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Original article

Physiological changes in bean (*Phaseolus vulgaris* L.) plants with irrigation reduced and foliar applications of PectiMorf®

Cambios fisiológicos en plantas de frijol (*Phaseolus vulgaris* L.) cultivadas con riego reducido y aplicaciones foliares de PectiMorf®

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ABSTRACT: The effect of foliar applications of PectiMorf® was studied in bean plants (*Phaseolus vulgaris* L.) cultivated under two irrigation variants. For this, 12 concrete containers were planted with the cultivar "Tomeguín 93". The irrigation consisted of applying 100 and 50 % of the ETc (standard evapotranspiration of the crop) and the PectiMorf® foliar applications were 150 mg ha^{-1} at 20 and 35 days after sowing giving rise to the following four treatments: T1-100 % ETc, considered as control treatment. T2- 100 % ETc + P (P = PectiMorf® application at 20 and 35 DAS) T3- 50 % ETc + P and T4- 50 % ETc, considered as stress treatment. Seven days after the PectiMorf® applications (28 and 43 DAS) were evaluated, the soil moisture content and different physiological indicators such as growht in dried biomass, leaf water potential (Ψf), actual osmotic potential (Ψs), osmotic potential at maximum turgor (Ψ100s) and stomatal conductance (gs). In addition, the water potential of the soil at the level of the soil-root interfaces (Ψr) and the contribution of dehydration to changes in potential osmotic ΔΨ ss were calculated. The results showed a positive effect of the foliar applications of PectiMorf® in the improvement of plants water status in both irrigation variants.

Key words: bean, plant water relations, water stress.

RESUMEN: Se estudió el efecto de aplicaciones foliares de PectiMorf® en plantas de frijol cultivadas bajo dos variantes de riego, Se sembraron con el cultivar "Tomeguín 93" 12 canaletas de hormigón. El riego consistió en aplicar el 100 y el 50 % de la ETc (Evapotranspiración estándar del cultivo) y las aplicaciones foliares de PectiMorf® fueron de 150 mg ha^{-1}, a los 20 y 35 días después de la siembra (DDS), dando lugar a los siguientes tratamientos: T1-100 % ETc, considerado como tratamiento control; T2- 100 % ETc + P (P= aplicación de PectiMorf® a los 20 y 35 DDS); T3- 50 % ETc + P y T4- 50 % ETc, considerado, este último, como tratamiento estrés. A los siete días de realizadas las aplicaciones de PectiMorf® (28 y 43 DDS) se evaluó el contenido de humedad del suelo y los diferentes indicadores fisiológicos, como son: el crecimiento en biomasa seca, el potencial hídrico foliar (Ψf), el potencial osmótico actual (Ψs), el potencial osmótico a máxima turgencia (Ψ100s) y la conductancia estomática (gs). Además, se calculó el potencial hídrico del suelo a nivel de la interface suelo-raíz (Ψr) y la contribución de la deshidratación a los cambios en el potencial osmótico ΔΨss. Los resultados mostraron un efecto positivo de las aplicaciones foliares de PectiMorf® en la mejora del estado hídrico de las plantas de frijol en ambas variantes de riego.

Palabras clave: evapotranspiración, crecimiento, estrés hídrico.

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INTRODUCTION

Beans (*Phaseolus vulgaris* L.) are a staple food for human consumption that is grown throughout the world (1).

In Central America and the Caribbean, beans are often grown on soils with low fertility, which reduces yields (2). About 60 % of production is obtained under conditions of water deficit, so this factor is the most important contributor to yield reduction, after diseases (3). In Cuba, a great part of its production is obtained in conditions of scarce irrigation systems, so, surely, plants in some moment of their biological cycle are exposed to certain hydric stress, affecting processes that limit their development. In addition, results have been obtained in the cultivation of beans that show low productivity and inefficiency in the use of water (4).

To make production systems more efficient, different industries commercialize nutrient complexes containing micronutrients, amino acids, plant extracts and/or phytohormones, which have been called plant growth promoters of biological origin or biostimulants (5,6). The wide range of biostimulants offers a biotechnological alternative because it promotes plant growth and development, improves plant metabolism and protects plants against biotic and abiotic stresses (7,8).

PectiMorf® is a natural and innocuous biostimulant, composed of a mixture of oligogalacturonides, obtained from citrus pectin, whose active principle is a mixture of α-1,4 oligogalacturonides with different degrees of polymerization. It is considered a potent defense elicitor in plants and a stimulant of nodulation and root growth in beans (9). In addition, it can reduce or attenuate abiotic stress in plants (10).

The objective of the present work was to evaluate the physiological changes due to foliar applications of PectiMorf® on beans grown under reduced irrigation.

MATERIALS AND METHODS

This work was carried out in the central area of the National Institute of Agricultural Sciences (INCA), located in San José de las Lajas municipality, Mayabeque province. Twelve concrete containers of 2.60 m long by 0.60 m wide (1.56 m^2) containing Ferrallitic Red Leached soil (11) were used. In each container were sown 44 seeds, arranged in two rows, of beans (*Phaseolus vulgaris*), cultivar "Tomeguín 93", considered susceptible to water stress.

Two irrigation treatments were used and two foliar applications of PectiMorf® were made at a rate of 150 mg ha^{-1}, the first at 20 days after sowing (DAS) and the second at the beginning of flowering (35 DAS), resulting in the following four treatments:

T1-100 % ETc: irrigated at 100 % of the standard crop evapotranspiration, considered as Control treatment.

T2- 100 % ETc + P: irrigated at 100 % of the standard crop evapotranspiration and foliar applications of PectiMorf® at 20 and 35 DAS.

T3- 50 % ETc + P: irrigated at 50 % ETc and foliar applications of PectiMorf® at 20 and 35 DAS.

T4- 50 % ETc, irrigated at 50 % of ETc, considered as stress treatment.

Treatments were analyzed according to a randomized block experimental design with three replications.

Irrigation was applied by an automated micro-sprinkler system and water delivery was controlled by valves placed in each treatment.

Reference crop evapotranspiration (ETo) and ETc were calculated using the CropWat 8.0 program and using a 30-year series (1990-2020) of data from the Tapaste weather station, located 300 m from the experimental site.

The crop coefficients Kc used were: initial Kc= 0.15, mean Kc= 1.10 and final Kc= 0.65.

During the first five DAS, irrigation was equal in all treatments. Thereafter, irrigation was applied as appropriate for each irrigation variant. Other cultural attentions were applied equally to all plants.

Soil moisture (%) was measured at 28 and 43 DAS, coinciding with the evaluations of the different physiological indicators and it was performed using a HD2 Precise Moisture Measurement equipment equipped with a 16 cm long Moisture Sensor TRIME®-PICO TDR Technology, Germany. In each treatment, 30 measurements were taken at a depth of 16 cm.

The variables aerial and root dry mass in grams (g) were evaluated at 28 and 43 DAS. Dry masses were obtained by drying in a forced draft oven at 75 ºC until constant mass.

Leaf water potential (Ψf), current osmotic potential (Ψs) and osmotic potential at maximum saturation (Ψ 100 s) in leaves were measured in five plants per treatment and following the methodology (12).

Changes in Ψs (ΔΨs) and in Ψ100s (ΔΨ100s) were calculated according to the methodology used (14), as the difference in Ψs and Ψ100s, measured seven days after each foliar application of PectiMorf® (28 and 43 DAS), as well as the contribution of dehydration to changes in Ψs (ΔΨss).

Soil water potential, at the soil-root interface level (Ψr), was calculated (13), in this particular case, treatments T1-100 % ETc and T2- 100 % ETc + P were taken as controls (c) and T3-50 % ETc + P and T4-50 % ETc as stressed (e), according to the formula:

$$\Psi r = \left(\Psi * f^{e} - \left(\Psi f^{c}\right) * \left(gs^{e}/gs^{c}\right)\right.$$

where: Ψf^e and Ψf^c correspond to the mean value of leaf water potential of the plants of treatments T3-50 % ETc + P and T4-50 % ETc and T1-100 % ETc and T2-100 % ETc + P, respectively. The value of Ψr is assumed to be zero for plants in the control treatments.

Stomatic conductance (gs) was measured using a diffusion porometer model SC-1, in 10 plants for each treatment. In all water relations evaluations, leaves were taken from the upper third of the plants, exposed to the sun and fully developed.

The SPSS 19.0 statistical program for Windows was used to calculate the confidence interval of the means. The graphs of the results were made using the SIGMA PLOT 11.0 program.

RESULTS AND DISCUSSION

It can be seen that in irrigation treatments T1 and T2, soil moisture at 28 DAS was slightly above 100 % of the Field Capacity (F.C.), without differences between them. At 43 DAS in T2 the moisture decreased to around 90 % of F.C. and with differences with respect to T1, where the soil moisture was 100 % of the F.C. (Figure 1A).

In T4 and T3, values at 28 DAS were between 60 and 80 % of C. c. with differences in favor of T3, and at 43 DAS, the lowest value corresponded to T4.

In general, Ψr decreased in T3 and T4 plants with and without foliar application of PectiMorf®, due to water stress induced by irrigation at 50 % of ETc (Figure 1B).

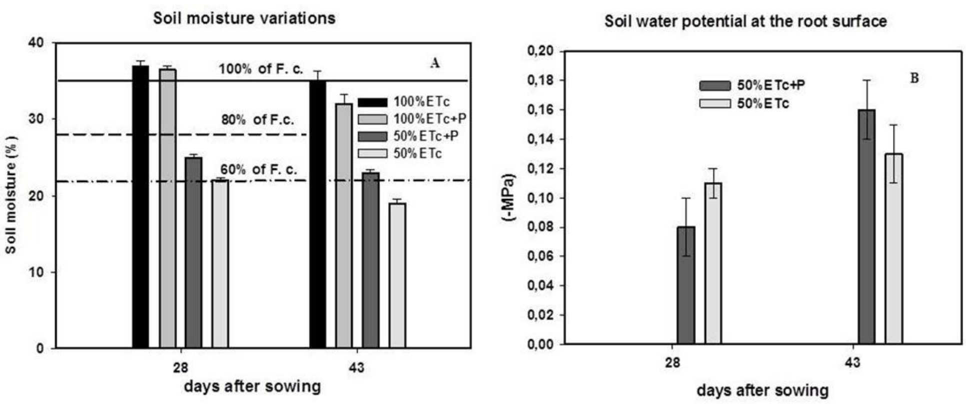
It is noteworthy that at 28 DAS there were differences in favor of the plants with PectiMorf® which presented the least negative values, while at 43 DAS there were no statistical differences between the plants of the two treatments.

This behavior evidences the effect of irrigation treatments on soil moisture differences and on interface of the soil-root, as well as a slight beneficial effect of PectiMorf® in terms of water economy by plants.

At 28 DAS, the highest values of root dry mass (Figure 2A) corresponded to T4 plants followed by T3, with differences between them, and the lowest values corresponded to T1 and T2 plants, with no differences between the two treatments. This behavior is basically associated with the fact that the lower soil moisture content favored root dry mass growth, regardless of the foliar application of PectiMorf®. However, at 43 DAS, a significant effect on the growth in dry mass of this organ was found, enhanced by the applications of PectiMorf®, demonstrating the rooting power of this product (14).

In a study carried out with bean plants (Cuba Cueto-25-9-N) biofertilized with Azofert®-F, it was concluded that the greatest effect of PectiMorf® was manifested in a greater development of the root system (9).

Regarding the biomass of the aerial part (Figure 2B) at 28 DAS, differences were found among plants of all treatments and the best values were obtained in the plants of T3 and the lowest in those of T1. At 43 DAS, the lowest values of this indicator were found in T1 and T4 plants, with no differences between them, and the highest values were found in T2 and T3 plants, showing the positive effect of



Bars above the mean values indicate the confidence Interval of the means α= 0.05

Figure 1. Soil Moisture Values (A) and Ψr (B)

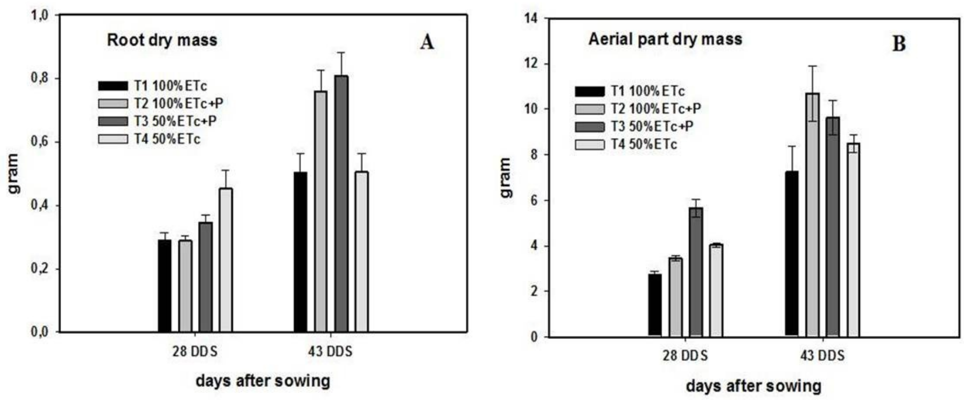


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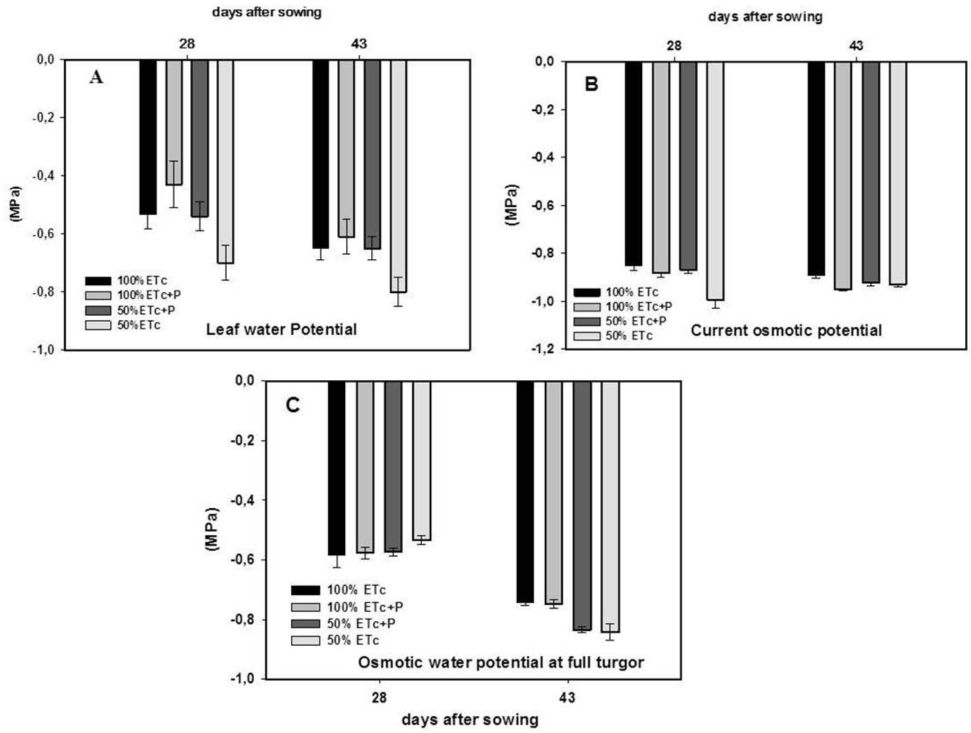
Figure 2. Effect of foliar applications of PectiMorf® on root (A) and aerial part (B) dry mass growth variables of bean plants grown with two irrigation variants



Bars above the mean values indicate the Confidence Interval of the means α= 0.05

Figure 3. Values of Ψ f (A), Ψ s (B) and Ψ 100 s (C)

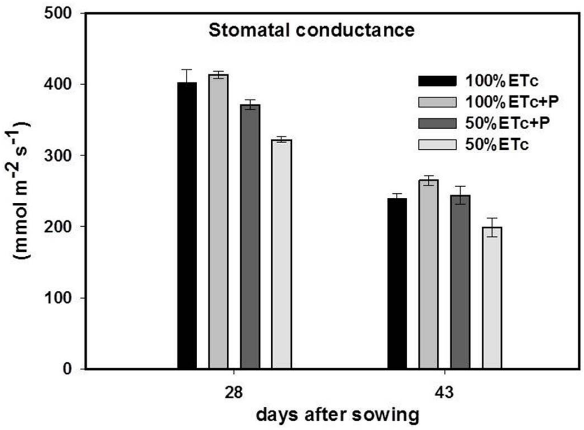
PectiMorf® on the increase of aerial dry mass, regardless of irrigation treatment. Studies on the physiological effects of water stress on bean varieties and lines have shown that increased growth of foliage biomass and root length can be useful criteria in the identification and selection of genotypes tolerant to this stress (15,16).

The effect of water stress on decreased soil moisture and soil-root interface was conducive to increased resistance to water uptake and led to a decrease in Ψ f (Figure 3A). It should be noted, that the most negative values of Ψ f at both 28 and 43 DAS occurred in T4 plants.

In the Ψ s evaluations (Figure 3B) at 28 DAS, it was found that the lowest values corresponded to T4 plants, and those of T3 presented values equal to those of T1 and T2. While, at 43 DAS the highest value corresponded to T1 plants, differing from the other treatments.

In the Ψ 100 s (Figure 3C), at 28 DAS, the slightly less negative value corresponded to the T4 plants with differences with the rest of the treatments and, at 43 DAS the T4 and T3 plants presented the most negative values without differences between them and if small differences with those of the other treatments. This behavior indicates that the osmotic adjustment process did not occur in the most stressed plants, which, in general, is associated with the speed of water stress development or the low accumulation of inorganic solutes that did not contribute to plant osmoregulation (17).

In Figure 4, it was found that at 28 DAS the lowest gs values corresponded to T4 plants, with differences of 50 mmol m^{-2} s^{-1} compared to those of T3 and of approximately 90 mmol m^{-2} s^{-1} with those of T1 and T2.



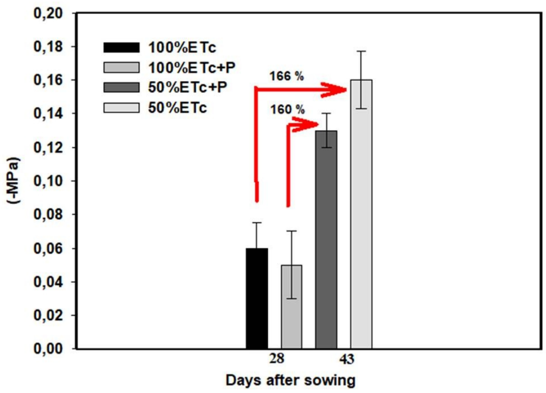
Bars above the mean values indicate the Confidence Interval of the means α= 0.05

Figure 4. Effect of foliar applications of PectiMorf® on gs of bean plants grown under two irrigation variants

At 43 DAS, in general, there was a decrease in gs in all treatments with respect to 28 DAS. It is important to note that the lowest gs also corresponded to the plants of the T4 treatment and the gs values of the T3 plants did not differ from the plants irrigated at 100 % ETC, with and without PectiMorf® application. This behavior evidences the potential of foliar applied PectiMorf® to attenuate the effect of water deficiency on such an important indicator as gs.

Due to the reduction in soil moisture, root surface water potential, and leaf water potential in stressed plants, stomatal conductance decreased considerably in T4 plants, functioning as a mechanism to evade excessive water losses, essentially agreeing with the findings of other research (17).

Figure 5 shows the contribution of dehydration to changes in osmotic potential ∆ΨSS. In the plants of the well water-supplied treatments, the values were in the order of -0.04 to -0.06 MPa, with no differences among them and in the stressed plants, the values were 160 and 166 % more negative with respect to their controls. In addition, the most harmful values corresponded to T4 plants irrigated at 50 % of ETc, without application of PectiMorf®.



Bars above the mean values indicate the Confidence Interval of the means α= 0.05.

Figure 5. Contribution of dehydration to changes in Ψs between 28 and 43 DAS in bean plants with different irrigation treatments

CONCLUSIONS

- A beneficial effect of foliar applications of PectiMorf® was observed in all the physiological indicators evaluated, which in some cases its evidence was slight, as in Ψr, Ψs, Ψ100s, good in Ψf and ∆ΨSS and very good in root dry mass and gs and its greatest effect was mainly patented in plants exposed to water deficiency.

RECOMMENDATIONS

- As a recommendation, further research is suggested, since the application of products such as PectiMorf®, or those with similar effects, in agricultural systems constitute a sustainable and essential option for the adaptation or tolerance of crops to climate change.

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