Nitrogen uptake efficiency by white cedar under different irrigation and fertilisation strategies on a sandy soil: model calculations

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SUMMARY
A combined conifer growth-soil water balance model was extended and parameterised to simulate the nitrogen (N) dynamics of a common nursery stock system [i.e., white cedar (Thuja occidentalis) grown for 2 years on a sandy soil]. The model was used to explore the effects on N uptake efficiency (Naue), N application rate (Nappl), and N loss (Nloss) of three irrigation strategies combined with a single, or a split fertiliser application at a recommended rate, without or with a correction for the mineral N content of the topsoil. Irrigation strategies used were: no irrigation, daily drip irrigation, or drip irrigation triggered by a pressure-head threshold value. Simulated N dynamics were in agreement with the measurements, but discrepancies were found between measured and simulated Nmin. The simulated Naue was 29% in the first growing season, and 68% in the second growing season. Correcting for Nmin reduced Nappl, especially in the non-irrigated strategy and in the threshold-irrigated strategy. Simulated N10 during the 2-year growing period ranged from 79 kg N ha⁻¹ for the non-irrigated strategy with a split-application, corrected for Nmin, to 248 kg N ha⁻¹ for the daily irrigated strategy with a split application. Simulated N concentrations in the percolating soil solution at a depth of 1 m exceeded the EU limit of 11.3 mg NO₃-N ¹⁻¹ in almost all simulations. In conclusion, additional measures are necessary to improve N., especially in the year of planting, to be able to reduce Nloss.

Irrigation usually increases dry weight (DW) production in ornamentals (Prönk et al., 2005), but it can also increase nitrogen (N) losses into the environment through increasing denitrification and nitrate leaching (Pionke et al., 1990). The Dutch Government has implemented regulations on N-inputs in agriculture and horticulture, as an increasing number of groundwater monitoring sites exceed the critical level of 11.3 mg NO₃-N ¹⁻¹ (Fraters et al., 2004). Regulation of N-inputs requires growers to optimise their management of N-sources in their production systems. The effectiveness of N-management can be evaluated from an assessment of the available-N uptake efficiency [Naue, i.e., total crop uptake divided by total available-N from fertiliser and N mineralised from soil sources, after Huggins and Pan (2003)]. Split N applications (Prönk and Challa, 2000) and adjusting N-fertilisation for mineral N in the topsoil (Nmin), useful strategies for increasing Naue and hence decreasing nitrate leaching. The effectiveness of split N-applications and adjusting N fertilisation for Nmin, however, also depends on the irrigation strategy used. As yet, it is not known whether split N applications, adjusting N fertilisation for Nmin or irrigation, optimise yields, improve Naue and/or result in groundwater N concentrations below the regulatory limits.

To answer these questions for field-grown conifers, we modified and parameterised a combined model consisting of a tree growth model CONGRO (Prönk et al., 2003) and a water and N-balance model FUSSIM2 (Heinen and De Willigen, 2001). We simulated N uptake by white cedar (Thuja occidentalis) effects of three irrigation strategies combined with a single or a split fertiliser application at a recommended rate, without or with a correction for Nmin on the available N uptake efficiency and on N leaching. The average results of simulations conducted for 30 stands, each over a 2-year cultivation period, with a first planting in 1970 and the last one in 1999, were analysed.

MATERIALS AND METHODS
Model structure
A combined conifer growth-soil water balance model (Prönk et al., 2005) was extended and parameterised to simulate the nitrogen (N) dynamics of white cedar (T occidentalis). The CONifer GROWth model (CONGRO) simulates dry weight (DW) production (see Table I for abbreviations) in ornamental conifers (Prönk et al., 2003), including root DW production and proliferation (Prönk et al., 2002), daily potential water demand (Prönk et al., 2005), and daily potential N...