Voluntary paper

DYNAMICS OF "ACUTE YELLOWING" IN SPRUCE CONNECTED WITH Mg DEFICIENCY

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Abstract. The development of "acute yellowing" and spontaneous regreening in spruce was followed by visual observations and by pigment, mineral and soil analyses. Studies of the population dynamics of "acute yellowing" in mapped natural regenerations of spruce (2000 trees) revealed a small-scale spatial and temporal mosaic of yellowing and spontaneously regreening trees, which was reflected in the Mg content of the needles, but not in changes in pH and in the amount of ammonia-exchangeable Mg in soil samples taken from the rooting areas of diseased and of healthy trees. These findings are not compatible with the assumption of cumulative damage by air pollutants and their depositions, which should lead to an irreversible and much more uniform decline within the stands. The findings rather suggest that "acute yellowing" is a syndrome of complex etiology. In extreme cases, it may be caused solely by too little plant-available Mg in the soil, or by severely restricted Mg uptake resulting from root diseases or antagonists of the rhizosphere flora or mycorrhrizae. In most cases, probably both determinants are involved. Magnesium fertilizing will be beneficial in any case since it abolishes the soil-born Mg deficiency and compensates the increasing of the threshold for Mg uptake by a biotic factor.

1. Introduction

Among the various syndromes ascribed to "Waldsterben" in Central Europe, the so-called "acute yellowing" of spruce (Kandler, 1985; Kandler et al., 1987) is the best defined. It is restricted to soils with low Mg supply, usually originating from silicate rocks (granite, sandstone etc.), and is accompanied by distinct Mg deficiency (Zöttl and Hützl, 1986; Kandler et al., 1987). The proportion of "acute yellowing" in the total area of forest damage of the Federal Republic of Germany is less than 10%, although it may reach more than 50% in certain areas with soils low in plant-available Mg. The majority of damage reported by the official annual surveys is due to crown transparency (foliage deficit), the main measure of "Waldsterben" (Kennel and Reitter, 1989). If foliage also shows discolouration, the damage class of a particular tree is increased depending on the percentage of the discolored foliage.

This paper reports on the dynamics of "acute yellowing" and spontaneous regreening, investigated by field observations, growth measurement, pigment, and mineral determinations in needles, and soil analyses.

1 Instead of the term "needle yellowing in higher elevations of the German Mittelgebirge," which is used in the official forest damage report of the German government, the shorter term "acute yellowing," formed in accordance with the phytopathological jargon (Kandler, 1985), will be used throughout the paper.
2. Mode of Yellowing and Regreening

"Acute yellowing" is characterized by yellowing and Mg deficiency in the older needles of both, young and old trees. The current year's needles remain green until new growth commences the following spring when Mg is translocated from the then previous year's needles to the young shoot. Yellowing starts at the tip of the previous year's needles and proceeds, preferentially on the upper (illuminated) side, homogeneously towards the needle bases. Usually, part of the lower half of the needles remain green without a sharp border between the yellow and the green portion. Thus, "acute yellowing" is clearly distinct from the numerous other types of chlorosis. In other types of chlorosis yellowing may spread to all needle seasons (N deficiency); it may remain restricted to the current year's needles (Mn deficiency), or may lead to zonal or punctual discoloration as in the case of most fungal and viral infections or infestations by sucking insects. Also O₃-triggered chlorotic mottle in pine (Miller et al., 1963) and patchy discoloration caused by mixtures of high concentrations of pollutants in fumigation experiments (Guderian et al., 1985) are clearly distinct from "acute yellowing."

"Acute yellowing" does not necessarily lead to fast needle loss, as is often assumed. Yellow needles remain on the tree for many years. Although, with time the originally bright yellow color becomes darker and the total pigment content decreases further, the ratios of the various pigment components remain at the original level for many years (Kandler et al., 1987). The needles may regreen even after several years of yellowing either spontaneously or after Mg fertilization. However, in many cases the yellow needles turn brown in the fall of the first year or at any time during the following years and are then shed. In such cases Mg deficiency may be combined with K deficiency or with fungal infections or infestations by sucking insects. In the case of biotic injuries, browning starts in a zonal or patchy pattern, while overlapping K deficiency intensifies yellowing and causes in its later stage a rather uniform browning of the needles. Potassium deficiency may be soil-born, common in Ca-rich soils, but occurs also in acid soils depleted by preceding agricultural use (Senser and Höpker, 1989). Potassium deficiency may also be caused by root and stem rot (Rehfueß, 1973).

Spontaneous regreening occurs in 2 modes: (1) the yellowing of the previous year's needles, that usually occurs during the new flush of growth, does not occur and the yellowed older needles become green again (mostly in young trees); or (2) although older needles remain yellow, the previous year's needles do not yellow, and thus "acute yellowing" is halted. If this process continues for several years normal tree color ensues. Spontaneous regreening by these 2 modes has frequently been observed in the Bavarian Forest and other mountain areas of Germany. Two typical cases have been documented by color photos of different stages of regreening (Kandler and Miller, 1989).

Regreening caused by Mg fertilization occurs within months or years depending on the quality and quantity of the fertilizer (Hättl, 1989). It proceeds from the needle's base to the tip and occurs first in needles of the primary branches as has been observed in our fertilization trials. The tips of the needles and needles in older secondary branches, which show only little new growth, may remain yellow for years. Such long lasting remnants are useful indicators of a previous period of yellowing in regreened trees and stands.