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Nitrogen Emissions (N_2O+N_2) and Redox Potential of a Peat Medium during Pot Plant Cultivation

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Summary

In horticultural pot plant production with ebb/flood irrigation, denitrification occurrs following irrigation events. It was the aim of the study to identify the main layers of denitrifying activity in the potting medium of ornamental plants. Thus, redox potential was measured at the same time as denitrification N emissions from pots of *Pelargonium zonale* grown in a peat/coir medium. Denitrification was measured using the acetylene inhibition technique. To investigate the redox potential, in each pot, three electrodes were positioned at 1, 3 and 5 cm distance from the bottom, respectively. After flood irrigation, N emissions increased at the same time as some electrodes per pot indicated a reduction of the redox potential. All electrodes reflecting a decrease in redox potential were positioned close to the pot bottom, i.e. in the peat layer with the highest water content after flood irrigation. However, not all electrodes in the lowest substrate layer showed a decrease in redox potential. It is suggested that this might be related to uneven availability of easily decomposable carbohydrates. It was concluded that in the applied cultivation system transient oxygen deficiency and denitrification occurred only in the substrate layer at the pot bottom.

Key words. Denitrification – redox potential – pot plants – peat medium

Introduction

Many reports in the literature (e.g. Weier et al. 1993; DeKlein and Logtestijn 1996; Shelton et al. 2000) as well as previous studies (Agner 2003) have emphasized the positive relationship between soil or substrate water content and denitrification. So far, N emissions from potted plants had only been related to mean water content (Agner 2003). Yet, the distribution of water within the potting medium is influenced by the irrigation technique. With ebb/flood irrigation, which is common in horticultural production, highest substrate water content may be expected close to the pot bottom. Thus, it was suggested that this layer was primarily responsible for denitrification N emissions from pot plants. To prove the appropriateness of this assumption, measurement of redox potential was considered useful. Under aerobic conditions, microbia generally use oxygen as electron acceptor, while during anaerobiosis oxidized inorganic soil components are reduced. When oxygen is depleted, nitrate is used next as electron acceptor, followed by ferric iron and sulfate (Patrick and Mahapatra 1968). As the reduction of the oxides is more or less sequential, the level of redox potential can be used as an indicator of the electron acceptor that is currently being used (Ottow and Fabig 1984). Thus, knowledge of redox potential is useful for identification of denitrifying sites.

To investigate the origin of gaseous N emissions within potted medium, a denitrification experiment was combined with measurements of redox potential to detect zones of high denitrifying activity.

Materials and Methods

Plant material and substrates

Experiments were conducted with six plants of *Pelargonium zonale* 'Grand Prix' grown in a commercial, completely fertilized peat medium composed of white peat and coir (plastic pots, volume 340 mL, pot height 8 cm). During cultivation, plants were fertigated with 1 g L^{-1} of a full compound fertilizer [Flory3, Euflor: 15 % N in form of NO_3 (4,5 %) and NH_4 (10,5 %), P_2O_5 (10 %), K_2O (15 %), MgO (2 %) and trace nutrients] according to horticultural practice.

Denitrification measurement

Denitrification measurement was conducted using the acetylene inhibition technique (Yoshinari et al. 1977) and flow-through chambers (Agner and Schenk 2005). The same pots were used as for measurement of redox potential. Acetylene application (5 Vol.%) started two hours before the irrigation event and continued until N emissions ended (Agner and Schenk 2005). At the start of the experiment pots were flood irrigated within the chambers for two hours with 1 L of a 150 mg NO_3-N solution. Air samples were taken from the chambers every one to four hours starting two hours after irrigation and ending when N_2O emissions ceased. The analysis of N_2O in air samples was performed by a gas chromatograph (Chrompack 9001) with an electron capture detector (ECD) according to a method described by Mosier and Mack (1980).

Measurement of redox potential

Electrodes for measurement of redox potential were fabricated by soldering platinum/iridium (Pt/Ir) wire (90:10; 0.4 mm diameter) to plastic coated copper wire. Sealing was achieved by use of a two-component glue and shrinkable tubing. Reliable functioning of the electrodes was confirmed by tests in calibration solution and distilled water. One day before the experiment, the electrodes were inserted into the planted potting medium. Each pot was equipped with nine electrodes: three at 1, 3 and 5 cm height from the pot bottom. Redox potential was measured every one to four hours starting before the irrigation event and ending when denitrification N emissions ceased. For measurement of redox potential a reference electrode (calomel) was inserted into the substrate surface. The potential difference between the reference electrode and the Pt electrodes was read off a potentiometer (pH-meter). The potential of the reference electrode (+247 mV) was added to these values to calculate the redox potential (Eh) (Böttcher and Strebel 1985). At the end of the experiment the position of the electrodes was controlled and noted because inserting the flexible electrodes into the rooted medium was sometimes difficult. The exact position of some electrodes varied by up to 0.7 cm from the intended position so that in pots 3 and 5 more than three electrodes were found in the lowest substrate layer (see Fig. 1, redox potential).

Results and Discussion

Denitrification N emissions started to evolve from the substrate about four hours after the beginning of irrigation (Fig. 1). The emissions reached a maximum after 10 to 12 hours, then they decreased and finally ceased. The course of emissions was similar to previously reported data (Agner 2003). There, the decrease of N emissions was shown to be related to the reduction of substrate water content after irrigation due to plant water uptake. Also, it was shown that denitrification was the main source of gaseous N emissions (N_2O+N_2) from irrigated peat potting medium (Agner and Schenk 2005).

The redox potential was measured in the substrate by nine electrodes per pot at different positions and distances from the pot bottom. Only data of those electrodes that indicated a decrease of the redox potential after irrigation were included in Fig. 1. All of these electrodes were located close to the pot bottom and not farther than 2.5 cm from it. The redox potential generally declined four hours after the start of irrigation, i.e. at the same time as N emissions started to evolve. The minimum of redox potential often coincided temporally with the maximum of N emissions. Towards the end of denitrifying activity the redox potentials increased rapidly although N emissions could still be observed. It is assumed that the applied electrodes did not sufficiently reflect the spatial distribution of redox potential. Spatial variability probably resulted from increasing diffusion of air (and oxygen) into the substrate, which generally raised the redox potential but still allowed the existence of denitrifying sites.

Before irrigation, the redox potential in the lower layer of the planted potting medium amounted to about 400 to 500 mV, which is within the lower range of redox potential in aerobic soils (Patrick and Mahapatra 1968). After irrigation, the redox potential decreased, but not beyond ca. 200 mV. This indicates that nitrate was readily available for reduction processes during the denitrification measurement, since the reduction of other oxidized substrate components due to absence of nitrate would have been indicated by a further decrease of the redox potential (Patrick and Mahapatra 1968). Although development of N emissions and redox potential were generally in accordance, the number of electrodes per pot indicating a change in redox potential as well as their amplitude were highly variable and did not necessarily correspond to the height of N emissions (Fig. 1). This hints at spatial inhomogeneity of reducing conditions in spite of the very limited volume of the potting medium (340 mL). Even in the lower peat layer (0–2.5 cm from the pot bottom) not all electrodes did show changes in redox potential. Possibly this can be related to observations made by Sextone et al. (1985), who investigated oxygen profiles and denitrification in soil aggregates. They reported that denitrifying activity was restricted to aggregates with anaerobic

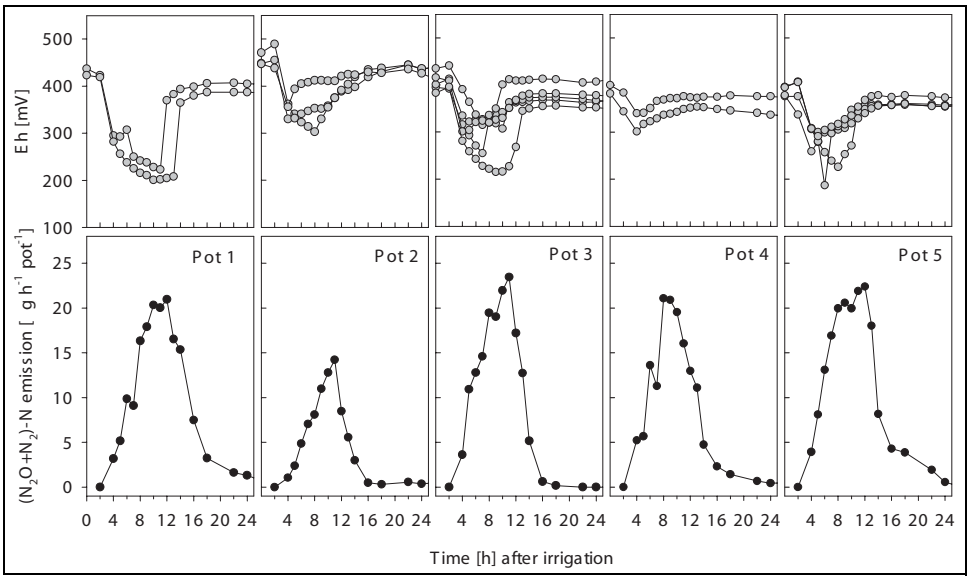


Fig. 1. Redox potential in the lower substrate layer (0–2.5 cm from pot bottom) and (N_2O+N_2)-N emission from five pots of a peat/coir substrate planted with *P. zonale* following irrigation (data are given only for those electrodes indicating a change in redox potential)

centres, but not all aggregates with anaerobic zones denitrified. This they related to a possible lack of available carbon or nitrate. Also in the present study, the absence of a decrease in redox potential at some electrodes might be due to a local lack of carbon. As easily decomposable carbon is the source of electrons for microbial metabolism, its availability is a premise for reduction processes. In addition, availability of carbon increases microbial activity overall and thus accelerates oxygen depletion. The amount of locally available carbon may therefore be responsible for the variability of redox potential. It might be related to plant roots, as indicated by the literature (e.g. FISCHER et al. 1989; FLESSA and FISCHER 1992).

With regard to the origin of gaseous N emissions, the present study showed that in the growing system applied the majority of denitrification N loss from potted substrate originated from the lower substrate layers.

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