Effects of substrate type on plant growth and nitrogen and nitrate concentration in spinach

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Abstract

The effects of three commercial substrates (a mixture of forest residues, composted grape husks, and white peat, black peat and coir) on plant growth and nitrogen (N) and nitrate (NO_3) concentration and content were evaluated in spinach (*Spinacia oleracea* L. cv. Tapir). Spinach seedlings were transplanted at 45 days after emergence into Styrofoam boxes filled with the substrates and were grown during winter and early spring in an unheated greenhouse with no supplemental lighting. Each planting box was irrigated daily by drip and fertilized with a complete nutrient solution. The NO_3 content of the drainage water was lower in coir than in the other substrates. However, shoot NO_3 concentration was not affected by substrate type, while yield and total shoot N and NO_3 content were greater when plants were grown in peat than in the mixed substrate or the coir. Leaf chlorophyll meter readings provided a good indication of the amount of N in the plants and increased linearly with total shoot N.

Introduction

The use of substrates and soilless culture systems for production of horticultural crops is increasing worldwide. Substrates often increase plant growth and yield in many crops, reduce the incidence of soil-borne diseases, and, when combined with collection of drainage water, increase the efficiency of water and nutrient use.[1-4] Despite these many benefits, there is currently very little information available concerning the influence of substrate type on plant growth and nutrient uptake in many crops, including leafy vegetables. Physical and chemical properties such as bulk density, water holding capacity, pH, cation exchange capacity, and nutrient content vary considerably among substrates and, therefore, likely have a considerable influence on plant development and nutrition.

Tissue nitrate (NO_3) concentrations tend to be higher when plants are grown in soilless culture systems,[5,6] and leafy vegetables such as spinach can accumulate levels that may be harmful to human health.[7,8] In many cases, the concentration of NO_3 in the plant tissues increases due to low light conditions and reduced photoperiod in these systems.[9-13] For example, a reduction of light from 800 to 200 $mol \times m^{-2} \times s^{-1}$ increased total shoot NO_3 concentration in spinach by more than 200%.[14] Nitrate accumulation also varies with the season, where it is often higher during the autumn and winter months than during the spring and summer.[15-17]

The objective of this study was to evaluate the influence of different substrate types on plant growth and shoot nitrogen (N) and NO_3 concentrations of spinach grown in an unheated greenhouse during the winter and early spring.

Materials and Methods

Growth conditions and substrates

The experiment was conducted in a greenhouse located at the *Herdade Experimental da Mitra* (38º31 52 N; 8º01 05 W), University of Évora, Portugal. The greenhouse was covered with thermal polyethylene and had no supplemental lighting. Air temperatures inside of the greenhouse ranged from 5 to 26ºC, and solar radiation ranged from 34 to 248 $W \cdot m^{-2} \cdot d^{-1}$. The experiment comprised three different commercial substrates: a mixture of forest residues, composted grape husks, and white peat (Substrato Universal Agriloja); a black peat blend (Super Terra Torfkultursubstrat 1; Hawita Flor, Germany); and a coir blend (Pelemix España S.L., Spain). Physical and chemical characteristics of the substrates, according manufacturer, are shown in Table 1. Mass wetness, moisture content, and bulk density were determined following the methods described by Fonteno and Harden (Table 2).[18]

Spinach (*Spinacia oleracea* L. cv. Tapir) seedlings were transplanted at 45 days after emergence into to Styrofoam planting boxes (100-cm long × 25-cm wide × 10-cm high) filled with 16 L of substrate. The seedlings were spaced 8-cm apart in three rows per box and 10-cm apart between rows. Treatments were arranged in a randomized complete block design with five replicate boxes per substrate treatment.

Each planting box was irrigated using 4 $L \cdot h^{-1}$ pressure-compensating drip emitters. Irrigation was controlled by a timer and averaged 20 to 30% drainage (leaching fraction) at each application. Nutrient solution was applied daily by fertigation, from transplanting to the day before harvest. The solution was made from fresh tap water [electrical conductivity (EC) of 0.3 $dS \cdot m^{-1}$; pH 7; and 0.10-0.30 $mmol \cdot L^{-1}$ NO_3] and initially contained 4.78 $mmol \cdot L^{-1}$ NO_3, 1.16 $mmol \cdot L^{-1}$ NH_4, 0.43 $mmol \cdot L^{-1}$ P, 4.29 $mmol \cdot L^{-1}$ K, 1.40 $mmol \cdot L^{-1}$ Ca, 0.49 $mmol \cdot L^{-1}$ Mg, 0.54 $mmol \cdot L^{-1}$ S, 46 $\mu mol \cdot L^{-1}$ B; 7.86 $\mu mol \cdot L^{-1}$ Cu, 8.95 $\mu mol \cdot L^{-1}$ Fe, 18.3 $\mu mol \cdot L^{-1}$ Mn, 2.60 $\mu mol \cdot L^{-1}$ Mo, and 7.64 $\mu mol \cdot L^{-1}$ Zn. The concentration was adjusted for plant growth at 21 days after transplanting (DAT) to 8.62 $mmol \cdot L^{-1}$ NO_3, 1.43 $mmol \cdot L^{-1}$ NH_4, 1.70 $mmol \cdot L^{-1}$ P, 4.45 $mmol \cdot L^{-1}$ K, 1.95 $mmol \cdot L^{-1}$ Ca, 0.49 $mmol \cdot L^{-1}$ Mg, 0.54 $mmol \cdot L^{-1}$ S, 46 $\mu mol \cdot L^{-1}$ B, 7.86 $\mu mol \cdot L^{-1}$ Cu, 8.95 $\mu mol \cdot L^{-1}$ Fe, 18.3 $\mu mol \cdot L^{-1}$ Mn, 2.60 $\mu mol \cdot L^{-1}$ Mo, and 7.64 $\mu mol \cdot L^{-1}$ Zn. The final pH of both solutions was 5.9.

Measurements

The pH, EC, and the concentration of NO_3 of the drainage water from each box was measured weekly using a potentiometer (pH Micro 2000 Crison), a conductivity meter (LF 330 WTW, Weilhein, Germany), and an ion-specific electrode and meter (Crison Instruments, Barcelona, Spain), respectively, following the

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