chapter twenty-two

Regeneration by direct seeding — a way to reduce costs of conversion

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22.1 *Introduction*

Many western European countries need less expensive regeneration methods for their Norway spruce (*Picea abies* [L.] Karst.) forests. Financial returns from timber production have declined severely over the past 15 years and levels of future returns are impossible to predict. Additionally, the increasing frequency of severe windthrow from winter storms has focused more attention on stand stability and has prompted efforts to convert pure Norway spruce forests to broadleaf or mixed stands. Foresters of Forstamt Weissenhorn in Bavaria, Germany implemented a technique for direct seeding beech (*Fagus sylvatica* L.) and European silver fir (*Abies alba* Mill.) in Norway spruce stands that costs about 20% of the cost for traditional planting methods and results in a mixed-species stand (Baumhauer 1996). The direct seeding approach seems to solve an important challenge to restoring off-site and pure Norway spruce plantations in Europe and provides low costs and high stocking density, thereby ensuring high wood quality in the future.

Forstamt Weissenhorn is a state forest in the Bavarian region of southern Germany. Soils are mostly poorly drained due to high clay contents. Norway spruce grows well, up to 40 $m^3 ha^{-1} year^{-1}$, but develops a shallow root system that increases the risk of windthrow. In 1984, Norway spruce plantations accounted for 89% of the area and dominated the older age classes (80 to 120 years). About one third (2,000 ha) of the spruce plantations

have been damaged by wind within the past 15 years. Predictions of future climate change suggest that Norway spruce will be eliminated as a commercial species in the region within the next 100 years due to summer drought. In response to this grim future, a decision was taken to quickly increase the regeneration of shade-tolerant and wind-stable species such as beech and European silver fir in order to take advantage of the favorable regeneration conditions under the remaining spruce stands. The goal is mixed stands with beech, fir, and spruce in equal amounts. Norway spruce regenerates naturally and vigorously; for the other species, direct seeding seemed a promising and cost-effective alternative to planting.

22.2 Silvicultural treatments

Traditional silvicultural approaches to manage spruce stands restrict regeneration treatments to older, often unstable stands that leave limited flexibility for regeneration treatments. Blowdown, followed by mortality from bark beetle attacks in old spruce stands, causes severe regeneration problems. Mortality opens the canopy, releasing natural spruce regeneration before sown fir and beech regeneration is able to establish. Until recently, fir and beech were sown in many old stands that are now too open due to the bark beetle attacks. Instead, they are underplanted with fir seedlings and beech wildings that can compete with the flush of spruce regeneration. Planting wildlings is cheaper than planting beech nursery stock. In younger spruce stands, direct seeding of fir and beech is now used to avoid future regeneration problems in the old stands.

Control of the light environment for regeneration by manipulating the canopy cover is essential for successfully establishing mixed stands. Thinning a spruce stand too heavily or too early will favor the spruce in the entire stand. This is particularly the case with directly sown fir and beech. Consequently, direct seeding generally requires lower and better-controlled light conditions than planting. Fir is a slow starter, but it can establish under a rather dense shelterwood; therefore, it is sown several years before the beech. Beech is intermediate between fir and spruce in shade tolerance, but it also needs to gain a foothold before the natural regeneration of spruce is released by canopy opening.

Direct seeding starts after crown thinning to open the canopy in spruce stands as young as 35 years old. Fir is sown 3 years later and beech is sown 10 to 18 years later. There are two major advantages of this strategy. First, the young spruce stands produce less seed than older stands, reducing the competition with beech and fir. Second, young spruce stands have a lower risk of blowdown or bark beetle attack and are likely to keep a shelterwood longer. The light shade of the shelterwood may facilitate individual tree differentiation in the late regeneration stages, reducing the need for precommercial thinning in the future.

Table 22.1 A Typical Timeline for the Regeneration of Spruce Stands

Regeneration Timeline (year)	Treatment
0	Heavy thinning to open the closed canopy. Canopy cover is reduced to 80% in stands beginning as young as 35 years old
3	Fir sowing
7	Shelterwood thinning where fir has established. Canopy cover is reduced to 70%
10–18	Beech sowing or planting
20–35	Two further thinnings to release the fir and beech regeneration and naturally regenerate spruce
Beyond 35	A final cut when the regeneration is complete

We can only provide an approximate schedule for the sowing and shelterwood thinning (Table 22.1). The timing and selection of the silvicultural treatments are decided by the forester, based on experience and site and stand characteristics. Additionally, seed years are important for the precise timing. Generally, fir is sown 3 years after the stand has been thinned to 80% canopy cover. Beech is sown or planted after the fir regeneration reaches a height of 15 to 20 cm (7 to 15 years later). Before sowing the beech, the shelterwood is thinned again to 70% canopy cover. After the beech regeneration is about 2 m tall, two more crown thinnings open the canopy. These thinnings gradually release the fir and beech regeneration and the naturally regenerated spruce. The final harvest of the stand is done about 35 years after the regeneration was initiated.

In the Forstamt Weissenhorn, hunting regulates the deer population to a level where fencing to protect the regeneration is unnecessary. If browsing on the new germinants or planted seedlings is a problem, jars with a commercial deer repellent are placed half-buried in the topsoil in a 20 × 20 m grid for 2 months. Direct seeding is best following major seed years, when seed predation by rodents, birds, and squirrels seems to be less and the germination percentage better than in years of lower seed production. Moreover, seed years offer inexpensive seed if they are collected and handled in large amounts.

22.3 Seed storage and handling

The seed stock requires no pretreatment if sown in the fall, whereas spring seeding necessitates storage and pretreatment to break seed dormancy. Nevertheless, spring seeding is recommended for beech in order to shorten the time beechnuts are on the forest floor and vulnerable to seed-eating mammals and birds. Controlled moisture content (28 to 32%) and 4°C is needed to break the dormancy of beech and prevent germination before seeding. Normally, the pretreatment takes 12 weeks, after which the beechnuts can be sown or stored at about −2°C until seeding. Stored seed should be mixed every week to prevent fungal attack. A local storage facility for agricultural crops was modified for storing beechnuts. Seeds are blown into the storage facility by airflow, and a built-in cooler controls the temperature.

Fir cones are collected in September from both standing and felled trees and placed on a wooden floor to dry, in a layer of up to 15 cm in thickness. In about 2 weeks, the cones

Figure 22.1 Locally developed sowing machine (Sämagrub) with two flexible seeding units. The machine, which is pulled by a 4WD farm tractor, can scarify a mineral soil seedbed without injuring the roots of the overstory trees.

Table 22.2 Costs for Direct Seeding

Beechnuts — 40 kg ha^{-1}, \$10 kg^{-1}	\$400 ha^{-1}
Fir seed — 3.5 kg ha^{-1}, \$50 kg^{-1}	\$175 ha^{-1}
Sowing with machine, 2 × \$125	\$250 ha^{-1}
Deer repellent protection	\$75 ha^{-1}
Total	\$900 ha^{-1}

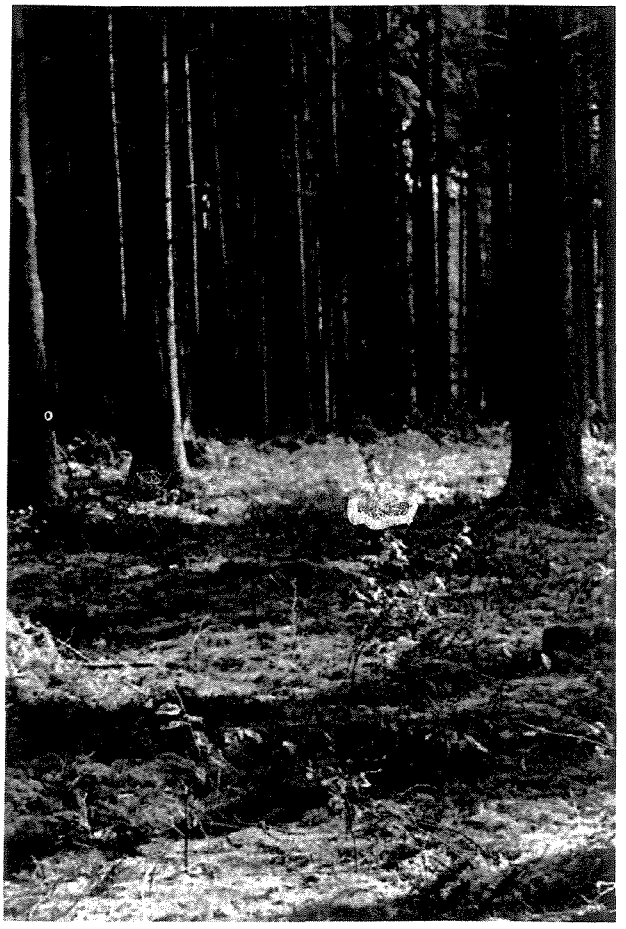

Figure 22.2 Direct seeding can support high stock density.

fall apart. The seeds are sorted from the scales and sown during the following fall and winter, which makes seed pretreatment unnecessary.

22.4 Sowing technique

Basically, all spruce stands are accessible for our locally developed sowing machine (Figure 22.1). Sowing by hand is also possible, but is more expensive. A 1.3-m wide 4-wheel-drive tractor pulls the sowing machine. The seeding density is controlled from the driver's position. This combination can climb slopes up to 30%, and can sow 1 ha h^{-1}. The sowing machine has two flexible seeding units, which scarify a mineral soil seedbed

without injuring the roots of the overstory trees. The capacity to sow 8 to 10 ha daily considerably reduces costs; large regeneration targets are reached in a short time, thereby avoiding seeding in less favorable years. Fir seeds are sown on the mineral soil seedbed surface and beechnuts are placed deeper in the mineral soil.

Generally, the amount of seed is 3.5 kg fir and 40 kg beechnuts, per ha provided the germination rate is high, which typically means 40% for fir and 80% for beech. Seed densities are increased if germination rates are lower. Sometimes, sycamore maple (*Acer pseudoplatanus* L.) is sown; this species is broadcast sown without seedbed preparation at 4 kg of seed per ha. Sycamore maple is sown less often than fir and beech because the target for this species is only 3 to 4% of the forest district. Largely used for supplementary planting if some of the main species fail to regenerate, sycamore maple can be sown on larger areas in a mixture with ash (*Fraxinus excelsior* L.) along small streams and rivers.

22.5 Costs

To establish a mix of species in pure spruce stands, fir and beech are traditionally planted in 30 m × 60 m groups, at 2 m × 2 m spacing for fir and 1 m × 1 m for beech. This corresponds to 833 fir and 3,333 beech seedling per ha. Fir and beech seedlings from nurseries cost \$1.87 and \$1.5 per seedling including planting, totaling \$6,600 ha^{-1}. At Forstamt Weissenhorn, foresters use beech wildings (seedling from natural regenerations) for

Figure 22.3 Direct-seeded beech develops good root systems.

planting, which cost less than nursery stock. Beech wildings cost $0.31 per seedling and a further $0.62 to plant. The total cost to establish planted fir (nursery stock), beech (wildings), and Norway spruce (natural regeneration) is typically $4,660 ha^{-1} at Forstamt Weissenhorn.

This technique of direct seeding costs $900 ha^{-1} (Table 22.2), which is approximately 20% of the cost of the least expensive planting method using beech wildings. Sowing by hand is more expensive, as the seedbed preparation is done by hand on terrain that is inaccessible for machinery. It takes about 15 h of labor per ha ($50 h^{-1} including benefits) to sow fir and an additional 15 h ha^{-1} to sow the beech. Hand sowing has been discontinued at Forstamt Weissenhorn for fir and beech. Because no seedbed preparation is needed, sycamore maple can be inexpensively sown by hand; the only costs are for 4 kg of maple seed ($90 kg^{-1}) and 1 h ha^{-1}, a total of $410 ha^{-1}.

22.6 Conclusion

Direct seeding offers a very cost-effective alternative to planting. The main disadvantages are: the higher risk due to the many predators of seeds and newly germinated seedlings, as well as the need for more intensive management to select suitable stands, properly treat and store seed, and apply deer repellents, if necessary. Among the advantages: direct seeding fits well with the principles of nature-based silviculture, and it supports high future stand quality by the high stock density (Figure 22.2) and by the natural development of root systems (Figure 22.3). Inventories have shown up to 160,000 sown beech saplings per ha (50 to 80 cm average height) 8 years after establishment. Moreover, it is a highly mechanized method that can overcome the combined problems of large regeneration areas to be treated in a short time with limited manpower. Direct seeding is an important silvicultural method in modern forestry as it reduces regeneration cost.

Reference

Baumhauer, H., Verjüngung durch Saat — ein Beitrag zur Kostensenkung, *Allgemeine Forst Zeitschrift/Der Wald*, 51, 1192, 1996.