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Mini Review

Phosphate Foliar Fertilization Can Alleviate Water Deficit Effects on Photosynthesis and Yield

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Mini Review

Slight dehydration of the plant will cause a reduction in cell turgor, especially in leaves, which will immediately paralyze cell growth and protein biosynthesis and decrease the stomatal aperture [1]. In addition, the limitation of CO_2 Assimilation Rate (A) under drought could also be due to the inhibition of Ribulose,1-5, Bisphosphate synthesis because the low ATP content in the chloroplast caused by the loss of ATP synthase activity and inorganic Phosphate (Pi) content in the chloroplast [3]. Therefore, A will be reduced, but not entirely, and carbohydrates synthesis will slow but continue. However, sucrose will not be exported for the growth of other tissues; it will be used only to maintain cell respiration, causing an accumulation of soluble sugars-P in the leaves' cells [2]. If the water deficit occurs at the pollination stage, the reduction in A and sucrose export for the reproductive organs will cause embryo abortion because of the lack of soluble sugars-P to maintain embryo growth [1]. However, due to growth arrest, sugars-P accumulation in the photosynthetic cells can stop Triose-Phosphate (Triose-P) export from the chloroplast due to the low availability of Pi in the cytoplasm. The export of Triose-P is done by Phosphate Translocator (PT) antiporter in exchange of Pi, and it is controlled by Fructose-2,6-Phosphate (F-2,6-P) concentration in the cytoplasm, which is increased by growth arrest under drought [4].

Therefore, three experiments were conducted with common bean (Phaseolus vulgaris L.) plants to evaluate when applying the Pi in the first and the effect of Pi foliar fertilization on A and yield in the two others. The common bean is an important source of proteins in Latin America. However, it is considered a poor soil phosphorus extractor due to its small root system, with low yield in Phosphorus-deficient soils like tropical soils [2]. The genotypes studied were A320 (a genotype that reduces stomatal conductance [gs] to maintain high leaf water potential [Ψleaf] under drought conditions), Carioca (a genotype widely used by farmers), and Ouro Negro (a new black seeded cultivar) were used in these experiments. The plants were growing in 10 L pots in a greenhouse and watered regularly before the imposition of water deficit when both genotypes were at the pollination (pre-flowering) stage (they have very similar growth cycles), the most sensitive stage to water deficit [2]. The genotypes were submitted to a mild water shortage until minimal Ψleaf was around -1.0 MPa [5]. In all three experiments, the foliar Pi fertilization was done in the leaves of half of the plants of the treatments, which were supplied with 12.5 mL of 10 g Pi.L-1, as Ammonium Dihydrogen Phosphate ($(NH_4)H_2PO_4$), also called mono Ammonium Phosphate (MAP). The other half also used 12.5 ml of 2.64 g N.L-1, as urea ($(NH_2)_2CO$), to compensate for the N added in the Pi fertilization. Some drops of the wetting agent Tween 80 were added to both solutions [3]. In the first experiment with the three genotypes, they received the foliar fertilization at three different dates: two days before suspending irrigation and the 6th or 11th days of water stress. Almost all Pi-supplied genotypes showed higher A values at the recovery for all dates of foliar spray, but mainly when Pi was provided two days before the drought. However, A of Carioca was more affected than A320 and Ouro negro, but not significantly when Pi was supplied two days before the water deficit. There were no significant differences in yield with or without Pi supply [3]. Two of the genotypes studied, Carioca (widely used by farmers) and Ouro Negro (a new black seeded cultivar), were used in a second experiment in the greenhouse [4]. The treatments of Pi foliar supply two days before water withholding, used in the first experiment, were repeated here. The rehydration of the plants was done when the leaf water potential (Ψleaf) was around-0.9 MPa (considered a mild water deficit for common bean) after only three days of drought, probably due to the high temperature inside the greenhouse (around 35ºC). Then the plants were rehydrated until the end of their cycle. During stress, A was measured at three hours: 09:00 h, noon, and 15:00h [4]. In this second experiment, Carioca with an extra Pi supply exhibited higher A values only on the first day of water deficit at 09:00 h and on the third day at 15:00 h. Therefore, the extra foliar Pi effect did not cause significant differences in A for Carioca. However, for Ouro negro, additional Pi supply induced higher A values for all daytime measurements. At 9:00 h, water-stressed Pi foliar sprayed Ouro negro plants had higher A values on the second and third days of stress [1]. At noon, these plants had higher A on days zero, two, and three of water stress, as did the rehydrated plants, and at 15:00 h, Ouro negro Pi foliar sprayed plants had higher A values on the first, second, and third days of water deficit. The mild water deficit did not cause a significant reduction in yield components for both genotypes with or without drought. However, the Pi extra-supplied Ouro negro significantly increased the pod number per plant, an important yield component for breeding programs, while the other yield components were unaffected [5].

The third study was conducted with A320 and Ouro Negro, growing in 10 L pots in a greenhouse. Two days after the foliar Pi supply, a mild water deficit was imposed for seven days, when the Ψleaf was around-1.1 MPa (a mild water deficit for common bean), and then rehydrated until the end of their cycle. Then the plants were rehydrated until harvest [6]. A and gs of both genotypes were not affected by Pi supply during dehydration for both genotypes. Nevertheless, A and gs on A320 and A on Ouro Negro, both supplied with Pi, were higher than non-Pi-provided plants after rehydration. In addition, the photosynthetic O_2 evolution (Ac) of rehydrated A320 with foliar Pi supply was also higher than for non-Pi-supplied plants. There were no significant differences for yield components of Pi supplied genotypes water stressed plants compared to control plants. However, after the drought, the dry seed weight of both genotypes with Pi supply was very close to that of control plants irrigated continuously, but not significantly. In addition, water stressed Ouro Negro without Pi supply presented a significant reduction in dry seed weight compared to control plants irrigated continuously [5]. The results revealed an up-regulation of the recovery of photosynthesis after water deficit induced by the foliar Pi supply, which can increase some yield components in this condition, but it was genotype-specific.

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