with the May applications, the applicator often had to lift lower branches to treat the stem. The applicator treated between two pine rows per pass.

The triclopyr basal treatment used 20% Garlon 4, 10% Cide Kick II penetrant, and 70% diesel---a commonly-applied streamline mixture. To compare a newer equal-priced mixture, imazapyr as Chopper (2 lb ae/gal) was mixed at 6% with diesel with no penetrant (none tested would mix). The 1992 cost of the triclopyr mixture was $19.00/gal, while the imazapyr mixture had been lowered to $12.00/gal. Since summary figures will show only the triclopyr use costs, these values should be reduced by 37% to estimate imazapyr mixture costs.

Other treatments were added during the following late dormant season (March 2 and 3, 1988) using herbicide mixtures or water (to simulate application), as follows:

h. Streamline basal spray with txiclopyr as Garlon 4 at 20% to all woody competition within. a 3-ft radius of pines whose height was greater than half-height of the pine and all hardwoods between pine rows that equaled average pine heights (referred to as "around pines").
i. Streamline basal spray with water to all woody plants (greater than 2 ft tall), in order to compare dormant season (DS) applications to the previously applied growing season (GS) treatments.
j. Soil spots in a grid using a spotgun and water at a simulated rate of 3.0 lb ai hexazinone per acre or 6 quarts per acre of Velpar L as prescribed by soil texture and presence of resistant species.

Treatment h was applied to one added plot per block using the herbicide mixture and with treatments i and j were applied also to previously treated plots using water to gain eight observations for timing and herbicide usage.

For the dormant season streamline applications, a 0.1 gpm spray tip was used, since the heavier stream of the 0.2 gpm tip was not required to penetrate foliage as in the growing season applications. Values for water when streamlining were multiplied by 0.92 to correct for the lower flow rates of the diesel mixture compared to water at the same pressure and spray tip as determined by calibration tests. One row of pines was treated with each pass. A CP3 backpack sprayer was used at 30 psi.

Applications of soil spot grids tested three different commonly-used application tools: a) the Chem-trol Spotgun (black, metal), b) the Herbicator Spotgun (yellow, plastic), and c) Model 30 Gunjet with a straight-stream tip. Three test applicators rotated the tools on three different plots. The Chem-trol and Herbicator Spotguns are syringe-type, positive displacement spotguns that were calibrated for 2.33 ml per spot. The Model 30 Gunjet was fitted with a straight-stream tip (2 gpm @ 40 psi) and all applicators practiced to apply approximately 2.33 ml per spot; 2,437 spots per acre were applied on a 6- X 3-ft spaced grid with no spot within 3 ft of a pine. The rate of 6 quarts per acre cost $60 using 1992 prices. Three rows of pines were treated per pass. With spotgunning, the same number of spots can be used over a wide range of rates while adjusting only the milliliters per spot. Thus, the productivity findings can apply to a wide range of rates when using the same grid spacing.

To assess productivity and costs, application times and herbicide (water simulated) usage were recorded for each plot. A rest and preparation period separated each plot so that productivity estimates are for partially rested workers and only productive hours. Labor was cost at $8 per hour, which was $7 per hour for pay and $1 per hour for overhead.

Linear regression analysis was used to examine and describe relationships between woody plant density and worker productivity and herbicide usage, over the range of conditions tested. By pooling across herbicides, eight observations were used for each regression. Productivity and herbicide usage in this study represent difficult stand conditions since woody plants were 4 years old after site preparation (with 3 year old pines) and were reaching the upper size limits for hand-applied release treatments. Although a wide range of stand densities were included from this one site, often only one observation was made at the higher densities, which would make these preliminary findings for depicting the upper limits of productivity and usage.

RESULTS AND DISCUSSION

Early analyses of both pine growth and woody plant control, 2 and 3 growing seasons after treatment (GSAT), have shown the test treatments in the original study to be significantly different (5%) from the check (1,8). Brushsawing has significantly increased growth of individual pines compared to the check, but not stand-level growth. Further, imazapyr treatments were controlling woody plants significantly better than triclopyr treatments. Thus, all treatments have resulted in a significant effect, at least with one response variable of reduced woody competition or pine growth improvement. However, longer term monitoring will be required to accurately evaluate the cost-return for these treatments.

Woody rootstocks ranged from 3,100 to 11,870 per. acre across all plots at the time of establishment (1). Mean heights per plot ranged from 3.5 to 5.2 ft and mean gld's ranged from 0.3 to 0.4 inches. Of the 38 woody species on site, the major competitors (percent of rootstocks) were red oaks (15%), sweetgum (14%), sumacs (14%), blackgum (6%), hickories (6%), white oaks (6%), and dogwood (4%), while red maple, persimmon, black cherry, and yellow poplar were present at 2 to 3% each.

Table 1 examines the correlations among three woody plant density measures and worker productivity and herbicide usage. On average, both rootstocks per acre and stems per acre had higher correlations with productivity and usage than basal area (gld) per acre. All correlations were significant at the 5% level except worker productivity for directed sprays and brushsawing with basal area. Because of the practical ease of surveying rootstocks per acre (RTSK) compared to stems per acre, rootstock density was used in the remaining analyses.

Streamline

Figure 1 shows the relationships for the three streamline treatment options among rootstocks per acre and worker productivity, labor costs, herbicide usage, and herbicide costs. R-squares ranged from 0.64 to 0.97, indicating moderate to strong relationships. There were obvious "highly influential points (HIP's)", i.e., singular large values, that increased the R-square values somewhat. The most reliable portion of these relationships are in the range from 3,000 to 6,000 rootstocks per acre where data points were more numerous.

Although linear models have been used, it should be recognized that there are natural non-linear components in both productivity and herbicide usage. With productivity, the fact that a worker must walk back and forth between two or three pine rows to check for treatable stems means that even with no rootstocks there can be a time component and thus the curves would parallel the x-axis at low rootstock numbers. At high numbers of rootstocks there can be increased efficiency as the "walk time" needed to reach a treatable stem decreases between rootstocks, which should mean declining upper slopes. In these data, the upper levels may not have been reached. With herbicide usage, a zero intercept could be assumed (i.e., no rootstocks require no herbicide), but was not mandated here. There should then be an approximately linear part of the curve where each additional rootstock treated would add a herbicide volume equal to treating the mean stem diameter. With increasing rootstock density, the average rootstock size would decrease resulting in a decline in herbicide usage per additional rootstock.

Streamline treatments in the dormant season of all stems were almost three times faster than similar growing season treatments. When comparing the treatment of all stems versus "around pines", it was faster to treat only around pines below 7,500 rootstocks per acre, but it became slower above this density. This finding is strongly influenced by the HIP's and must be considered tentative.

Comparing the herbicide costs between growing and dormant season streamlining of all stems in the most reliable range:

	3.000 RTSK	6.000 RTSK
Growing season	$68	$113
Dormant season	32	67
Difference	$36	$46

Herbicide mixture costs are somewhat more than double for growing season treatments of 3,000 rootstocks compared to dormant season applications, while the difference is only 68% more at 6,000 rootstocks. A simple comparison of herbicide costs between growing season streamlining of all stems versus around pines is as follows:

	3.000 RTSK	6.000 RTSK
All stems	$32	$ 67
Around pines	13	34
Difference	$19	$ 33

These calculations show that herbicide costs for treating all stems is about twice that for treating around pines and somewhat proportionally greater at lower rootstock numbers. More herbicide use would also require more refill time for sprayers and would increase labor costs.

Directed Foliar Sprays

The linear regressions for directed sprays explained 70% and 73% of the variation, indicating moderately strong relationships (Figure 2). The same non-linear components discussed with streamlining would also apply here. In general, directed spray applications were faster than streamlining all stems within the reliable range of rootstocks (Figure 5).

increase with increasing rootstock density, but essentially treatment times are similar across the range of rootstock densities. This is due, of course, to the same grid application being made regardless of hardwood density. Treatment time was about a half-hour per acre with labor costs from \$3.46 to \$3.87 per acre. Thus, the labor costs for spotgun treatments in grids is the lowest of the test methods when rootstocks exceed 2,800 per acre, in the reliable range of values (Figure 5). As stated earlier, herbicide costs with this treatment are determined by the rate, which is prescribed according to soil texture, organic matter, species mix, and pine age and size.

Brushsaw

The treatment times and labor costs for brushsawing relative to woody density are shown in Figure 4, with a linear regression having a R-square of 0.81. Total costs for brushsawing are comparatively low, since no herbicide costs are involved, while labor costs are the highest of the test treatments above 3,000 rootstoclcs per acre (Figure 5). The linear relationship would indicate that a rested laborer could cut about 3,300 rootstocks per hour when using the saw and technique tested.

Total Cost Comparison

The comparison of total treatment costs (TC) shown in Figure 6 uses the following functions that combine labor and herbicide costs:

Streamline GS All Stems TC = 20.95 + 0.01778 RTSK
$R^2=0.69$, Root MSE= 27.08

Streamline DS All Stems TC = 0.62 + 0.01267 RSTK
$R^2=0.90$, Root MSE= 12.27

Streamline DS Around Pines TC = -7.76 + 0.00832 RSTK
$R^2=0.98$, Root MSE= 3.69

Directed Foliar Sprays TC = 13.60 + 0.00313 RSTK
$R^2=0.80$, Root MSE= 3.65

Brushsaw treatments would just be the labor cost per acre (LCA). The total cost for spotgunning would add \$10 per quart to the LCA depending on the herbicide rate.

With less than 4,100 rootstocks per acre, streamlining around pines was the lowest cost herbicide treatment and above this density, directed sprays had the lowest costs (Figure 6). The range of spotgun treatment costs (from 2.25 to 8.00 quarts per acre) are shown in Figure 6 and indicate that if the lowest Velpar rate could be used (2.25 quarts per acre) then spotgun applications would be less costly than directed sprays when rootstocks exceed 4,000 per acre. On this Piedmont site, spotgun applications were never less than directed sprays and this would hold for most Velpar rates. The brushsaw treatment had the lowest TC even though resprouting was severe without a herbicide application (1).

The number of rootstocks per acre that can be treated for $50---a nominal release investment---would be as follows, as calculated from the above functions:

Streamline GS All Stems	1,049
Streamline DS All Stems	3,919
Streamline DS Around Pines	6,959
Directed Foliar Sprays	11,592
Brushsaw	14,691

Of course, only a small proportion of the 6,959 rootstock would be treated when applications are made only "around pines". Total costs for spotgun treatments would exceed $50 on this site.

The use of these regression equations may assist contractors and planners in estimating treatment times, herbicide quantities, and expense in performing manually-applied release treatments, setting maximum limits for herbicide usage and productivity.

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Table 1. The correlation coefficients and **probabilities of a greater F** between both worker productivity and gallons of herbicide used and three measures of woody plant density for three different streamline application methods, a directed foliar spray application, and brushsawing (n = 8).

	Worker Productivity (hr/acre)	Herbicide Usage (gal/acre)
	Streamline Growing Season All Stems	
Rootstockslacre	0.8804	0.8005
	0.0039	**0.0170**
Stems/acre	0.9283	0.8356
	0.0009	0.0093
BA(gld)/acre	0.7228	0.9299
	0.0428	0.0008
	Streamline Dormant Season AN Stems	
Rootstockslacre	***0.9867***	0.9419
	0.0001	0.0005
Stems/acre	**0.9802**	0.9541
	0.0001	0.0002
BA(gld)/acre	**0.9377**	0.8783
	0.0006	0.0041
	Streamline Dormant Season Around Pines	
Rootstockslacre	**0.9461**	**0.9732**
	0.0004	**0.0001**
Stems/acre	0.9655	0.9 196
	0.0001	0.0012
BA(gld)/acre	**0.9397**	0.8568
	0.0005	0.0066
	Foliar Directed Sprays	
Rootstockslacre	0.8526	0.8365
	0.0071	0.0096
Stems/acre	0.7044	0.8854
	0.0511	0.0034
BA(gld)/acre	**0.5094**	0.6817
	0.1972	0.0626
	Brushsaw	
Rootstocks/acre	0.9009	---
	0.0023	---
Stem/acre	0.8942	---
	0.0027	---
BA(gld)/acre	0.5468	
	0.1608	---

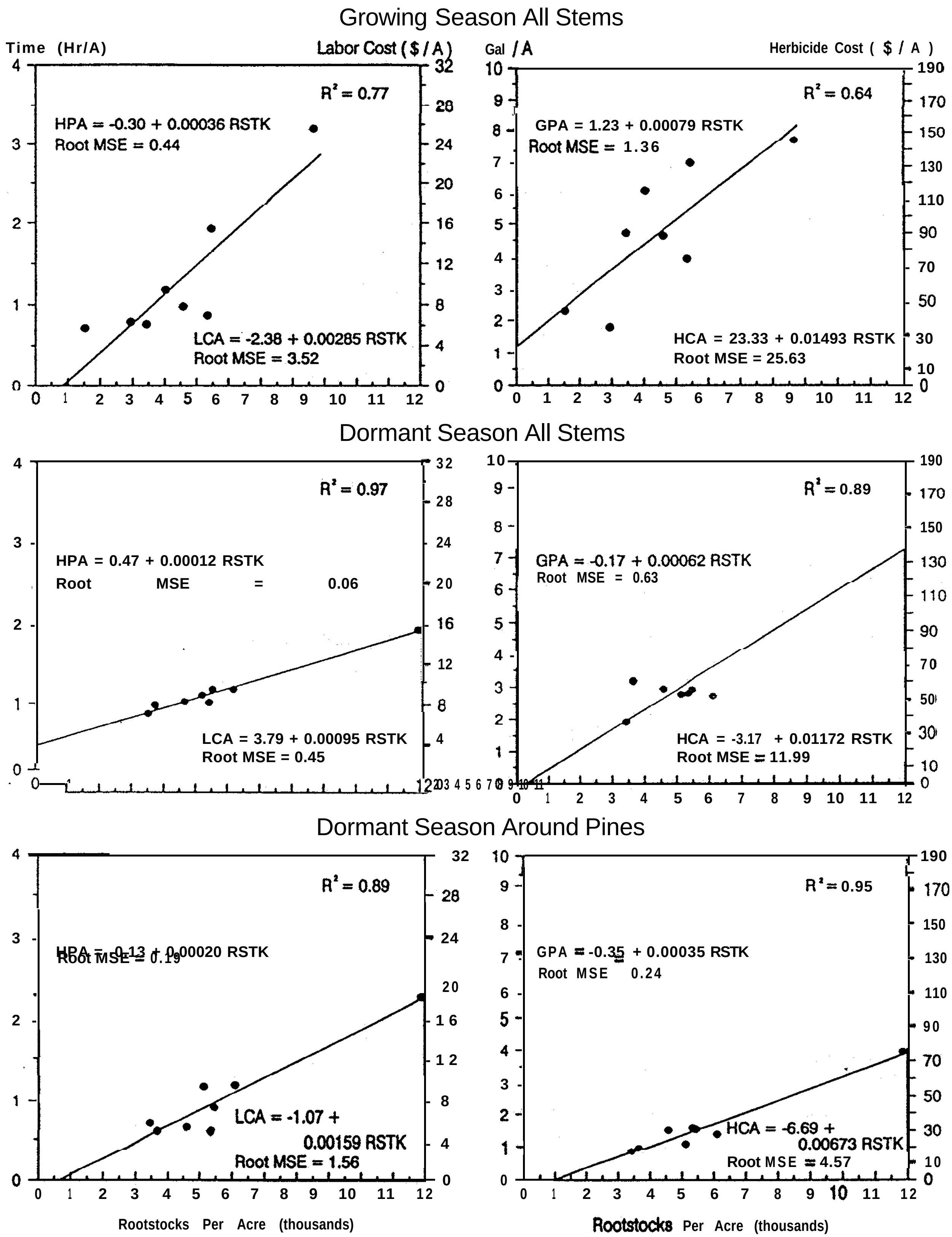

Figure 1. Three streamline application methods and the linear regression relationships between rootstocks per acre (RSTK) and treatment times in hours per acre (HPA), labor costs per acre (LCA), gallons of herbicide per acre (GPA), and herbicide costs per acre (HCA).

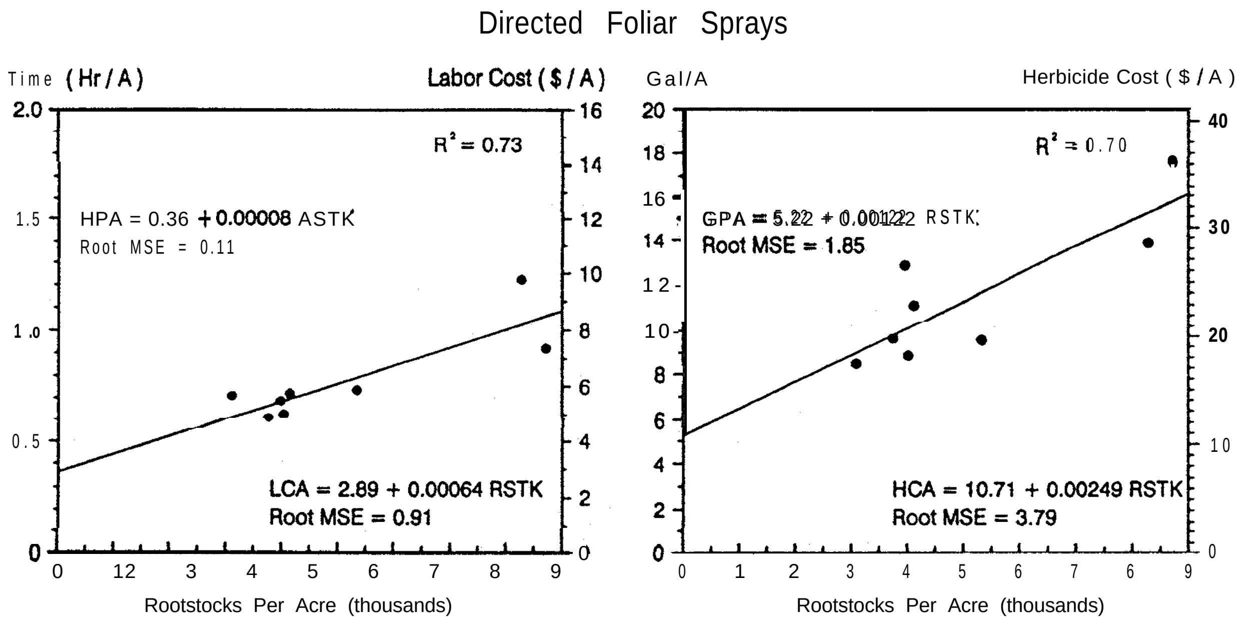

Figure 2. Directed foliar spray applications and the linear regression relationships between rootstocks per acre **(RSTK)** and treatment times in hours per acre (HPA), labor costs per acre (LCA), gallons of herbicide per acre (GPA), and herbicide costs per acre (HCA).

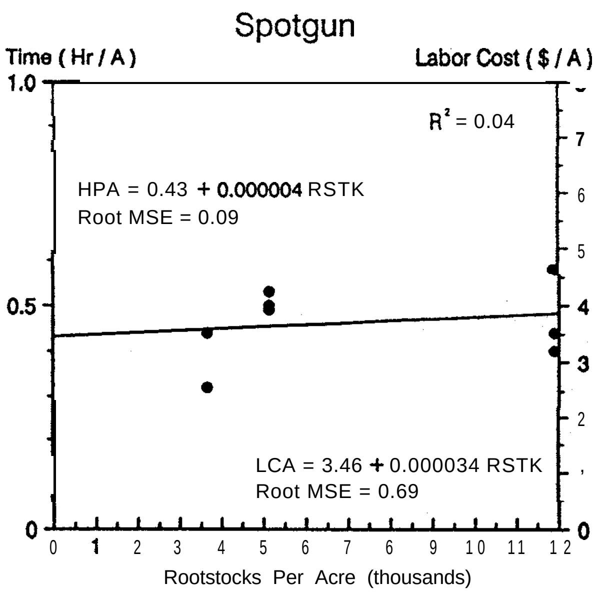

Figure 3. **Spotgun** grid applications (3 x 6 ft grid) and the linear regression relationships between rootstocks per acre **(RSTK)** and treatment times per acre (HPA) and labor costs per acre (LCA).

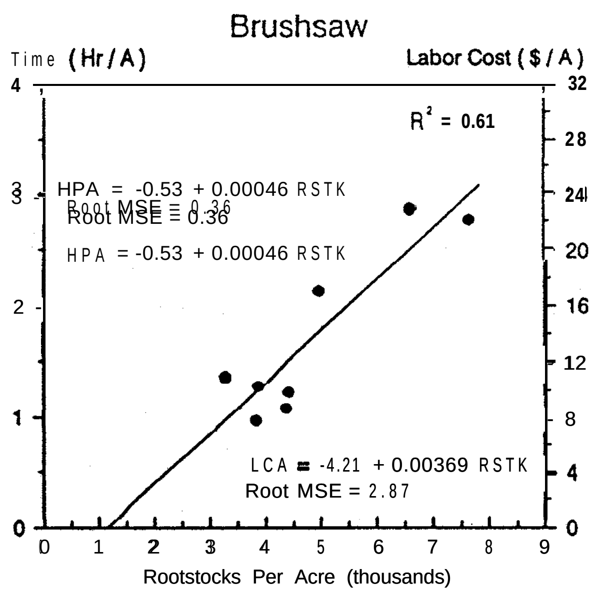

Figure 4. Brushsawing treatments and the linear regression relationships between rootstocks per **acre (RSTK)** and treatment times per acre (HPA) and labor costs per acre (LCA).

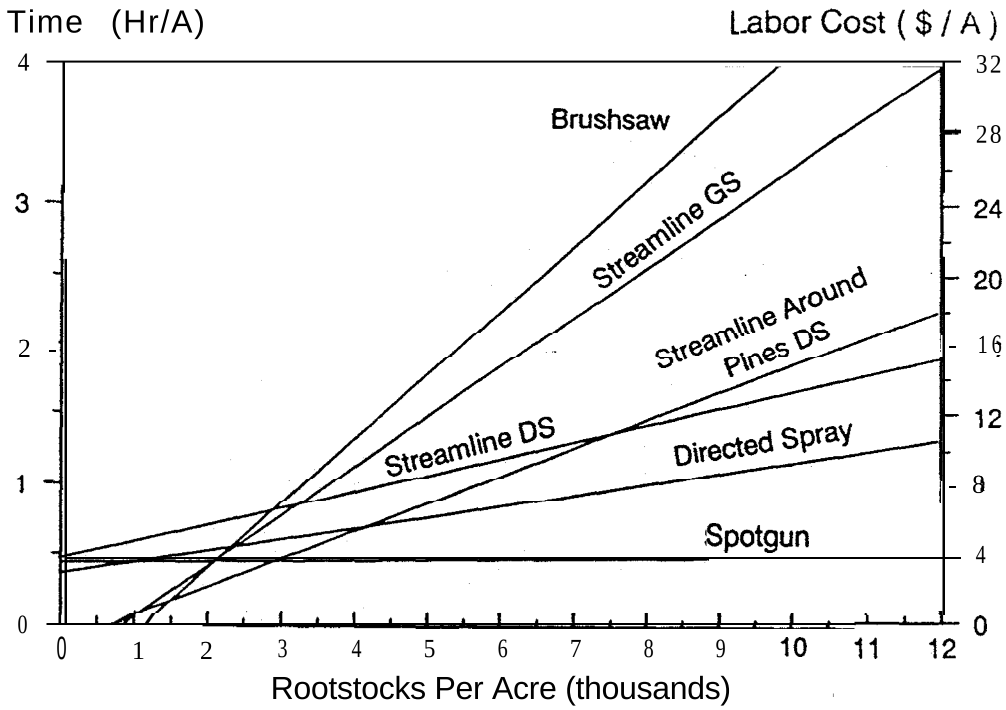

Figure 5. Labor cost comparisons for brushsawing, streamlining in both the growing season (GS) and dormant seasons (DS), directed foliar Spraying, and spotgunning.

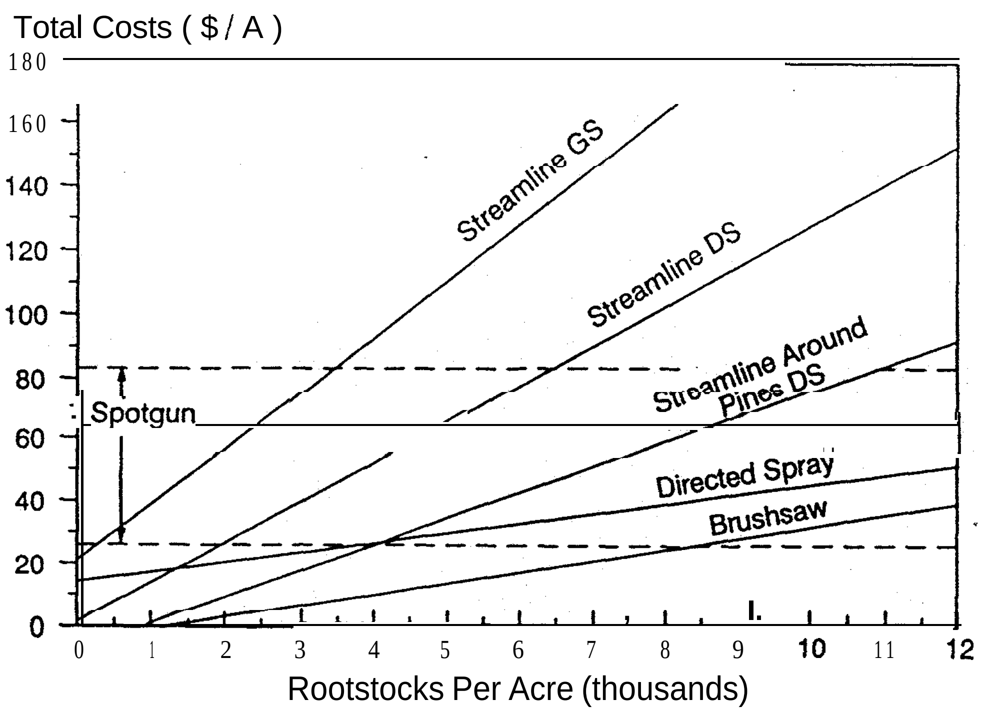

Figure 6. Treatment cost comparisons for brushsawing, streamlining in both the growing season (GS) and dormant seasons (DS), directed foliar spraying, and spotgunning (showing the range of posible rates).