Nutrient and water use efficiency at leaf level of cucumber plants under contrasting soil nutrient and lignosulfonate level

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To reduce the use of commercial conventional inorganic fertilizers, the possibility of using pulp and paper industry wastes in agriculture as an alternative source of nutrients is under study and discussion. In this study sodium lignosulfonates (LS), by-product from the paper industry, was mixed with dry sandy soil to achieve its concentration in the substrates, equal 0, 1.0, 2.5, 5.0, and 10 % (v/v), designated as 0LS, 1LS, 2.5LS, 5LS and 10LS treatments, respectively. Cucumber (*Cucumis sativus* L.) were grown in pots filled with the substrates under controlled conditions. For half of the pots, the nutrient solution, and for the other half, water was supplied (SNA, sufficient nutrient availability, and LNA, low nutrient availability, respectively).

Results

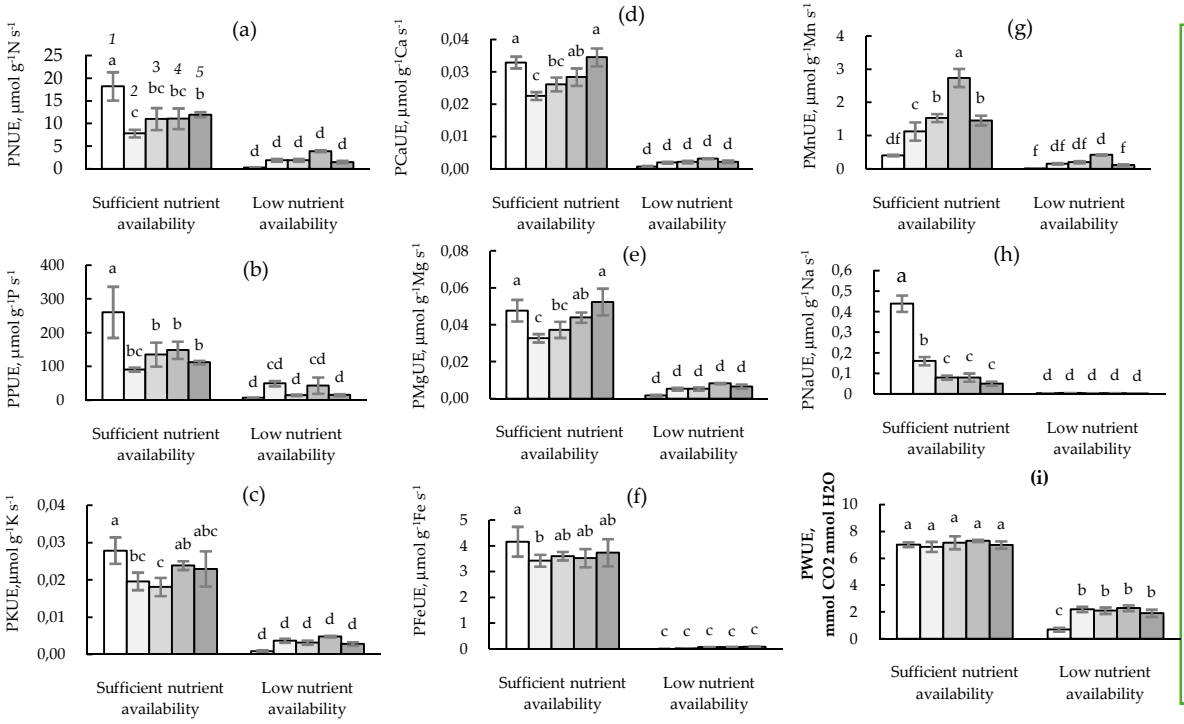

Fig. Photosynthetic nitrogen (PNUE, a), phosphorus (PPUE, b), potassium (PKUE, c), calcium (PCaUE, d), magnesium (PMgUE, e), iron (PFeUE, f), manganese (PMnUE, f), natrium (PNaUE, h) and water (WUE, i) use efficiency for cucumber plants grown on the soil with lignosulfonate concentration of 0 (*1*), 1 (*2*), 2.5 (*3*), 5 (*4*) and 10 (*5*) % under conditions of sufficient or low nutrient ability. Different letters indicate significant differences at $P < 0.05$.

For all elements under the study, photosynthetic nutrient use efficiency was lower for LNA than SNA seedlings (Table). The LS effect on the use efficiency of elements depended on the soil's ability of nutrients. While for the PNUE, PPUE, PKUE, and PFeUE values, the two-way ANOVA revealed an insignificant effect of the LS treatment ($P > 0.05$), PCaUE, PMgUE, PMnUE, and PNaUE were significantly altered by both LS application and nutrient availability ($P < 0.01$). For the most of studied leaf element concentrations in the LNA seedlings, no significant effect of LS on photosynthetic nutrient use efficiency was observed. The LS application decreased PNUE, PPUE, and PNaUE, respectively, by 74, 114, and 79% on average among all LS seedlings grown under SNA condition. For the PKUE, PCaUE, PMgUE, and PFeUE values, a significant LS-related decrease was found only for the 1LS and 2.5LS SNA seedlings. Unlike other elements under the study, LS enhanced PMnUE values following the increase in soil LS content from 1LS to 5LS regardless of soil nutrient ability.

Conclusions

The impact of nutrient availability on plant physiological traits of cucumber seedlings was stronger than the lignosulfonate impact. The decline of nutrient availability affected seedlings growth and photosynthesis more than leaf nutrient content, excluding leaf Fe concentration. Moreover, the decline of nutrient availability increased leaf mass per area and decreased the CO_2 assimilation rate, photosynthetic nutrient and water use efficiency. The nutrient availability affected the seedling's response to lignosulfonate. Whereas lignosulfonate decreased nutrient use efficiency, except Mn, under sufficient nutrient availability, it slightly improved efficiency under low nutrient availability, but this impact was not successful to eliminate the negative effects of soil nutrient deficiency on cucumber seedlings.