# Tree Regeneration Response to the Group Selection Method in Southern Indiana

**Dale R. Weigel,** *USDA Forest Service, North Central Forest Experiment Station, 811 Constitution Avenue, Bedford, IN 47421, and* **George R. Parker,** *Department of Forestry and Natural Resources, Purdue University, 1159 Forestry Building, West Lafayette, IN 47907-1159.*

**ABSTRACT.** *Tree regeneration response following the use of the group selection method was studied within 36 group openings on the Naval Surface Warfare Center, Crane Division in south central Indiana. Two different aspects and three time periods since cutting were examined. The objectives were to determine whether aspect, age, species group, location within the opening, or their interactions had any influence on the number of stems or average height of the tree regeneration. Among openings up to 20 yr since cutting, yellow-poplar and dogwood were most abundant for stems greater than 2.5 cm diameter at breast height (dbh), and dogwood and cherry-ash-walnut were most abundant for stems less than 2.5 cm dbh. The location × species group interaction also influenced the number of stems greater than 2.5 cm dbh. Stems less than 2.5 cm dbh were influenced by the age × species group and aspect × species group interactions. The north aspect and the oldest openings contained the most stems per hectare less than 2.5 cm dbh. The interaction of age and species group influenced average height for stems greater than or equal to 2.5 cm dbh. Average height increased with age for stems greater than or equal to 2.5 cm dbh. North. J. Appl. For. 14(2):90–94.*

Since the 1960s, even-aged regeneration systems have been recommended for central hardwood forests (Roach and Gingrich 1968, Sander and Clark 1971). Recently, however, interest has been increasing in the use of group selection to convert central hardwood forests to uneven-aged communities, particularly on public lands (USDA For. Serv. 1991).

This interest has emphasized the lack of scientific information about how well central hardwood species regenerate under uneven-aged methods. Specific questions include: How does the composition of the parent stand determine the composition of the future stand; what effect does opening size have on the type and development of regeneration, and how does this change over time; and does the species composition vary within different portions of openings and/or between different aspects? This paper describes patterns of regeneration in group selection openings by aspect and age of opening, and by location within the opening.

## Study Site

This research was conducted on the Naval Surface Warfare Center (NSWC), Crane Division, located in south central Indiana, where the uneven-aged regeneration system has been used since the early 1960s. NSWC contains over 62,000 ac of which more than 48,000 are forested.

Nearly the entire NSWC is unglaciated and lies within the Crawford Upland Section of the Shawnee Hills Natural Region as described by Homoya et al. (1985). It is characterized by rugged hills with sandstone cliffs and rockhouses. The forest vegetation consists of oak-hickory on the upper slopes, with a mesic component in the coves and bottoms. Soils in the study area are the Wellston association characterized as deep and moderately deep, gently sloping to very steep, well-drained soils formed in loess and material weathered from sandstone, siltstone, and shale on uplands (USDA Soil Conserv. Serv. 1988).

## Methods

All timber sale contracts, using the group selection method, from the period 1971 to 1985 were examined for potential sample sites. The stands were divided into three groups depending on the time of harvest: 6–10 yr (1981–1985), 11–15 yr (1976–1980), and 16–20 yr (1971–1975). After year 20, timber stand improvement work influenced the composition of the groups. Stands younger than 6 yr were still changing rapidly, and species dominance was not yet apparent. Group openings in bottomlands or on ridges were not sampled.

The openings were divided into two groups—north and south aspect—using aerial photos and topographic maps

The divisions, north aspect 315°–135° and south aspect 136°–314°, were based on previous work in southern Indiana by Hannah (1968) and Van Kley (1993). Six openings from each of the three age classes for each aspect were randomly selected for sampling. Thus, there were 12 openings per age class, or 18 openings per aspect, for a total of 36 openings. All were examined to verify that: (1) the aspect was north or south; (2) the opening was fairly distinct and discernible; (3) the surrounding stand was mature upland central hardwoods; and (4) the opening was not an old field reverting to forest. Each group opening failing to meet conditions (2) through (4) was dropped, and a new one was randomly selected. The selected openings were irregular in shape and varied in size from 0.07 ha to 0.23 ha with an average size of .13 ha.

Woody plant species were sampled on transects extending from the center to the edge of each opening. One-meter-wide transects were used for stems less than 2.5 cm diameter at breast height (dbh, 1.37 m above ground), and 2-m-wide transects were used for all stems greater than or equal to 2.5 cm dbh. Transects extended upslope, downslope, and in both directions across the slope, beginning 1 m from the center of the opening and ending at the edge of the opening as defined by the trunks of the adjacent mature trees. Ending the transects at the base of the trees bordering the opening follows Runkle's (1982) method of measuring extended canopy gaps. Each transect was subdivided into 1 m lengths for sampling woody species along the transect. Field data collection was completed during the summer of 1991.

Height (in 25 cm categories) and distance from the plot center (in 1 m increments) were measured by species for each stem less than 2.5 cm dbh. Dbh (to the nearest 0.1 cm), height (nearest 1 m), crown class (in relationship to the regeneration), and distance from the plot center (1 m) were recorded by species for woody stems greater than or equal to 2.5 cm dbh.

For analysis, the species were put into the following eight groups: (1) oak–hickory, (2) yellow-poplar, (3) dogwood, (4) beech–sugar maple, (5) shrubs and small trees, (6) cherry–ash–walnut, (7) sassafras, and (8) miscellaneous species.

Also for analysis, distance from plot center was grouped into three categories: center, first 4 m from plot center; middle, area after the first 4 m and before the last 4 m; edge, the last 4 m of the transect.

Aspect was determined in the field, and area of each opening was calculated using the length of each transect to determine the area of an ellipse.

Analysis of variance, ANOVA, was used to determine whether the variables aspect, age, species group, location within the opening, or their interaction had any effect on the average number of stems per hectare or average height. When an effect was significant, the Student-Newman-Keuls multiple range test was used to determine differences between the means.

## Results

### Parent Stand

The species composition of each stand was obtained from NSWC's most recent forest inventory data, March 1991. The NSWC inventory placed each inventoried forest stand into a

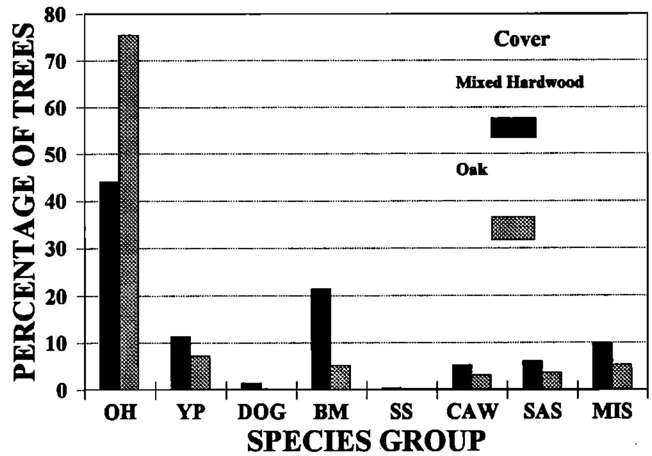


**Figure 1. Composition of the overstory of openings prior to harvest, by forest type based on NSWC inventory data. (Abbreviations follow Table 1.)**

cover type and size class. The parent stands of the 36 openings consisted of 4 cover type-size class groups: oak–hickory poletimber, oak–hickory sawtimber, mixed hardwood poletimber, and mixed hardwood sawtimber. The species percentage and size distribution for the four cover type-size class groups were averaged, for each group, from across the entire NSWC. All openings sampled for our study were established in sawtimber stands. Single tree selection, in the stand surrounding the group openings, at the time of harvest (1971–1985), resulted in the poletimber classification for some stands in the 1991 inventory. Fifty-three percent of the openings were in the oak–hickory cover type, and 47% in the mixed hardwood cover type. The oak-hickory species group was the dominant species group constituting more than 75% of trees in the oak–hickory cover type, and 44% of the mixed hardwood cover type (Figure 1). The next most dominant species group was the beech–maple group with just over 20% of the trees in the mixed hardwood cover type. The only other species making up more than 10% of the original cover was yellow-poplar, with 11% in the mixed hardwood cover type.

### Number of Stems ≥ 2.5 cm Dbh

For stems ≥ 2.5 cm dbh, the number per hectare varied by the interaction of species group and location within the opening. The number of stems did not differ significantly by aspect or time since cutting.

The two most dominant species were yellow-poplar and dogwood. Compared to the other six groups, these two species had at least double to triple the number of stems per hectare (Figure 2). The other species groups did not differ significantly except for the oak–hickory, with fewest stems per hectare. Oak–hickory also differed significantly from sassafras and beech–sugar maple. Although the numbers of stems by species group changed with time since cutting, this interaction was not significant.

When the species group by location interaction was tested, yellow-poplar, dogwood, and the miscellaneous species group showed a significant difference between locations (Figure 3). The number of stems per hectare decreased from the center of the opening to the edge of the opening for the miscellaneous species and yellow-poplar

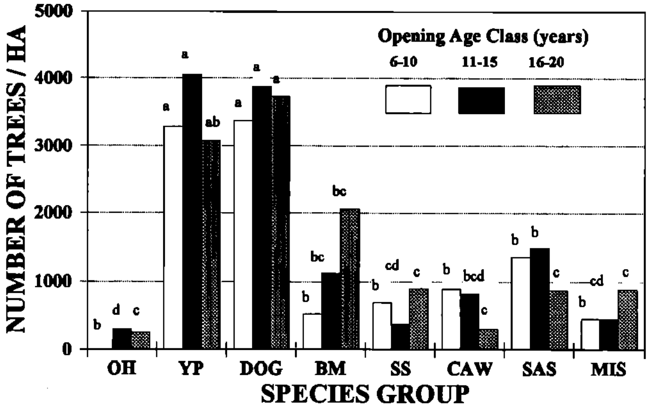


**Figure 2. Number of stems, greater than or equal to 2.5 cm dbh, by species group and age of opening. Species groups within individual age classes with similar letters do not differ significantly at α = 0.05. (Abbreviations follow Table 1.)**

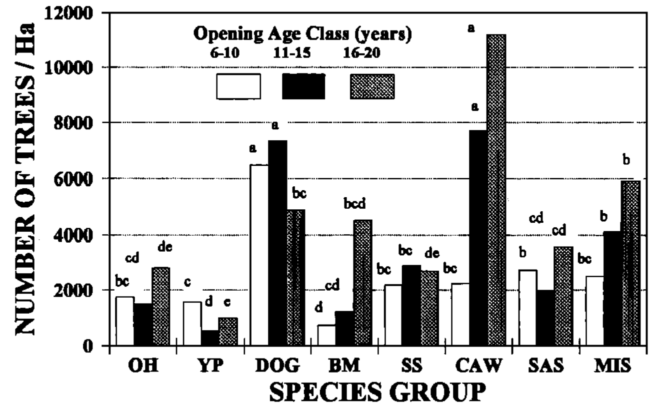


**Figure 4. Number of stems, less than 2.5 cm dbh, by species group and age of opening. Species groups within individual age classes with similar letters do not differ significantly at α = 0.05 (Abbreviations follow Table 1.)**

species groups. Dogwood contained the most stems per hectare in the middle location, but this number did not differ significantly from the center location. The edge location contained the fewest stems for dogwood. The oak–hickory group did not occur in the center location, and slightly more stems grew in the edge location than in the middle location.

### Number of stems < 2.5 cm Dbh

The interaction of time since cutting with species group, and the interaction of aspect with species group influenced the number of stems per hectare for trees < 2.5 cm dbh. However, location did not.

In the 6–10 yr openings, dogwood was significantly more abundant than all the other species groups (Figure 4). For openings 11–15 yr old, the cherry–ash–walnut species group was significantly more abundant than all species groups except dogwood. In the 16–20 yr openings, the cherry–ash–walnut species group was significantly more abundant than all the other species groups. The yellow-poplar group was next to least abundant in the youngest openings and least abundant in the older openings.

On north aspects (Table 1), the cherry–ash–walnut species group was significantly more abundant than everything else, and was second most abundant on the south aspects (Table 1). Dogwood was significantly more abundant on the south aspects and the second most abundant species group on the north aspects. The yellow-poplar species group had the fewest stems on both the north and south aspects. The oak–hickory species group was the second least abundant on north aspects, and fourth least abundant on south aspects.

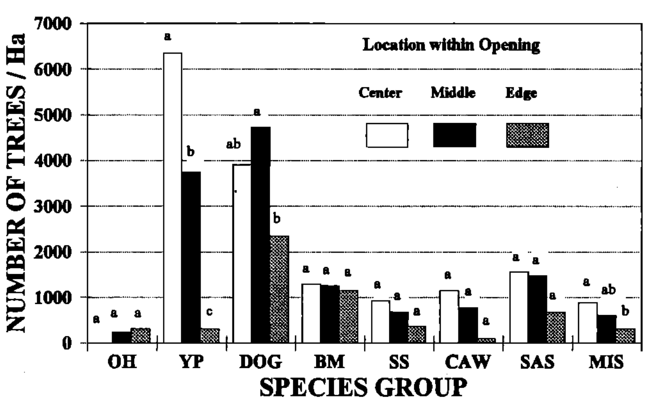


**Figure 3. Number of stems, greater than or equal to 2.5 cm dbh, by species group and location within the opening. Locations within individual species groups with similar letters do not differ significantly at α = 0.05. (Abbreviations follow Table 1.)**

### Average Height

The average height of stems ≥ 2.5 cm dbh differed significantly by the interaction of time since cutting with species group. All species groups showed a height increase from the most recent to the oldest openings except for dogwood, beech-maple, and cherry–ash–walnut (Figure 5). They were slightly shorter in the 16–20 yr openings compared to the 11–15 yr openings. In the youngest openings, the beech–sugar maple (7.7 m) species group was significantly taller than everything else. The oak–hickory species group was not present. Yellow-poplar (8 6 m) was the tallest species group in the 11–15 yr openings, and oak–hickory (5.8 m) was the shortest. In the oldest openings, yellow-poplar (10.1 m) was significantly the tallest and the oak–hickory (7.5 m) species group remained shorter than all other species groups except dogwood and miscellaneous.

**Table 1. Number of stems per hectare, less than 2.5 cm dbh, by species groups and aspect.**

| | Aspect | |
|---|---|---|
| Species group | North[1] | South[1] |
| Oak–hickory (OH) | 1,529.2[d] | 2,500.1[cd] |
| Yellow-poplar (YP) | 965.8[d] | 1,137.3[d] |
| Dogwood (DOG) | 6,316.7[b] | 6,152.3[a] |
| Beech–maple (BM) | 2,107.9[d] | 2,205.0[cd] |
| Shrubs/small trees (SS) | 3,899.0[c] | 1,275.5[d] |
| Cherry–ash–walnut (CAW) | 10,012.7[a] | 4,088.7[b] |
| Sassafras (SAS) | 1,947.2[d] | 3,580.7[bc] |
| Miscellaneous species (MIS) | 5,441.4[b] | 2,900.6[bc] |

1 Means in the same column with similar letters do not differ significantly at α = 0.05.

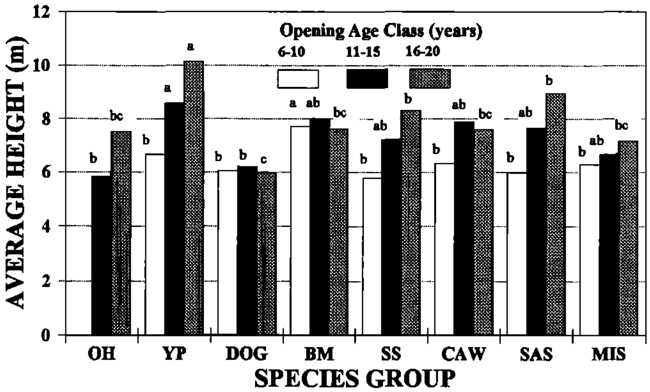


**Figure 5. Average height of stems, greater than or equal to 2.5 cm dbh, by species group and age of opening. Species groups within individual age classes with similar letters do not differ significantly at $\alpha = 0.05$. (Abbreviations follow Table 1.)**

## Discussion

The parent stands in our study were dominated by the oak–hickory group, but future stands will include a diversity of species dominated by yellow-poplar. As indicated by the number of stems ≥ 2.5 cm dbh and < 2.5 cm dbh, the oak–hickory were the least abundant of any species group. This suggests that the oak–hickory species group will not dominate the future stand. For the stems ≥ 2.5 cm, yellow-poplar was dominant in all but the youngest openings. Oak–hickory remained among the shortest species groups in openings of all ages.

These results differed from those reported by Runkle (1981) and Barden (1981), who suggested that species replace themselves in larger canopy gaps. However, their research was conducted in forest stands where shade-tolerant species dominated the forest canopy, and shade-tolerant species replaced shade-tolerant ones. In stands with oak-hickory overstories similar to ours, Standiford and Fischer (1980) reported a decrease from 80% oak before harvest to 7% oak 12 to 15 yr later. Fischer (1987) and George and Fischer (1991) observed a similar trend for clearcuts on the Hoosier National Forest, where oak–hickory declined in numbers from the original parent stand.

Number of stems did vary from the center of the opening to the edge for stems ≥ 2.5 cm dbh. The center location always had significantly more stems per hectare than did the edge location. The middle location always had less than the center but more than the edge location. This can be partially explained by the fact that yellow-poplar was one of the most dominant species groups in the openings. Yellow-poplar, being intolerant, should be most common in the more sunny areas in the center and middle portions of the opening and less common in the shaded areas around the edge of the openings (Minckler and Woerheide 1965).

For stems < 2.5 cm dbh there was a significant continual increase in the number of stems from the youngest openings to the oldest, especially cherry–ash–walnut. This would indicate that there was a steady influx of new stems into the openings. Runkle (1982) reported this same influx of seedlings in canopy gaps for the first 15 yr following canopy gap creation. However, the dogwood stems were of sprout origin and thus their numbers decreased as the sprout clumps self-thinned. The fast growth rate of yellow-poplar and its shade intolerance (Beck 1990) explains the few yellow-poplar stems present in the < 2.5 cm class. Yellow-poplar either outgrew the competition or could not survive in the shade.

The height growth of the species groups corresponded well with mean growth rates observed by Yetter and Runkle (1986) and George (1988). For canopy gaps, Yetter and Runkle reported mean height growth for dominant stems with yellow-poplar having the second highest growth rate and beech and northern red oak the slowest. George reported average annual height growth for dominant plot trees in a clearcut. Yellow-poplar had the second highest growth rate after aspen. For white, red, and black oak, observed growth rates were a foot or less per year.

## Application

We do not know the quantity and type of advanced regeneration present before harvest. Sander (1978) and Sander et al. (1983) suggested that securing oak in future stands would depend on its presence as advance regeneration prior to cutting. When oak advance regeneration is not present in sufficient quantities, steps are necessary to increase the quantity. Loftis (1985, 1988) recommended the use of herbicide to remove undesirable stems, allowing for the increase in size and number of desirable ones.

Oak stems are a minor component in the developing canopy of the openings that we studied. There are sufficient oak stems greater than 2.5 cm to dominate the opening but in a subordinate position. Release of the most vigorous stems within a few years after harvest may provide a full canopy of oak in the developing canopy.

This suggests that to obtain sufficient oak in future stands, openings might be located in areas with abundant oak advance regeneration, oak advance regeneration be increased prior to harvest, or proper cultural treatment be given to oak stems in the developing canopy.

## Literature Cited

BARDEN, L.S. 1981. Forest development in canopy gaps of a diverse hardwood forest of the southern Appalachian Mountains. Oikos 37:205–209.

BECK, D.E. 1990. Yellow-poplar. P. 406–416 *In* Silvics of North America, Vol. 2. USDA For. Serv. Agric. Handb. No. 654.

FISCHER, B.C. 1987. The regeneration response to clearcutting on the U.S. Forest Service Hoosier National Forest. Wayne-Hoosier Nat. For. USFS Contract No. 53-52B1-5-01086. 95 p.

GEORGE, D.W. 1988. Tree regeneration response to clearcut harvesting on the Hoosier National Forest. Ms. thesis, Purdue Univ. 124 p.

GEORGE, D.W., AND B.C. FISCHER. 1991. The occurrence of oak reproduction after clearcut harvesting on the Hoosier National Forest. North. J. Appl. For. 8:144–146.

HANNAH, P.R. 1968. Estimating site index for white and black oaks in Indiana from soil and topographical factors. J. For. 66(5):412–417.

HOMOYA, M.A., D.B. ABRELL, J.R. ALDRICH, AND T.W. POST. 1985. The natural regions of Indiana. Proc. Ind. Acad. of Sci.. 94:245–268.

LOFTIS, D.L. 1985. Preharvest herbicide treatment improves regeneration in southern Appalachian hardwoods. South. J. Appl. For. 9(3):177–180.

LOFTIS, D.L. 1988. Regenerating oak on high-quality sites, an update. P. 199–209 in Proc. Guidelines for regenerating Appalachian hardwood stands. Morgantown, WV.

MINCKLER, L.S., AND J.D. WOERHEIDE 1965. Reproduction of hardwoods 10 years after cutting as affected by site and opening size. J. For. 57:424–428.

Roach, B.A., and S.F. Gingrich. 1968. Even-aged silviculture for upland central hardwoods. USDA For. Serv. Agric. Hand. No. 355. 39 p.

Runkle, J.R. 1981. Gap regeneration in some old-growth forests of the eastern United States. Ecology 62(4):1041–1051.

Runkle, J.R 1982. Patterns of disturbance in some old-growth mesic forests of Eastern North America. Ecology 63(5):1533–1546.

Sander, I.L. 1978. Silvicultural systems for the oak-hickory forest type. P. 344–348 in North America's forests: Gateway to opportunity. 1978 Joint Conv. of SAF and CIF.

Sander, I.L., and F.B. Clark. 1971. Reproduction of upland hardwood forests in the central states. USDA For. Serv. Agric. Hand. No. 405. 25 p.

Sander, I.L., C.E. Mcgee, K.G. Day, and R.E. Willard. 1983. Oak-hickory. P. 116–120 *in* Silvicultural systems for the major forest types of the United States. USDA For. Serv. Agric. Handb. 445.

Standiford, R.B., and B.C. Fischer. 1980. Fifteen year results of three harvesting methods on composition and development of regeneration in southern Indiana upland hardwoods. P. 408–419 *in* Proc. Central Hardwood For. Conf. III. Columbia, MO.

USDA Forest Service. 1991. Amendment to the Hoosier National Forest land and resource management plan. 87 p.

USDA Soil Conservation Service. 1988. Soil survey of Martin County, Indiana. 148 p.

Van Kley, J. 1993. Ecological land type phase classification for the Hoosier National Forest. Ph.D. Diss., Purdue University. 436 p.

Yetter, T.C., and J.R. Runkle. 1986. Height growth rates of canopy tree species in southern Appalachian gaps. Castanea 51(3)157–167.