# TEN YEAR REGENERATION OF SOUTHERN APPALACHIAN HARDWOOD CLEARCUTS AFTER CONTROLLING RESIDUAL TREES

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Abstract: Two upland hardwood stands were clearcut in 1978 and three treatments to control the unmerchantable and/or cull trees were applied. The treatments applied to the residual trees were chainsaw felling, herbicide injection, and a control, where residual trees were left standing. Regeneration was sampled 10 years after the cutting. Variables such as total number of stems, number of free-to-grow stems, and number of free-to-grow commercial species were used to evaluate the effect of the treatments. Statistical analysis showed that hardwood regeneration is promoted by controlling residual trees. Total number of stems, number of free-to-grow stems, and number of free-to-grow commercial species of the large regeneration class (stems ≥4.5 ft height) were significantly increased by the chainsaw and injection treatments. Controlling residuals significantly increased sprouting of all species (including commercial and non-commercial), the number of free-to-grow trees,and the number of commercial species and free-to-grow commercial species with respect to the control treatment. The number of oaks being regenerated was not affected by either treatment. The injection treatment did not result in a significant increase of the seedling component in the regeneration. Differential mortality was observed among the treatments from years five to ten, resulting in the attenuation of treatment differences, especially between the chainsaw and injection treatments. A shift towards early successional species was observed after the harvest, but the specific composition was unaffected by the treatments. Ten years after the clearcut, the chainsaw treatment is recommended as a means of controlling residual trees. This treatment promoted adequate hardwood regeneration, and compared to the injection treatment, is easier to implement, cheaper and aesthetically more pleasing.

## INTRODUCTION

Commercial clearcutting results in the removal of all merchantable trees leaving saplings, small poles and cull trees standing. If residual trees are left uncut they may develop into wolf trees and seriously interfere with the regeneration of commercially desirable species (Trimble 1972; Marquis 1981a).

Regeneration guidelines recommend the removal of those residual trees when clearcutting (Kellison et al. 1981, Roach and Gingrich 1968). Controlling residuals can be done in several

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ways. Large culls can be deadened or felled, and the small residuals can be injected or sprayed with chemicals, lopped with saws or axes or reduced by shearing or drum chopping (Beck 1980).

In this study, two methods of controlling residuals were chosen to examine the response of hardwood regeneration: chainsaw felling and herbicide injection. They were compared to a commercial clearcut in which the residuals were left standing. Deadening of the residual trees with herbicide has the intention of promoting the seedling origin component in the new stand as opposed to chainsaw felling of residuals which should favor the stems of stump origin. This paper reports the differences in the quantity and quality of the regeneration among the different methods of controlling residuals ten years following clearcutting.

## METHODS

The two study sites (the Robertson and the Willits tracts) are included within the Chestnut Oak Forest region and are located in western North Carolina on lands that belong to Champion International Corporation. The Willits tract is located in Jackson County on a north to northeast aspect with a red oak site index of 80 ft on a 50 year base (good site). The Robertson tract is located on a north to northwest aspect with a red oak site index of 70 ft (average site).

Portions of the forest on the Willits tract were in pasture or cultivation around the turn of the century, while the Robertson tract was always forested but subjected to repeated highgrading. Both stands were experimentally clearcut in the winter to evaluate alternative methods of controlling residuals. The installation of the study was done by Champion International Corporation in cooperation with the North Carolina State University Hardwood Research Cooperative, and followed the study design found in Kellison and Gardner (1977).

At the time of clearcutting, the Willits tract had a merchantable basal area of 69 square feet per acre in 124 trees per acre aged 60 to 80 years. The trees were mainly red maple (*Acer rubrum* L.), yellow-poplar (*Liriodendron tulipifera* L.), cucumber magnolia (*Magnolia acuminata* L.), hickories (*Carya* spp.), white oaks (*Quercus alba* L., *Quercus prinus* L.), sweet birch (*Betula lenta* L.) and red oaks (*Quercus rubra* L., *Quercus coccinea* Muenchh., *Quercus velutina* Lam.). The Robertson tract had 114 merchantable trees per acre aged 75 to 150, and a basal area of 76 square feet per acre. The primary species at the Robertson tract were white and red oaks, hickories and red maple.

Twelve plots of 1.25 acres were established on each site to allow for 4 replications of three treatments in a randomized complete block design. In each plot, four 0.004 ac subplots were established for regeneration subsampling. The treatments applied to control the residual trees were:

> 1.- Control: all residual trees left standing to represent the typical condition following commercial clearcutting with a diameter limit of 6 inches dbh.

2.- Chainsaw: clearfelling all residual stems bigger than 1-in dbh with chainsaws.

3.- Injection: injecting all residual stems bigger than 1-in dbh with the herbicide TORDON 101[R] using hypo-hatchets[R].

The original subplot centers were permanently marked for regeneration sampling. Effects of the treatments were evaluated five years after the clearcut by Petruncio (1985).

Ten year regeneration was measured during the summer of 1988. Large regeneration or stems ≥ 4.5 ft tall were sampled on enlarged subplots of 0.02 acres having as a center the smaller 0.004 ac subplots. Species, dbh in inches, height in feet and origin were recorded for every stem. Origin was classed as seedling or sprout. In the case of sprouts, only one dominant stem was measured, but total number of stems per clump was recorded. No distinction was made between seedlings and seedling sprouts. In addition, stems were judged whether they were overtopped by competitors or free-to-grow. Trees identified as present prior to the 1978 harvest were not included in the analysis of regeneration. On the basis of fiber and timber values, species were classified as commercial and non commercial. All oaks (*Quercus* spp.), hickories, pines (*Pinus* spp.), maples (*Acer* spp.), yellow-poplar, cucumber magnolia, blackgum (*Nyssa sylvatica* Marsh.), beech (*Fagus grandifolia* Ehrh), sycamore (*Platanus occidentalis* L.), sweet birch, black cherry (*Prunus serotina* Ehrh), white ash (*Fraxinus americana* L.), eastern red cedar (*Juniperus virginiana* L.), yellow buckeye (*Aesculus octandra* Marsh.), hemlock (*Tsuga canadensis* Carr.) and basswood (*Tilia heterophylla* Vent.) were considered commercial. All other species were considered as having non-commercial value.

To analyze treatment effects on regeneration, number of trees, which is considered to be acceptable in stands less than 15 years old (Gingrich, 1967), has been used as a measure of stand density. The statistical analysis was done on the square root transformation of the data to stabilize the variance (Rawlings, 1988). Analysis of variance was used and planned comparisons among the treatments were done at the 10 percent significance level.

## RESULTS AND DISCUSSION

At the time of harvest, the control plots had a residual basal area of 30 $ft^2$ per acre on both of the tracts. Ten years after the clearcut, the residual basal area was 33 $ft^2$ on the Willits tract and 22 $ft^2$ on the Robertson tract. From years 5 to 10, residual tree mortality was 32 percent on the Willits tract and 20 percent on the Robertson. Although mortality has been greater on the Willits tract, the surviving residuals have been able to withstand the severe conditions of sudden exposure better than the ones in the Robertson tract. Quality of the residual trees varies and many show signs of crown dieback and epicormic branching. The high rate of residual mortality surpasses what Marquis (1981) reported for the residual trees in the Allegheny hardwoods. This mortality may be due to the fact that these trees were not selected in any way for species or quality. On the injection plots, many of the trees that were herbicided were still standing as dead snags. The herbicide treatment was almost 100 percent effective on the Robertson tract; however, on the Willits tract some trees survived and at year ten accounted for 7 $ft^2$ of the basal area per acre. Where mortality occurred, injection resulted in total kill of the tree with no subsequent sprouting.

Large regeneration

Besides analyzing the effects of the treatment on the total number of stems of the large regeneration class (stems $\geq$ 4.5 ft tall), several species groups were also analyzed separately. Free-to-grow stems were analyzed because they have either a dominant or codominant position in the canopy, commercial species and free-to-grow commercial species were analyzed because of their economic importance, and finally oaks were analyzed due to the interest of silviculturists and the public to promote their regeneration in the Southern Appalachians.

On both tracts, there were more stems per acre of the large regeneration class when the residual trees were controlled, either by chainsaw felling or by herbicide injection, than when the residuals were left standing. In general, the chainsaw treatment resulted in more stems per acre than the injection treatment for the two sites (see Tables 1 and 2). The statistical analysis for the Willits tract (Table 1) revealed that when all large regeneration stems were considered together, no significant differences arose among the treatments, but there were significantly more free-to-grow stems in the chainsaw and injection treatments than in the control treatment . The number of stems per acre of commercially desirable species was not affected by the treatments. The injection treatment produced significantly more free-to-grow commercial species with respect to the control treatment. Petruncio (1985) reported a significant increase in the number of seedling origin stems of commercial species on the injection plots compared to the control plots. The ten year results showed that this trend has not persisted over time and that the number of seedling-origin stems was unaffected by the treatments. On the other hand, the proportion of sprout origin stems was significantly increased by the chainsaw and injection treatments compared to the control treatment. This significance was found for the total stem regeneration, free-to-grow stems, commercial species and free-to-grow commercial species.

Oak regeneration was examined separately from the other species because of poor oak regeneration among the treatments, although the injection plots provided a slightly higher number of oaks per acre than the control and chainsaw plots.

On the Robertson tract, stem density of the large regeneration class was lower than on the Willits tract, but the number of free-to-grow stems and the number of free-to-grow commercial species were greater than on the Willits tract (Table 2). Again, this reflects the difference in site quality between the two tracts. Since the Willits tract was able to support a greater stem density, by year ten it had already reached canopy closure. Although, the Robertson tract had fewer stems per acre and canopy closure was not fully reached, the site had more stems per acre that were not overtopped, compared to the Willits tract. Overall, few significant differences were detected, even though there was a tendency for the chainsaw plots to have higher regeneration densities than on the other plots.

Table 1.--Mean density (stems/acre) of large regeneration stems (≥4.5 ft height) on the Willits tract.

| | Treatment | | |
|---|---|---|---|
| | Control | Chainsaw | Injection |
| All species[1] | | | |
| Total stems[2] | 3938 | 6100 | 5191 |
| Seedling stems | 1494 | 1803 | 1562 |
| Sprout stems[3] | 800[a] | 1563[b] | 1338[b] |
| Free-to-grow stems | | | |
| Dominant stems[4] | 675[a] | 1178[b] | 1240[b] |
| Seedling stems | 306 | 422 | 519 |
| Sprout stems | 369[a] | 756[b] | 722[b] |
| Commercial species | | | |
| Total stems | 2796 | 3403 | 3322 |
| Seedling stems | 1146 | 1403 | 1796 |
| Sprout stems | 434[a] | 700[b] | 697[b] |
| Commercial species free-to-grow | | | |
| Dominant stems | 461[a] | 684[ab] | 824[b] |
| Seedling stems | 265 | 334 | 453 |
| Sprout stems | 196[a] | 350[b] | 371[b] |
| Oaks | | | |
| Total stems | 678 | 875 | 925 |
| Seedling stems | 253 | 431 | 588 |
| Sprout stems | 163 | 228 | 188 |

Means designated with different letters are significantly different at 0.10 significance level
[1]All species include commercial and non-commercial species.
[2]Total stems include all stems per sprout clump plus seedlings.
[3]Sprouts include only one dominant stem per sprout clump.
[4]Dominant stems include one dominant stem per clump plus seedlings.

The control plots had significantly less total numbers of stems per acre than either the chainsaw or the injection plots. This difference was also observed for the number of stems of sprout origin. The number of free-to-grow stems per acre was increased by the chainsaw treatment when compared to the control treatment. The chainsaw treatment also increased the total number of stems of seedling origin, and the number of stems of sprout origin for the

Table 2.--Mean density (stems/acre) of large regeneration stems (≥4.5 ft height) on the Robertson tract.

| | Treatment | | |
|---|---|---|---|
| | Control | Chainsaw | Injection |
| All species[1] | | | |
| Total stems[2] | 3309[a] | 6716[c] | 4500[b] |
| Seedling stems | 1772[a] | 3263[b] | 2847[ab] |
| Sprout stems[3] | 422[a] | 841[c] | 659[b] |
| Free-to-grow stems | | | |
| Dominant stems[4] | 869[a] | 2019[b] | 1247[ab] |
| Seedling stems | 566 | 1378 | 806 |
| Sprout stems | 303[a] | 641[b] | 441[ab] |
| Commercial species | | | |
| Total stems | 2381 | 3134 | 2750 |
| Seedling stems | 1328 | 1834 | 1500 |
| Sprout stems | 269 | 319 | 347 |
| Free-to-grow commercial species | | | |
| Dominant stems | 629 | 1134 | 865 |
| Seedling stems | 413 | 884 | 584 |
| Sprout stems | 216[a] | 250[ab] | 281[b] |
| Oaks | | | |
| Total stems | 856 | 984 | 1022 |
| Seedling stems | 313 | 438 | 366 |
| Sprout stems | 147 | 134 | 175 |

Means designated with different letters are significantly different at 0.10 significance level
[1]All species include commercial and non-commercial species.
[2]Total stems include all stems per sprout clump plus seedlings.
[3]Sprouts include only one dominant stem per sprout clump.
[4]Dominant stems include one dominant stem per clump plus seedlings.

free-to-grow class in comparison to the control treatments. It is interesting to note that the injection treatment significantly increased the number of sprout origin stems of free-to-grow commercial species with respect to the control treatment. Also the injection treatment did not have any effect on the number of seedling-origin stems present in the ten year regeneration.

The analysis of the five year regeneration (Petruncio,1985) revealed significantly higher quantities of commercial species in the chainsaw treatment than in the control treatment, and

Table 3.--Mean density (stems/acre) of large regeneration stems (≥4.5 ft height) for the Willits tract and the Robertson tract combined.

| | Control | Treatment Chainsaw | Injection |
|---|---|---|---|
| All species[1] | | | |
| Total stems[2] | 3623[a] | 6407[c] | 4845[b] |
| Seedling stems | 1633[a] | 2533[b] | 1955[b] |
| Sprout stems[3] | 611[a] | 1202[c] | 999[b] |
| Free-to-grow stems | | | |
| Dominant stems[4] | 772[a] | 1599[b] | 1243[b] |
| Seedling stems | 436[a] | 900[b] | 663[b] |
| Sprout stems | 336[a] | 699[b] | 580[b] |
| Commercial species | | | |
| Total stems | 2589 | 3269 | 3036 |
| Seedling stems | 1236 | 1619 | 1648 |
| Sprout stems | 352[a] | 509[b] | 521[b] |
| Free-to-grow commercial species | | | |
| Dominant stems | 545[a] | 909[b] | 844[b] |
| Seedling stems | 339 | 609 | 518 |
| Sprout stems | 206[a] | 300[b] | 326[b] |
| Oaks | | | |
| Total stems | 767 | 930 | 973 |
| Seedling stems | 282 | 434 | 477 |
| Sprout stems | 155 | 181 | 181 |

Means designated with different letters are significantly different at the 0.10 significance level.
[1]All species include commercial and non-commercial species.
[2]Total stems include all stems per sprout clump plus seedlings.
[3]Sprouts include only one dominant stem per sprout clump.
[4]Dominant stems include one dominant stem per clump plus seedlings.

a significant decrease in the number of oaks of large and small regeneration classes on the injection plots with relation to the control plots. None of these differences have persisted.

To determine if the treatments react differently at both locations, a combined analysis of variance of the two study sites was done (Table 3).

The control treatment presented significantly less total number of stems, free-to-grow stems, and free-to-grow stems of commercial species than the chainsaw and injection treatments . The chainsaw and injection treatments significantly increased seedling origin and sprout origin stems of the total large regeneration and free-to-grow regeneration with respect to the control plots. The proportion of sprout origin stems was also significantly increased by the chainsaw and injection treatments in the commercial species, and the free-to-grow commercial species, compared with the control treatment. The lack of difference in number of sprout origin stems of commercial species between chainsaw and injection treatments is probably a result of the treated residual stems being of non-commercial species.

Neither the number of oaks, nor the seedling or sprout components in the oak regeneration was affected by the treatments. As verified by the treatment means analysis for every location, the injection treatment did not promote the seedling component nor did it decrease the number of sprouts present in the regeneration.

## Stand composition

Free-to-grow stems have reached a dominant or codominant position in the canopy so they provide insights into the stand composition for the immediate future. Treatment distribution of the most important species coupled with their sprout percentage is shown for both tracts in Tables 4 and 5.

On the Willits tract, four species, red maple, yellow-poplar, sweet birch, and black locust (*Robinia pseudoacacia* L.), accounted for more than 45 percent of the total stocking and together with the non-commercial group dominated the stand (Table 4). Yellow- poplar was the tallest species in every treatment averaging 22 feet in the control and injection plots and 26 feet in the chainsaw plots. Red maple, sweet birch and black locust followed in height respectively, without marked differences among them. Red maple was by far the most prolific sprouter, averaging 10 stems per clump on the control plots, 6 on chainsaw plots and only 3 on the injection plots.

Both Wendel (1975) and Lamson (1976) demonstrated for hardwood stands such as these, where a high proportion of the regeneration is of sprout origin, that usually one sprout per clump will develop into a good quality tree in the new stand. Sweet birch and yellow-poplar were usually the only species that could germinate from seeds and grow fast enough to occupy the canopy. After clearcutting in the Southern Appalachians, black locust often forms dense thickets that can severely reduce growth of other commercial species (Beck and McGee, 1974). This is why black locust was not considered to be a commercial species in this study. Nonetheless, the effect of black locust on the stand was not seen as detrimental. Black locust sprouted from root suckers and was distributed in small clumps of 2 to 3 individuals scattered throughout the plots but did not form dense thickets. In addition, as Boring and Swank (1984) have pointed out, black locust's short life span coupled with its capacity of increasing soil nitrogen through fixation provides conditions which may facilitate forest growth and successional species replacement.

Table 4.--Number of free-to-grow stems per acre and sprout percentage by species and treatment on the Willits tract.

| Species | Control treatment | | Chainsaw treatment | | Injection treatment | |
|---|---|---|---|---|---|---|
| | Stems/ac | Sprout % | Stems/ac | Sprout % | Stems/ac | Sprout % |
| Red maple | 87 | 93 | 99 | 92 | 147 | 74 |
| Yellow-poplar | 85 | 48 | 125 | 53 | 159 | 33 |
| Northern red oak | 32 | 50 | 78 | 44 | 78 | 28 |
| Red oaks | 15 | 40 | 32 | 41 | 122 | 39 |
| White oak | 38 | 66 | 91 | 52 | 59 | 80 |
| Sweet birch | 172 | 9 | 140 | 24 | 66 | 33 |
| Black locust | 81 | 100 | 238 | 100 | 188 | 100 |
| Other commercia | 134 | 22 | 119 | 55 | 192 | 37 |
| Other non-commercial | 131 | 68 | 256 | 66 | 228 | 71 |
| Total | 675 | 55 | 1178 | 64 | 1240 | 58 |

Table 5.--Number of free-to-grow stems per acre and sprout percentage by species and treatment on the Robertson tract.

| Species | Control treatment | | Chainsaw treatment | | Injection treatment | |
|---|---|---|---|---|---|---|
| | Stems/ac | Sprout % | Stems/ac | Sprout % | Stems/ac | Sprout % |
| Red maple | 200 | 40 | 362 | 22 | 200 | 42 |
| Yellow-poplar | 115 | 5 | 294 | 4 | 165 | 4 |
| Red oaks | 48 | 60 | 134 | 30 | 123 | 46 |
| Chestnut oak | 122 | 54 | 153 | 45 | 144 | 46 |
| White oak | 44 | 30 | 47 | 34 | 62 | 45 |
| Dogwood | 100 | 53 | 463 | 54 | 175 | 59 |
| Other commercial | 170 | 20 | 161 | 21 | 207 | 23 |
| Other non-commercial | 168 | 13 | 400 | 34 | 171 | 29 |
| Total | 869 | 35 | 2019 | 31 | 1247 | 37 |

Red oaks predominated the oak regeneration. The amount of northern red oak (*Quercus rubra* L.) present in every treatment was much greater than the density reported by McGee and Hooper (1975) in a ten year old clearcut on the Bent Creek Experimental Forest (North Carolina) of higher site quality. The authors found only 10 free-to-grow red oak stems per acre contrasting with what is reported here; 32 stems per acre in the control treatment and 78 stems in the chainsaw and injection treatments. Beck and Hooper (1986), reevaluating the same stand as in the previous study, reported that 10 years later oaks comprised less than 4 percent of the stand's basal area and northern red oak was less than 1 percent. The northern red oak trees present in this study were 4 to 6 feet shorter than yellow-poplar. More than 55 percent of the chainsaw and injection subplots and 37 percent of the control subplots had one or more northern red oak stem present. The uncertainty that remains is whether these red oaks are going to be able to maintain their present position in the canopy. Oliver (1980) thinks that red oaks will eventually out compete the other species and form the dominant canopy. Beck and Hooper (1986) and Loftis (1988) believe that this will not occur on high quality sites in the Southern Appalachian hardwood forests where yellow-poplar is the major competitor. Species included in the non-commercial group, including dogwood (*Cornus florida* L.), sassafras (*Sassafras albidum* (Nutall) Nees), and sourwood (*Oxydendrum arboreum* (l.) DC), are expected to be soon relegated to the understory. These lower stratum species can act as a "trainers" (Ross et al. 1982) and keep the upper stratum trees well pruned (Oliver, 1980).

On the Robertson tract (Table 5) black locust and sweet birch were absent in the dominant strata. The commercially dominant species, red maple, yellow-poplar, white oaks (especially chestnut oak (*Quercus prinus* L.)) and red oaks, comprised 64 percent of the free-to-grow stems in the control plots, 50 percent on chainsaw and 56 percent on the inject plots. Yellow-poplar had outgrown chestnut oak by 6 feet on the control plots. On the other two treatments, chestnut oak was the tallest tree, although it surpassed yellow-poplar and red maple by only 4 to 2 feet. Because the Robertson tract is of lower site quality than the Willits tract, yellow-poplar was not able to compete as aggressively as it had on the Willits tract. When considering all species together, sprouting percentages were generally lower on the Robertson tract than on the Willits tract. Red maple stems of sprout origin made up 74 to 93 percent of the free-to-grow stems on the Willits tract, but on the Robertson never exceeded 42 percent. This may result from older trees being logged on the Robertson tract, which would decrease the sprouting capacity of the stumps (Wendel, 1975).

Of the non-commercial free-to-grow species, dogwood made up more than 37 percent of the stems, but it was 6 to 12 feet shorter than the tallest dominant tree. Other species that comprised the non-commercial group, mainly sassafras, sourwood and Carolina silverbell (*Halesia carolina* L.) were also shorter than the tallest tree. These species will continue to lag behind the overstory and can regulate sprout clump competition from the side, so they will not expand and dominate large areas (Ross et al. 1982).

The total number of stems in the large regeneration class, including all stems per clump plus all seedlings, have declined over time for both tracts (Figure 1). From years 5 to 10 both tracts had control plot mortality rates near 30 percent. The chainsaw plots had mortality rates of 44 and 27 percent on the Willits and the Robertson tracts, respectively. The injection plots had less than 10 percent mortality on both tracts. Mortality rates have decreased the

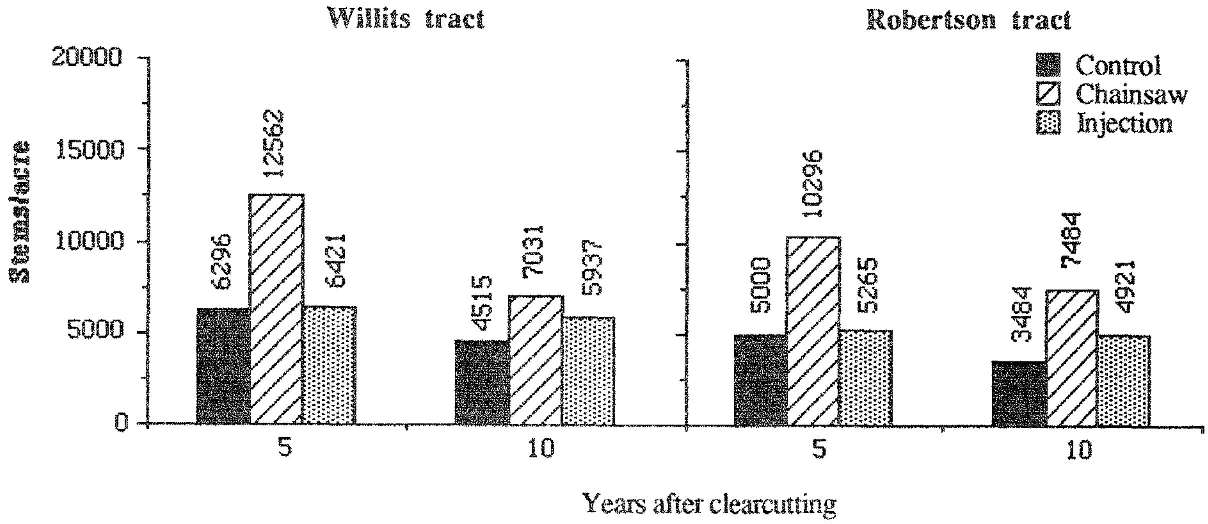


Figure 1. Change in the total number of stems per acre of the large regeneration class (stem≥4.5 ft height) from year 5 to year 10 following clearcutting, by treatment and site.

differences among treatments, especially among the chainsaw and inject treatments. Figure 2 follows sprout-origin (includes only one stem per clump) evolution over the years. Sprout origin stems have decreased by more than 50 percent for every treatment on the Willits and the Robertson tracts with the exception of the inject treatment on the Robertson tract which had only a 22 percent sprout decrease. Again, the differences at year five, particularly among the chainsaw and the injection treatments, have been attenuated to the point that an analysis of variance only detected significant differences among the control and either the chainsaw and injection treatments but not between the chainsaw and the injection treatments (see Tables 1 and 2). A higher reduction of the sprout component was reported by Gammon et al. (1968) for a seven year old hardwood clearcut in southern Michigan where only 22 percent of the sprouts survived. By contrast, seedling origin stems have increased dramatically over time (Figure 3). This increase can be attributed to several factors: seedlings growing over 4.5 feet and moving from the small to the large regeneration class, natural thinning and healing of stems sprouting from stems of small stumps (that at year ten were indistinguishable from true seedlings), and germination of new seedlings that continue to reproduce since the cut (as is the case of yellow-poplar, Minckler and Woerheide, 1965). From years 5 to 10 after clearcutting, the difference in the number of seedling-origin stems between the chainsaw and injection treatments has decreased for both tracts, contrasting to the control treatment where differences have increased in relation to the other two treatments.

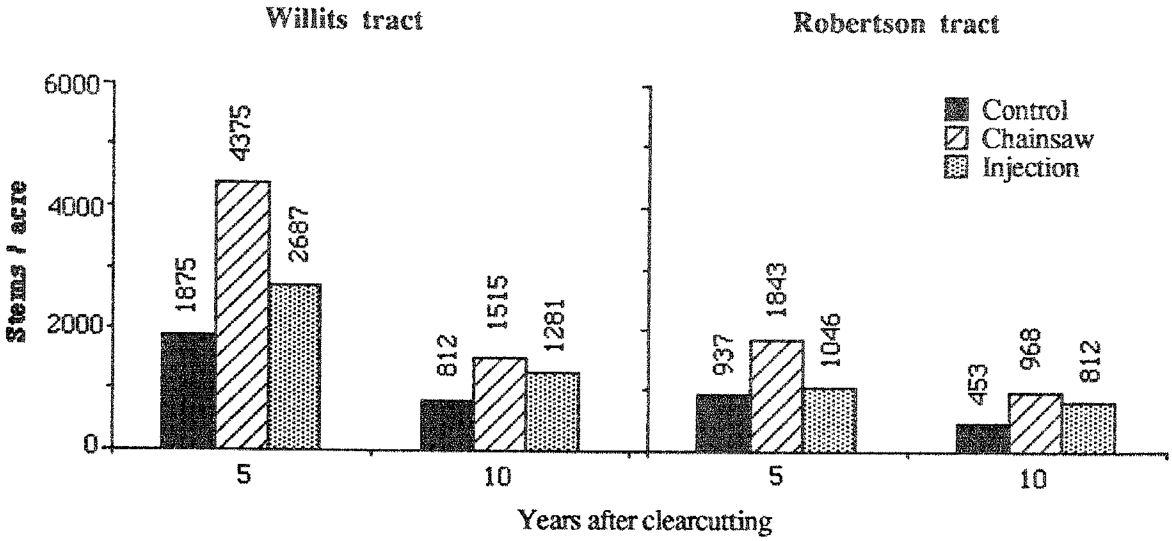


Figure 2. Change in the total number of sprout origin stems per acre (only one stem per clump) of the large regeneration (stems≥4.5 ft height) from year 5 to year 10 following clearcutting, by treatment and site.

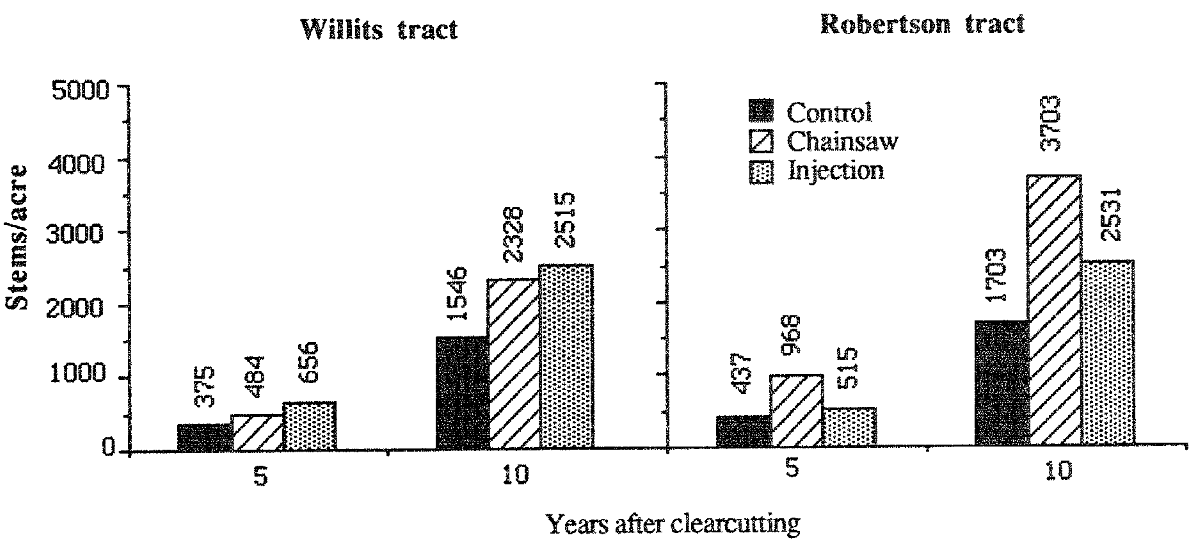


Figure 3. Change in the total number of seeding origin stems per acre of the large regeneration class (stems≥4.5 ft height) form year 5 to year 10 following clearcutting by treatment and site.

## SUMMARY

The absence of many of the significant differences that were observed in the evaluation of the study five years ago was a consequence of the differential mortality rates presented by the treatments. This mortality had especially attenuated the differences between the chainsaw and injection treatments. After 10 years, the amount and quality of regeneration promoted by the chainsaw treatment, coupled with its economic and aesthetic advantages over the injection treatment, indicated that chainsaw felling the residuals is the most desirable management option when regenerating hardwood stands of good to average productivity in the Southern Appalachians.

Natural thinning is expected to continue in the years to come as a result of competition, and as Beck and Hooper (1986) reported, the decline may be more rapid in the next five years than what has been observed until now. A follow up of this study is necessary to determine the degree and intensity of the treatments at the end of the rotation.

Besides timber values, other considerations concerning the removal of residuals have to be examined, for example, the economic implications of the treatments. Chainsaw felling the residuals either at the time of harvest or after, is considered to be less expensive than herbicide injection of the residuals (Brenneman, 1988). In regard to aesthetic values, the standing dead trees left by the injection treatment, which persist for at least a decade after logging, can have an adverse impact on the scenic beauty of the stand (Vodak et al. 1985). If wildlife is a matter of concern, leaving chosen residual trees will provide nesting cavities, some mast, and vertical stratification (Smith, 1988). Ultimately, landowner objectives, whether timber oriented or others, will dictate whether and how to remove the residual trees.

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