NORWAY SPRUCE - A QUALITY REFORESTATION SPECIES

Edwin H. White
SUNY College of Environmental Science and Forestry

and

Eric J. Jokela
Department of Forestry
University of Florida
Gainesville, Fl

Norway spruce is a native European conifer commonly planted since the late 1800's as an ornamental and for shelterbelts and plantations in eastern North America. It presently occupies 60,200 acres of commercial forest land in New York, with about 49 percent classified as sawtimber, 39 percent as poletimber and 12 percent as sapling stands (Considine and Frieswyk 1982). The increased popularity of Norway spruce as a commercial species in the Northeast reflects the strong demand for long-fibered wood and the need to replace red pine as a plantation species on sites where imperfectly drained soils have reduced productivity (Stone et al. 1954). Norway spruce is also tolerant to scleroderris canker (*Gremmeniella abietina* (largerb.)) which can severely damage red pine on cool and moist sites.

METHODS

Data for the study were collected from thirty-seven stands located throughout the Allegheny Plateau region in central New York (42°40'N, 72°20'W). The stands were all even-aged, unthinned, fully stocked plantations that varied in age from 45 to 55 years old (mean = 51 years), and were established from seed sources originating in the Black Forest of Germany. The landscape was dominated by rolling glacial till uplands and deep U-shaped, steep-sided valleys (Hutton and Rice 1977). Elevations of the study sites varied from 1260 to 2080 ft. Soils supporting the sample stands were characterized as acidic, channery silt loams that formed in glacial till derived from sandstone, siltstone, and shale bedrock of the Devonian period (Table 1). Total rooting depth to either fractured bedrock or fragipan varied from 12 to 30 in. and soil drainage ranged from poorly-drained to somewhat excessively-drained. The climate is humid continental with cold, snowy winters and cool, moist summers. Mean monthly temperatures range from 21 degrees F. in January to 64 degrees F. in July. Approximately 50 in. of precipitation are received annually with about 50% occurring during the 120 to 150 day growing season.

Soils

Three randomly located soil pits were constructed in each stand and described using standard procedures. The A, Ap, and AB subhorizons were all grouped into the A master horizon to characterize variables such as horizon thickness. Similar procedures were used for the B horizon. Percent coarse fragments (>2 mm; ocular estimate --% by volume) within each master horizon were computed as the average of each contributing subhorizon, weighted by thickness.

Soil samples were collected from 0-6 in. in each pit from all four pit faces and composited for laboratory chemical and physical characterization.

Topographic variables such as slope gradient, aspect, distance to ridge top, and local slope length were measured

Table 1. General soil characteristics of study site locations.

No stands				
Unstratified	Stratified[1]	Classifications	Soil series	Drainage class
3	2	Loamy-skeletal, mixed mesic Typic Dystrochrepts	Lordstown/ Arnot	Well drained somewhat excessiv drained
6	3	Coarse-loamy, mixed mesic Typic Fragiochrepts	Bath	Well drained
20	15	Coarse-loamy, mixed mesic Typic Fragiochrepts	Mardin	Moderate well-dra
8	3	Fine-loamy, mixed mesic Aeric Fragiochrepts	Volusia/ Chippewa	Somewhat poorly drained to poorl drained

'Data set stratified by a common planting density (1210 stems/ac).

directly in the field. Local slope length, representing an expression of local drainage conditions, was measured as the distance from the point of origin of local overland flow (e.g. ridge top or upper bench flat) to the base of the slope (or bench) where deposition of sediments begin. Stand elevations were determined from U.S. Geological Survey topographic maps. An expression developed by Stage (1976) was used to examine the collective effects of aspect and slope gradient on productivity. This procedure empirically determined the optimum aspect for tree growth using the sample data while considering the interaction effects of slope.

Volume Equations

A total of 228 trees (6 per stand) representing the range of crown classes and diameters were destructively sampled for developing volume prediction equations. The form of the volume equation used was:

$Y = bo + bi\ D + b2\ D^2 + e$ where

Y tree volume (ft3)

D dbh (in.)

b's regression coefficients

e error term

The stem volume prediction equations were used to estimate total and merchantable standing volume on each plot by applying them to the inventory data.

Soil-Site Equations

Soil-site prediction equations were developed using stepwise multiple regression procedures. Mean annual increment (MAI) was chosen over total standing volume as the dependent variable because, despite the narrow range in ages of the sample stands (10 yrs.), age was significantly correlated ($r = 0.42$; $p = 0.01$) with total standing volume. By using MAI, age was eliminated as a potential independent variable.

RESULTS AND DISCUSSION

General Stand Characteristics

The mean age of the sample stands was 51 years. Average total height of dominant and codominant stems ranged from 58 to 93 ft. (mean = 75 ft.), and live crown ratios ranged from 43 to 63% (mean = 53%). Basal area varied among stands (150 to 239 ft2/ac; mean = 199 ft^2/ac) with Norway spruce generally comprising greater than 90% of the total. Quadratic mean stand diameters ranged from 6.5 to 10.6 in. (mean = 8.2 in.), and stem densities of Norway spruce ranged from about 325 to 930/ac. The wide range in stem densities reflects differential spacing at establishment (i.e., 680 to 4840 stems/ac) and natural mortality of the less vigorous trees.

Calculated as a percentage of the original planting density, Norway spruce mortality across all sites varied from 39 to 83% (mean = 58%). The highest mortality levels were in stands planted at the closest initial spacings, and those stands still have the highest stem densities.

The most common initial planting density (n = 23 stands) was 1210 stems/ac (6 ft.spacing). Mortality levels under this planting density ranged from 39 to 68% (mean = 56%). Average total height of the dominant and codominant stems, used as an expression of site quality, was significantly correlated (r = 0.65, p = 0.0008) with tree mortality. Thus, higher quality sites generally showed higher levels of tree mortality than did poorer quality sites. Even though the somewhat poorly drained and somewhat excessively drained sites had slightly lower levels of mortality than the moderately well-drained and well-drained sites, no statistically significant differences (p = 0.05) were detected. The lack of statistical significance may reflect the variability encountered and the small sample size of 3 stands, 4 stands, and 2 stands for the somewhat poorly drained, well-drained, and somewhat excessively drained classes, respectively.

<u>Total and Merchantable Standing Volume</u>

Estimates of total volume for the 38 stands ranged from 5431 to 8833 ft^3/ac (mean = 7318 ft^3/ac) and merchantable volume from 4431 to 8218 ft^3/ac (mean = 5689 ft^3/ac) (Table 2). The most productive stand (age 48 years) contained 39% more total volume and 46% more merchantable volume than the least productive stand (age 50 years). Merchantable volume represented approximately 90% of the total standing volume, and stumps accounted for 3% and bark 10%. Values for MAI ranged from 109 to 175 ft^3/ac/yr., and 19 of the 38 stands had MAI values greater than the overall mean of 145 ft^3/ac/yr. The narrow range in ages of the sample stands and lack of data for periodic annual increment make it impossible

Volume component	Standing volume		Mean ann.incre	
	Mean	Range	Mean	Ra
	.....ft^3/ac.....		..ft^3/ac/yr	
Total volume(ob)(stump excluded)	7318	5431-8833	145	109
Total volume(ib)(stump excluded)	6560	4860-7932	130	98
Total volume(ob)(stump included)	7575	5617-9147	150	113
Total volume(ib)(stump included)	6789	5031-8204	135	100
Merchantable volume(ob)(stump excluded)	6589	4431-8218	130	90
Merchantable volume(ib)(stump excluded)	5931	3973-7389	117	82

[1] Values are based on data from 4 plots at each of the 38 stands

to determine, without further measurements, whether MAI has culminated. However, forest management tables from Great Britain

Table 2. Estimates of standing volume and mean annual increment for 38 unthinned Norway spruce stands in central New York.1

suggest that MAI typically culminates in thinned stands between the ages of 63 and 79 years for high and low quality sites, respectively (Hamilton and Christie 1971). Culmination of MAI should occur earlier in these unthinned stands.

Mean total standing volume was 7332 ft^3/ac for the 23 stands planted at 1210 stems/ac and 8104 ft^3/ac for the two stands planted at 4840 stems/ac (3 ft. spacing). Stiell and Berry (1973a) found that closer initial spacing in 50 year old unthinned white spruce stands in eastern Canada produced greater yields at all ages. Although it appears that this is true for the Norway spruce stands sampled in this study, neither total standing volume nor MAI were significantly correlated ($p = 0.05$) with initial stem density. The lack of statistical significance could be due to the few number of stands sampled with high initial densities.

Analysis of covariance of the 23 stands planted at 1210 stems/ac revealed no statistically significant ($p = 0.05$) differences in Norway spruce stand volumes by soil drainage classes. However, the well-drained and moderately well-drained sites appear to have higher volumes than the somewhat poorly drained and somewhat excessively drained sites. Although these results are based on a limited sample size, they do support previous findings that indicate that Norway spruce is generally tolerant of a wide range of soil moisture conditions (Hosley 1936). Camirand et al. (1983) reported that in 20 to 31 year old Norway spruce stands in Quebec, growth was not significantly different among diverse drainage classes, although best growth occurred on well-drained sites.

The adaptability of Norway spruce to a broad range of soil drainage conditions is one attribute that may favor its planting over red pine on many sites on the Allegheny Plateau. Unlike red pine, Norway spruce appears far less sensitive in terms of survival and long-term productivity to inclusions of somewhat poorly drained soils, which typify many sites. Thus, this attribute offers an important advantage for foresters interested in treating large contiguous acreages under similar management prescriptions.

MAI values for Norway spruce in central New York are generally higher than those previously recorded for this species in eastern North America. MacArthur (1964) reported a MAI of 124 ft3/ac/yr. for a 44 year old stand in Quebec. Similarly, Hughes (1970) documented a MAI value of 144 ft^3/ac/yr. for a 51 year old stand in New Brunswick. Hosley (1936) reported a single plot MAI estimate of 221 ft^3/ac/yr. for an unthinned, 37 year old, site index 90 stand in south-central New York. This estimate may reflect a regional maximum in total net volume production for Norway spruce and is impressive in light of Hamilton and Christie's (1971) suggestion that MAI of high quality Norway spruce stands in Great Britain culminates after age 60.

Estimates of total standing volume of Norway spruce in central New York are comparable to yields reported for indigenous conifers of eastern North America. Predicted total volume yields from 50 year old unthinned white spruce stands in eastern Canada (6 ft. spacing) range from 3273 to 6817 ft^3/ac for site index classes 50 and 80, respectively (Stiell and Berry 1973a). Total predicted volumes for 23 Norway spruce stands (equivalent initial spacing) from the current study averaged 8% higher (7332 ft3/ac; total height = 75 ft.) than the site index 80 yield for white spruce. The most productive Norway spruce stand sampled at this spacing (8318 ft^3/ac; total height = 73 ft.) was 22% higher. Total volume yields for unthinned red pine stands (6 ft. spacing) range from 4202 to 8904 ft^3/ac for site index classes 50 and 80, respectively (Stiell and Berry 1973b). The most productive Norway spruce stand from the current study (equivalent initial spacing) had a predicted total volume yield approximately 7% lower than the site index class 80 yield for red pine. These comparisons are encouraging since site index 80 stands of white spruce and red pine are not commonly found on these same soils. The only other native conifer with comparable levels of production on these soils is eastern white pine. However, because of damage from the white pine weevil (*Issodes strobi* (Peck.)), it is no longer commonly planted for commercial purposes on the Allegheny Plateau.

Results from this study also provided a quantitative assessment of site characteristics related to volume production of Norway spruce plantations in New York. Multiple regression statistical analyses indicated that soil properties reflective of differences in internal soil drainage and aeration, soil volume, and fertility in the primary rooting zone were factors most consistently correlated with growth. Topographic features such as slope length, distance to ridge top, aspect, and elevation made little or no independent contribution to the predictive equations developed for MAI.

Although Norway spruce can tolerate a wide range of soil drainage conditions, best growth was generally observed on the well and moderately well-drained soils. Shallow (<15 in.), poorly-drained soils with characteristic gley horizons were among the least productive sampled. Moderate amounts of coarse fragments within the B horizon appeared to enhance productivity through better aeration and internal drainage.

Decisions regarding species-site selection tend to vacillate over time. Norway spruce has experienced no exception to this rule, periodically receiving favor and disfavor for reforestation purposes. Undoubtedly, part of this apparent indecision is related to insufficient information on attributes and site requirements for this species. Quantitative results generated from this study should aid yield prediction and site classification decisions for Norway spruce in Northeastern North America.

Results from this investigation indicate that volume production for Norway spruce in New York is as good as, or better than, that reported for native conifer species commonly planted in the northeastern United States and eastern Canada. These results demonstrate the potential of Norway spruce as a fiber source and support its continued use as a plantation species in this region. Norway spruce shows suitability for planting on well-drained, moderately well-drained, and somewhat poorly drained silt loam soils, particularly on sites where native conifer species such as red pine have failed or exhibited reduced productivity.

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