USE OF AN ORGANIC FERTILIZER IN REVITALIZATION OF PROTECTIVE FORESTS IN THE AUSTRIAN ALPS AFFECTED BY FOREST DECLINE [1]

by

Gerhard Glatzel, Klaus Katzensteiner, Hubert Sterba and Kurt Haselwandter [2]

Abstract. BIOSOL*), an organic fertilizer based on sterilized and dried mycelial residue from commercial antibiotic production, was tested as an alternative to mineral fertilizers in field experiments designed at revitalizing Norway spruce stands (*Picea abies*) affected by forest decline in Lech, Vorarlberg. Basal area increment responded positively and significantly to both mineral fertilizer and BIOSOL. Foliar nutrient levels increased only slightly and no major changes in soil microbial activity or mycorrhizal status were observed. Thus fertilization with moderate amounts of fertilizer seems to be a safe method to increase tree vigour without dramatically changing site parameters. Both fertilizer treatments were not sufficient to increase the production of viable seeds to an extent desired for improved regeneration of the stands. Due to its slow release characteristic BIOSOL is considered superior to soluble inorganic fertilizers for high elevation sites with soils of low sorption capacity and high leaching potential.

*)registered trademark of Biochemie Ges.m.b.H., Kundl, Austria

Additional Key Words: protective forests; forest decline; soil amelioration.

Introduction

The decline of protective forests in the Alps is a pressing problem. In many areas these forests were grazed by cattle, sheep or goats for centuries. In addition to browsing and trampling of young trees, such practices caused mineral nutrient depletion, soil compaction and injury to main roots. High game densities and the current problems with air pollution are aggravating the situation and many Alpine forests are in poor condition.

The forests of the well known tourist resort LECH in the Arlberg region of Western Austria, are typical examples of such declining forests. These forests are still used for grazing or as a refuge for livestock when early snow hits the alpine pastures. Most forests exhibit extremely imbalanced age structure. Regeneration has been virtually eliminated for decades or even centuries and thus old trees dominate. Many of the old trees are affected by root- and heart-rot and by mineral deficiencies due to the steady removal of biomass by grazing. As these forests decline and loose their protective function against avalanches and soil erosion, major efforts have to be undertaken to insure their revitalization and regeneration.

Natural regeneration is considered the most desirable method of regenerating these forests, mainly because the genetic information of the local tree populations is to be conserved. The poor vitality and the progressive deterioration of the old trees, which rarely produce viable seed, make this goal unattainable in many cases. A means to temporarily restore the vitality of these ageing stands and to carry them through the regeneration period are, therefore, much sought after.

The experiments in LECH are designed to test the use of fertilizer to improve the mineral nutrition of the trees and thus enhance vitality and seed bearing capacity. As soluble

[1]Paper presented at the symposium "Reclamation, a Global Perspective", Calgary, Alberta, Canada, August 27-31, 1989.

[2]Gerhard Glatzel is Professor, and Klaus Katzensteiner is Graduate Student at the Institute of Forest Ecology, Hubert Sterba is Professor at the Institute of Forest Yield Science, Universitaet fuer Bodenkultur, Vienna, Austria. Kurt Haselwandter is Associate Professor at the Institute of Microbiology, University of Innsbruck, Austria.

Proceedings America Society of Mining and Reclamation, 1989 pp 357-362
DOI: 10.21000/JASMR89010357

https://doi.org/10.21000/JASMR89010357

mineral fertilizers are subject to significant leaching losses at high altitude - high precipitation situations with a vegetation period as short as four months, a slow-release organic fertlizer (BIOSOL), based on mycelial biomass from commercial antibiotic production, was included. In pot experiments (Glatzel & Fuchs 1986) this fertilizer had shown very positive effects on root growth of Norway spruce (*Picea abies*).

Materials and Methods

Experimental Sites

LECH is a well known skiing resort in Vorarlberg, the westernmost province of Austria. The elevation of the experimental area is 1550 to 1600 m. The mean annual temperature is 3.8 C, the mean annual precipitation 1500 mm, the mean annual duration of snowcover is 193 days and the cumulative snow deposition amounts to 780 cm per year. Geologically the area belongs to the northern Calcareous Alps. Moraine till and talus material of dolomite, limestone and shale comprises the parent material for soil formation at the two experimental sites Lech 5 and 6. Both sites are on the lower and only moderately steep part of mountain slopes originating above timberline at more than 2000 m elevation and leveling off at the valley floor at 1530 m. The aspect of Lech 5 is SSE while that of Lech 6 is NE. Due to the uneven micro relief and the disturbances from grazing; soil properties show extreme variation within small areas. Generally rendzina soils dominate but intermixing with shallow brown earths is common, especially at Lech 6. On stony or gravelly ridges the soil is well drained and rather dry, while wet soils with peaty O-horizons dominate in small dells. $pH_{(KCl)}$ is between 4.6 (Lech 5) and 5.4 (Lech 6) in the A-horizon and increases to about pH 7 at the C-horizon boundary. As a consequence of a long history of grazing by cattle, nutrient pools in the soil are depleted. Soil nutrient contents are generally lower at Lech 5 due to its higher content of rocks and gravel and due to heavier grazing at this warmer, more exposed site.

Forest Stand Characteristics

Open stands with small clumps of trees characterize both sites. There are about 270 to 280 trees per hectare. The estimated mean age is more than 200 years. The standing biomass (wood plus bark) is 290 m^3 at Lech 5 and 520 m^3 wood with bark at Lech 6. The visual assessment of tree vitality, based on parameters such as needle loss and yellowing (Pollanschütz 1985), gave a mean crown index of 1.6 which indicates above average needle loss.

Foliar analysis (table 1) of needles harvested from the 7^{th} whorl indicated nitrogen deficiency on both sites and, in addition phosphorus deficiency at Lech 5.

Table 1. Foliar nutrient content in 1985 before treatment (new needles from the 7^{th} whorl, mean values from 18 (Lech 5) and 27 (Lech 6) trees)

Element	Content $mg.g^{-1}$ dry matter Lech 5	Lech 6
Nitrogen	10.40	12.20
Phosphorus	1.45	1.58
Potassium	7.35	6.29
Calcium	3.97	3.36
Magnesium	1.53	1.21

Experimental Design

Because of the extreme heterogeneity of the soils and stands, conventional plot experiments were not possible. Therefore tree clumps of similar density were singled out and used as experimental units. Fertilizer was applied in a circular area with a diameter of 30 m around the central tree. Measurements were taken from the central tree or from the next neighbours when the central tree was damaged by snow, storm or lightning during the experiment.

The following treatments were tested

a) Control
b) Mineral N-P-K-fertilizer (15:5:18, P and K as oxides) chloride free, with magnesium (3 % MgO) and trace elements
400 $kg.ha^{-1}$ were applied both in 1985 and 1987
c) BIOSOL
1000 $kg.ha^{-1}$ were applied both in 1985 and 1987

The number of replications was 6 at Lech 5 and 9 at Lech 6.

Table 2 gives the composition of the organic fertilizer BIOSOL, an organic fertilizer based on mycelial biomass from commercial antibiotic production by BIOCHEMIE Ges.m.b.H. - Kundl, Austria. Residual antibiotic activity was destroyed by heat treatment. Because part of the nitrogen is bound in chitin it is only slowly released by microbial action in the soil. BIOSOL is also especially rich in siderophores ("iron carriers") and can therefore improve trace element nutrition (Haselwandter et al.1988).

Table 2 Composition of the organic fertilizer BIOSOL

Parameter	Content (percent)
Organic matter	70
Organically bound N	5 - 6
Soluble N	less than 5
P (as P_2O_5)	1 - 2
K (as K_2O)	3 - 4
Mg (as MgO)	0.5 - 2.5
Ca (as CaO)	3 - 5
Antibiotic activity	below detection limit

Measurements and Analyses

Diameter growth: by means of permanent dendrometers.
Crown vitality: by visual inspection (Pollanschütz 1985)
Cone production: counting with binoculars
Seed Yield and Viability: mechanical or heat seed extraction, seed testing by X-ray analysis.
Mineral Nutrition: foliar analysis on current and older needles from the seventh whorl.
Soil Analysis: conventional soil analysis supplemented by biochemical analysis. Microbial biomass by the method of Anderson and Domsch (1987).
Mycorrhiza: survey of mycorrhiza types and subsequent counting of mycrrhizal root tips of representative root samples.

Results

Tree Growth

Because the diamaters of the study trees varied substantially, and basal area increment is correlated with diameter, analysis of covariance was used to reduce the error due to variances in initial stem diameter. Table 3 shows the annual increments in basal area per tree.

Table 3 Mean annual increment in cm^2 basal area per tree

Site Year	Control	BIOSOL	Mineral Fertilizer
LECH 5			
1986	17.4	19.7	19.8
1987	6.6	11.3	12.8
1988	16.9	24.5	22.0
86-88	13.6	18.5	18.2
LECH 6			
1986	27.8	35.1	29.9
1987	14.8	21.4	18.8
1988	19.9	32.5	27.1
86-88	20.8	29.7	25.3

The increment was generally much smaller at Lech 5 due to its poorer soil. In 1987 an extremely cool summer led to a marked setback in growth. Both fertilizer treatments had significantly (at 1 percent level) increased growth by 33 percent over a three year period. The difference between the BIOSOL and the mineral fertilizer treatment was not significant at the 5 percent, but significant at the 10 percent level.

Crown Vitality

Even though the visual appearence of crowns in terms of color and needle density on new shoots had improved, these changes were not statistically significant (at the 5 percent level). Extreme variation between individual trees was the main reason that the method of using visual symptoms was inadequate in an experimental design where only one tree was the experimental unit. This method gives much better results in conventional designs with more observational units per replication.

Foliar Nutrient Contents

Figure 1 shows the mean values for the foliar nutrient levels in the current year's needles from the 7^{th} whorl for the years 1986 and 1988. These data show that the fertilizer treatments did not induce pronounced changes in the foliar nutrient levels. As tree growth had significantly increased, it can be assumed that extra nutrients from the fertilizer enabled the trees to increase their canopy mass rather than their foliar nutrient content. It is extremely unlikely that the very small changes in the mineral content of the needles could have an effect on hardiness or resistance against disease or insects.

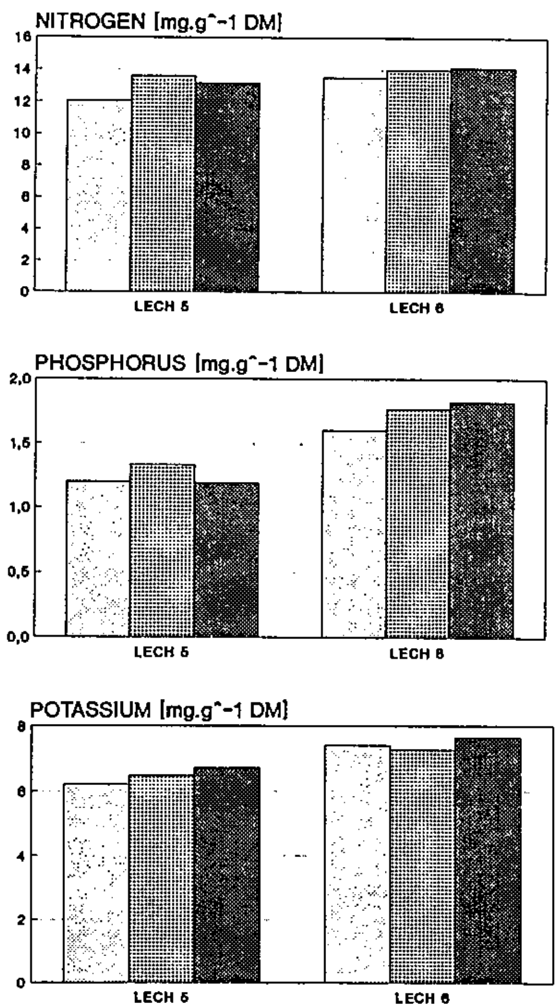

Figure 1 Foliar nutrient content ($mg.g^{-1}$ dry matter of current year's needles; mean for the years 1986 and 1988)

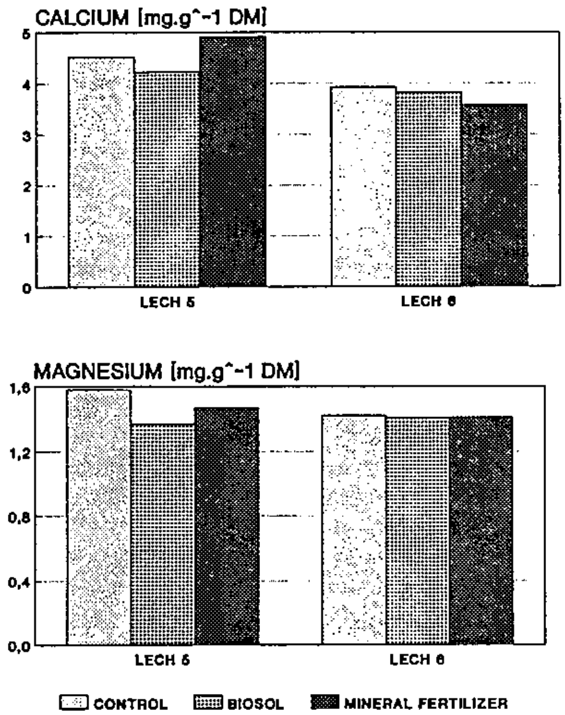

Figure 1 continued

Soil Biology and Mycorrhizae

Respiration of soil samples collected from the various treatments at Lech 6 in 1988 showed no significant differences under laboratory conditions. Microbial biomass as determined by the method of Anderson and Domsch (1987) in soil samples from Lech 6 collected in July and September 1988 was similar for all treatments in July but showed a statistically significant decrease at the fertilized sites in September. Possibly the easily degradable material was utilized early in the vegetation period and that microbial populations broke down later in the season.

The counts of mycorrhizal root tips of light color, which are usually considered to be a measure of functional mycorrhizal infection, for root samples taken from Lech 6 in 1987 and 1988 showed large variation. Statistically significant effects of the fertilizer treatments on mycorrhizal infections could not be detected despite fourfold subsampling per treatment unit.

Seed Production and Fertility

During the first three years of the experiment less than half of the trees produced a moderate cone crop. There were no treatment effects. Figure 2 shows the length of the cones and the percentage of viable seeds from X-ray analysis from the 1988 harvest. In Lech 6 BIOSOL treatment had a statistically significant effect on cone length. Cone diameter and cone mass were not significantly changed. The percentage of viable seeds was slightly higher in the BIOSOL treatment at both sites and lower in the mineral fertilizer treatments. The effect was just not significant (5 percent level).

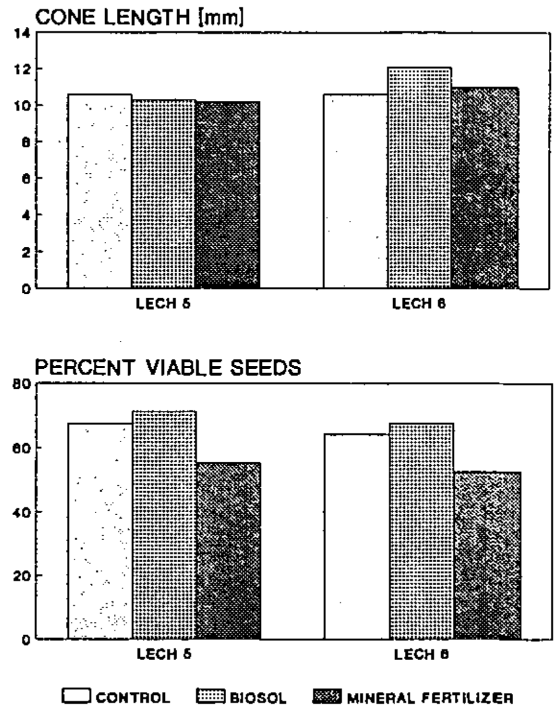

Figure 2 Cone length and percentage of viable seeds from the 1988 seed crop

Discussion

After three years the experiments in Lech have shown that Norway spruce (Picea abies) trees of poor vigour growing in high altidude protective forests can be revitalized by improving mineral nutrition. Most biometric variables, especially visual assessment of tree crown status, proved to be inadequate for estimating tree vigour when an individual tree represents the treatment unit. The most reliable variable was basal area increment measured by permanent dendrometers. Fertilizer treatments increased basal area growth by 33 percent. The result was statistically significant.

Foliar nutrient levels at the 7th whorl were only slightly increased by fertilization. Improved growth seems to result more from additional foliage rather than from higher nutrient levels in the existing foliage. The frequently expressed concern that fertilizer application at high altitudes may decrease hardiness or increase susceptibility for deseases and pests seems not warranted under our treatment regime. Soil biochemical analyses and mycorrhizal counts gave no indication of dramatic changes due to fertilizer application. At these nutrient depleted sites additional nutrients are rapidly incorporated into the tree and herbaceous vegetation and into soil sinks. Based on these results a slightly higher fertilizer dosage is recommended for future trials.

Cone production was not affected by the fertilizer treatment. The value of increased flowering or cone production would be doubtful for a wind pollinated species under a situation where only some stands are treated. Even though cone length and the yield of viable seeds was slightly higher in the BIOSOL treatment, it appears that moderate and local fertilizer addition are not sufficient to bring a dramatic increase in seed production of declining high elevation Norway spruce stands.

The organic fertilizer BIOSOL proved to be at least equal in effect to an inorganic fertilizer when an equivalent amount of nitrogen is applied. The main advantage of the organic fertilizer is its slow release of nitrogen, which makes overdosing and losses to the ground water from leaching less likely.

Literature

Anderson, J.P.E. and K.H. Domsch. 1978. A physiological method for the quantitative measurement of microbial biomass in soils. Soil Biol. Biochem. 10, 215-221. https://doi.org/10.1016/0038-0717(78)90099-8

Glatzel, G. und J. Fuchs. 1986. Zur Anwendung organischer Spezialdüngemittel bei schwierigen Aufforstungen. AFZ 9/10, 201-204.

Haselwandter, K., R. Krismer, H.P. Holzmann and C.P. Reid. 1988. Hydroxamate siderophore content of organic fertilizers. J. Plant Nutr. 11:959-967. https://doi.org/10.1080/01904168809363860

Pollanschütz, J. 1985. Instruktionen für die Feldarbeit der Waldzustandsinventur nach bundeseinheitlichen Richtlinien 1984 - 1988. Forstliche Bundesversuchsanstalt, Wien. 69 p.