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The effect of low phosphorus on morphological and physiological characters of gooseberry plants (*Physalis peruviana*)

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Highlights: P-deficiency decreased total biomass and changed the dry matter distribution, the leaf numbers, the total leaf area, and the root length density, as consequence of the photosynthesis rate reduction. In addition, P-deficiency induced enhancement of antioxidant activity, catalase, peroxidase, with a reduction of the total protein. There are evidences related to the damage of cell membranes by reactive oxygen species (ROS).

Keywords: Phosphorus stress, *Physalis peruviana*, plant adaptation.

Physalis peruviana is a tropical fruit (gooseberry) native to South America, used by Precolombian cultures. This plant is well adapted to Andean mountain conditions, including low phosphorous available which is a characteristic from volcanic soils of South America (Herrera *et al*., 2011). This research was focused on determining the stress effect by phosphorus deficiency on some morphological and physiological characteristics of P. *peruviana*. The experiments were performed under greenhouse conditions of the National University, Colombia. The experimental design of random complete blocks was used with 5 treatments, 4 repetitions as follows; two control treatments with 0 and 6 mg P_2O_5 kg^{-1} substrate (P0 and P6), and three treatments with increasing levels of P in soil solution, 12, 25 and 50 mg P_2O_5 kg^{-1} substrate (P12, P25 and P50).

The main results showed that P-deficiency significantly decreased the accumulation of total biomass (leaf, steam and root), changes the dry matter distribution in plant, increasing the Root: Shoot ratio under stress treatments (P0 and P6). The leaf numbers, the total leaf area, and root length density also decreased under stress treatments, as consequence the reduction rate of photosynthetic and transpiration. In addition, P-deficiency induced the significant enhancement of antioxidant activity (Ruiz-Sánchez *et al*., 2010**)**, in term of catalase from P0 to P50 (392 to 163 CAT mg g^{-1} leaf tissue, respectively), peroxidase from P0 to P50 (0.78 to 0.16 POD mg g^{-1} leaf tissue, respectively), in 30 days old seedlings, and the remarkable enhance of the prolina synthesis was observed, from P0 to P50 (771 to 161 mg g^{-1} leaf tissue, respectively), in 60 days old seedlings. On the other hand, it was showed increasing levels of the soluble protein, from the stress treatment P0 (0.109 mg g-1 leaf tissue) to the other treatments P6, P12, P25 and P50, form 0.535, 0.569, 1.086 and 1.277 mg g-1 leaf tissue, respectively), in 30 days old seedlings. Two evidences were found related to the damage or alteration of cell membranes configuration by ROS activity. First, it was observed an increase of electrolytes leakage under stress treatments (P0 and P6) in contrast with P25 and the positive control treatment (P50); second, it was observed a remarkable change between phosphorous (P) and sulphur (S) concentration in the leaf tissue. The experimental results showed the lowest P concentrations in leaf tissue under the stress treatment, P6 (1.4 g K^{-1}), with respect the other treatments P12 (1.5 g K^{-1}), P25 (1.9 g K^{-1}) and P50 (2.9 g K^{-1}), and *vice versa* the highest S concentration in leaf tissue, under the stress treatment (3.55 g K^{-1}), with the other treatments, P12 (1.42 g K^{-1}), P25 (2.02 g K^{-1}) and P50 (2.43 g K^{-1}). Those results suggested the composition of cell membranes could change from phospholipids by sulpholipids, with a change in the cell membrane configuration; this variation could facilitate the electrolytes leakage, which can be detected with increasing levels of conductivity in distilled water solution with leaf tissue. Finally, the results have been used to design a functional model related to the interaction between morphological and physiological characters.

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