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Common bean yield under water suppression and application of osmoprotectants

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Key words:
Phaseolus vulgaris
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water stress
yield

A B S T R A C T

The objective of this study was to evaluate the performance of the common bean crop grown with application of osmoprotectants based on algae of the genus *Durvillaea potatorum* in the winter crop season, with occurrence or not of water suppression. The experiment used a randomized block design, in split plots, arranged in a 4x7 factorial scheme, in which the plots were composed of four treatments - periods of water suppression (7, 14, 21 days and the control treatment: 100% of field capacity throughout the crop cycle) and the subplots consisted of seven types of osmoprotectants. The treatments with osmoprotectants was applied during the full flowering of the common bean. Three days after application of osmoprotectants, the treatments with suppression of irrigation were established. The use of osmoprotectants based on algae of the genus *Durvillaea* does not affect the variables plant height, stem diameter, stem and pod dry matter, first pod height, number of pods per plant and number of grains per pod in common bean plants cultivated with occurrence of water suppression. Common bean plants under water restriction conditions have lower leaf and shoot dry matter and lower 100-grain weight. Common bean grain yield was influenced by the type of osmoprotectants and the water suppression period.

Palavras-chave:
Phaseolus vulgaris
Durvillaea potatorum
déficit hídrico
rendimento

Produtividade do feijoeiro sob supressão hídrica e aplicação de osmoprotetores

R E S U M O

Objetivou-se, neste estudo, avaliar o desempenho da cultura do feijão comum cultivado com a aplicação de osmoprotetores à base de extratos de algas marinhas do gênero *Durvillaea potatorum* na safra de inverno com ocorrência ou não de supressão hídrica. O delineamento utilizado foi em blocos casualizados e em parcelas subdivididas em esquema fatorial 4 x 7, as parcelas foram compostas por quatro tratamentos - períodos de supressão hídrica (7, 14, 21 dias e o controle: 100% da capacidade de campo durante todo o ciclo da cultura); nas subparcelas os tratamentos foram sete tipos de osmoprotetores. A aplicação dos tratamentos com osmoprotetores ocorreu em plena floração do feijoeiro. Três dias após a aplicação foram estabelecidos os tratamentos de supressão de irrigação. O uso de osmoprotetores à base de algas do gênero *Durvillaea* não afeta as variáveis altura de plantas, diâmetro de caule, massa seca de caule e vagens, altura de inserção da primeira vagem, número de vagens por planta, grãos por vagem em plantas de feijão em cultivo com ocorrência ou não de supressão hídrica. Plantas de feijão estabelecidas em condição de restrição hídrica apresentam menor massa seca de folhas e parte aérea e massa de cem grãos. O rendimento de grãos do feijoeiro foi influenciado pelo tipo de osmoprotetor e pelo período de supressão.

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Introduction

The common bean crop (*Phaseolus vulgaris* L.) is one of the most traditional foods, with significant social and economic importance. Brazil stands out as the largest producer and consumer of beans in the world. In the season of 2013/2014, it was estimated that approximately 3.3 million hectares of common bean were cultivated internally, with mean yield of 1,026 kg ha^{-1} (CONAB, 2015).

Water deficit is one of the main causes of failure in common bean yield (Carvalho et al., 2014), especially when it occurs in three critical stages, which are germination, flowering and grain filling, leading to low grain yield (Soratto et al., 2003).

Extracts of various algae genera, such as *Ascophyllum* spp., *Laminaria* spp., *Ecklonia* spp., *Sargassum* spp. and *Durvillaea* spp., have been used in agriculture to minimize the losses caused by water restriction. The greatest use of these substrates occurs in the continent of Oceania, although still little known, while tissue analyses demonstrated that 46 to 60% of the weight of this species is composed of carbohydrates, which could act in the signaling in plant tissues (Craig, 2011).

There is also the presence of compounds related to the defense of the plants against stresses (Guiry, 2012), promoting better vegetative development, especially of roots, and greater tolerance to abiotic (such as drought and salinity) and biotic stresses (Sharma et al., 2014).

Effects of the application of algae extracts on the plants have been reported in various important crops in Brazil, such as soybean, wheat, potato, coffee, etc. (Mógor et al., 2008; Oliveira et al., 2011). Based on the above, this study aimed to evaluate the performance of common bean cultivated under the application of osmoprotectants based on extracts of marine algae of the genus *Durvillaea potatorum* in the winter crop season, with occurrence or not of water suppression.

Material and Methods

The study was carried out at the experimental field of the Federal Institute of Goiás, Campus of Rio Verde, located in Rio Verde, GO, Brazil, at altitude of 750 m.

The climate of the region is Aw (Köppen-Geiger) - Tropical, with rains concentrated in the summer (October to April) and a well-defined dry period during the winter season (May to September), with mean annual rainfall from 1200 to 1500 mm. The climate data along the experiment are shown in Figure 1.

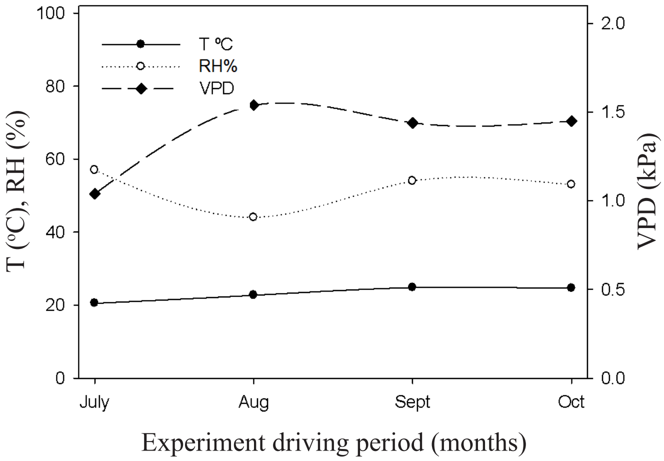

Figure 1. Climate data referring to temperature – T (ºC), relative air humidity – RH (%) and vapor pressure deficit – VPD (kPa) along the experimental period

The experimental area, located on a distroferric Red Latosol, showed the following physicochemical characteristics, determined in the layer of 0-20 cm: pH ($CaCl_2$) 6.2; P 7.06 mg dm^{-3}; K 204 mg dm^{-3}; Ca 5.77cmol$_c$ dm^{-3}; Mg 1.63 cmol$_c$ dm^{-3}; Al 0.0 cmol$_c$ dm^{-3}; V% 42 and O.M. 63.42 g kg^{-1}.

The experimental design was randomized blocks, with three replicates. The treatments were arranged in split plots in a 4 x 7 factorial scheme. The periods of irrigation suppression (7, 14 and 21 days, besides the control – 100% of field capacity along the entire crop cycle) were evaluated in the plots, while the application of osmoprotectants based on extracts of marine algae (T1- EA/GB/KPM/AS; T2- EA/GB/KPM; T3-EA/AS/KPM; T4- EA/KPM; T5-EA/GB; T6-EA ; and T7- Control) were evaluated in the subplots. The experimental units consisted of four 5-m-long bean rows and only the two central rows were considered for evaluations, disregarding 0.5 m on each side.

The conventional soil tillage was performed through one harrowing with a disc harrow and two harrowings with leveling harrow. The crop was sown one day after soil tillage and the seeds were previously treated with fungicides based on Carboxin + Thiram at the doses of 60 + 60 g of active ingredient, respectively, per 100 kg of seeds. Sowing was performed on July 14, 2014. Manual weeding was performed until the crop canopy closed, in order to control weeds. Sowing was manually performed at a spacing of 0.50 m between rows and 14 seeds were planted in each linear meter of furrow, at the depth of 0.04 m.

Fertilization at sowing was performed using 300 kg ha^{-1} of formulated fertilizer 4-30-16 (N, P_2O_5, K_2O) and, as top-dressing, 300 kg ha^{-1} of urea divided at 20 and 35 days after emergence (DAE).

Three applications of the fungicide Nativo® (trifloxystrobina + tebuconazole) were performed at the doses of 0.5, 0.6 and 0.8 L ha^{-1} for the control of diseases in the phenological stages R1, R3 and R5, and one application of the insecticide metamidofós (Metamidofós Fersol®) at the dose of 0.8 L ha^{-1} in R6 for the control of whitefly and bedbugs.

A surface drip irrigation system was used in the experiment, with nominal flow rate of 1.0 L h^{-1} and spacing of 0.20 m between emitters. Irrigation was performed using a puncture digital tensiometer, with sensitivity of 0.1 kPa, installed at the depths of 0.10, 0.20 and 0.30 m, and 0.10 m distant from the emitter, with daily reading of the soil matric potential (Ψm). The necessity of irrigation was determined using the critical tension of 50 kPa. Soil physical-hydraulic characteristics were determined through the soil water retention curve (Genuchten, 1980).

The treatments based on algae extracts were applied in the stage of full flowering of the common bean crop (R6 until

45 DAE), using a backpack sprayer, equipped with a CO_2 cylinder at constant pressure of 2.5 bar and an application lance with four flat-fan nozzles (model TT1100), applying the equivalent to 150 L ha^{-1} of mixture. After three days of application of the osmoprotectants, the irrigation suppression treatments started as follows: irrigation was suspended in all treatments, except in the control (T7); after 7, 14 and 21 days, irrigations were reestablished in the respective periods of suppression, according to crop water demand until physiological maturation.

For the characterization of the growth variables of the common bean crop, three biometric evaluations were performed: at 7, 14 and 21 days, corresponding to the treatments of irrigation suppression, using three plants from the evaluation area of each experimental unit.

The variables analyzed in this experiment were: plant height (PH), leaf area (LA), number of leaves (NL), stem diameter (SD), shoot dry matter (ShDM), leaf dry matter (LDM), stem dry matter (StDM), pod dry matter (PDM), first pod height (FPH), number of pods (NP), number of pods per plant (NPP), number of grains per pod (NGP), number of empty pods (NEP), 100-grain weight (100GW), harvest index (HI) and grain yield (Y).

PH was measured using a measuring tape, from the soil surface until the apex of the plant; SD, measured using a digital caliper with precision of 0.01 mm, close to the soil surface; LA, determined based on the analysis of images through the program ImageJ; and NL determined through direct count, considering all fully expanded leaves. The dry matter values were obtained using a scale with resolution of 0.01 g, after 72 h of permanence of the plant parts in a forced-air oven at 65 °C, until constant weight.

For harvest, 96 DAE, plants from the evaluation area were manually collected; then, 10 plants were randomly selected for the count of total number of pods per plant. From these plants, 50 pods were randomly collected for the determination of the number of grains per pod and 100-grain weight, in duplicate. The values of grain yield and 100-grain weight were corrected to moisture content of 13%.

The results were submitted to analysis of variance and, when there was significance of the effects of treatments, multiple comparison analysis by Tukey test was performed for the qualitative data and regression analysis for the quantitative data, at 0.01 and 0.05 probability levels, using the statistical program SISVAR-ESAL.

Results and Discussion

There was no significance ($p > 0.05$) in the interaction of suppression period x osmoprotectants for the variables plant height, number of leaves, stem diameter and leaf area. However, when the factors were analyzed in isolation, the variables number of leaves and leaf area suffered significant effect ($p < 0.05$) of the suppression period. According to Figure 2, the behavior of the variables NL and LA is linear and decreasing, i.e., it decreases as the suppression period increases.

There was a reduction of 27.23% in NL after a suppression of 21 days in relation to the treatment without suppression of irrigation. Nascimento et al. (2011), working with irrigation and cowpea bean, observed greater reductions in the number of leaves per plant, 23 and 55% respectively, for the levels of 60 and 40% of water available in the soil. Oliveira et al. (2004) observed that lesser the number of leaves lower the leaf area which will directly reflects in crop yield.

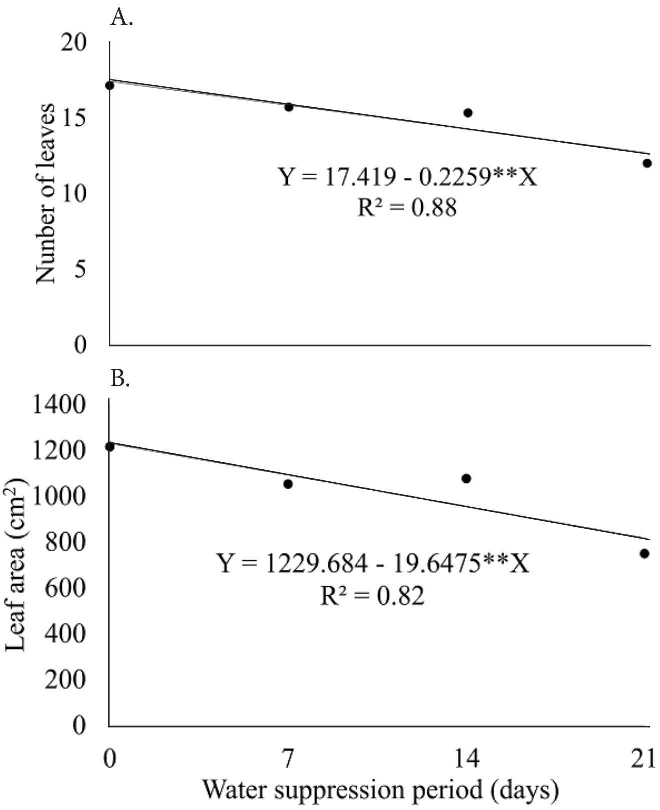

Figure 2. Number of leaves (A) and leaf area (B) of common bean as a function of the water suppression period

Leaf area showed reduction of 1.60% for each additional day of suppression, thus generating a reduction of 33.55% in leaf area for the 21 days of suppression of irrigation, in comparison to the control. Leaf area is an important parameter in the determination of the photosynthetic capacity, optimal planting density, soil-water-plant relationship or in investigations on the nutrition of various crops and yield (Severino et al., 2004).

The interaction of sources of variation was not significant ($p > 0.05$) for the variables: leaf dry matter (LDM), stem dry matter (StDM), pod dry matter (PDM) and shoot dry matter (ShDM). However, when the factors were analyzed independently for the period of suppression, the variables LDM and ShDM showed significance; for the osmoprotectants, none of the variables was significant.

The variable LDM showed decreasing linear response (Figure 3A), with reduction of 1.29% per unit increase in the suppression of irrigation, i.e., a decrease of 27.18% in the comparison between the treatment with no suppression of irrigation and the treatment with suppression of irrigation of 21 days.

ShDM also showed decreasing linear behavior, with variation of 17.11% between plants with and without suppression of irrigation. Gomes et al. (2012), evaluating bean genotypes subjected to water deficit, observed reductions in LDM and ShDM of 49.65 and 33.09%, respectively.

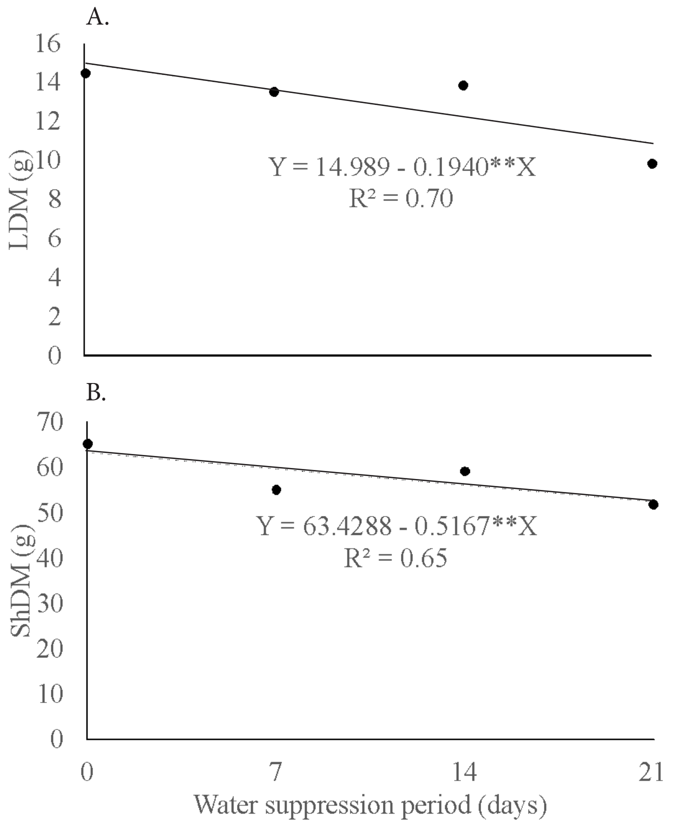

Figure 3. Leaf dry matter - LDM (A) and shoot dry matter - ShDM (B) of common bean as a function of the water suppression period

The results obtained in the present study indicate that the osmoprotectants can be a good alternative for short periods of water deficit, such as short droughts, for the production of shoot dry matter. As shown in Figure 3B, the reduction was less pronounced than in LDM, indicating greater stability of morphological and productive components of common bean, StDM and PDM, respectively, in relation to the periods of suppression of irrigation, probably due to the beneficial effect of the association with osmoprotectants.

The variables first pod height (FPH), number of pods (NP), number of pods per plant (NPP), number of grains per pod (NGP) and number of empty pods (NEP) were not influenced ($p > 0.05$) by the sources of variation (Figure 4).

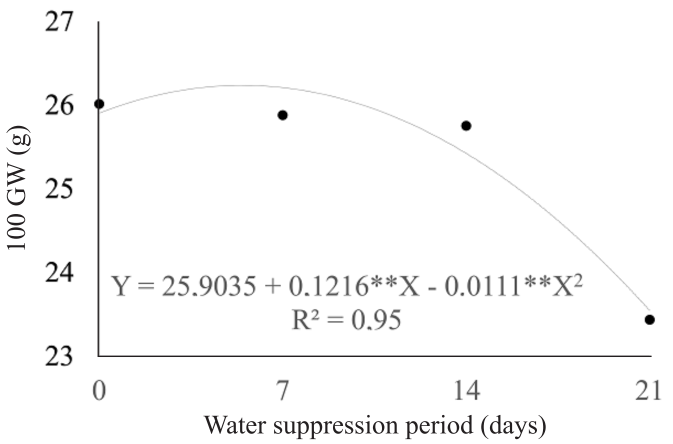

Figure 4. 100-grain weight (100GW) of common bean as a function of the water suppression period

The common bean yield was influenced by the interaction of periods of suppression x osmoprotectants. The period of suppression influenced 100-grain weight and the use of osmoprotectants interfered with the harvest index.

With the suppression of irrigation, there was a reduction and a quadratic response in the variable 100-grain weight (100GW), and its maximum point (26.24 g) occurred with a suppression of 5.47 days. These results corroborate with those of Gomes et al. (2012), who obtained 25.80 g for the variable 100-grain weight, applying a water depth of 333 mm in the common bean crop.

In the treatments that received 7 and 14 days of suppression of irrigation, there were reductions of 0.10 and 3.07% in relation to the maximum point and it was more pronounced at 21 days of suppression of irrigation (10.19%). This behavior indicates that this cultivar, under these conditions, can tolerate a deficit of up to 14 days, without drastic damages on its yield, since the 100-grain weight is one of the main productive components of the common bean.

The harvest index (HI) was higher when the osmoprotectants in T1 (EA/GB/KPM/AS) were applied, with mean of 70.23%, while the control showed the lowest mean (54.66%). However, T1 was statistically equal to T2 (EA/GB/KPM), T3 (EA/AS/KPM), T4 (EA/KPM) and T5 (EA/GB), only differing from T6 (EA) and T7 (None). These results evidence the importance of osmoprotectants based on algae extract in the component harvest index.

In the follow-up analysis of the water suppression periods for the common bean yield (Y), in each type of osmoprotectants (Figure 5A), there was difference between the periods only for the osmoprotectants in T2 and the highest yield was estimated according to the regression equation, for a suppression of irrigation of 10.33 days, causing a yield of 3,180.05 kg ha^{-1}, superior to the mean for common bean of third season in the state of Goiás, which was equal to 2,914 kg ha^{-1} in the 2014/15 season (CONAB, 2015).

According to the regression equation, it is possible to observe that the lowest yield (2,252.42 kg ha^{-1}) was obtained in the treatments with 21 days of suppression of irrigation, evidencing the sensitivity of the common bean to water deficit. The common bean is considered as a species with low tolerance to water stress, and 60% of its cultivation on the planet is subjected to this factor, causing the drought to be the most important cause of yield reduction (Aguiar et al., 2008).

According to the follow-up analysis of the types of osmoprotectants in each water suppression period for the yield of the common bean (Figure 5B), the highest yield at 14 days of suppression is associated with the application of the osmoprotectant T2 (EA/GB/KPM). Hence, it can be claimed that, at 14 days of suppression of irrigation, the best osmoprotectant is T2 (EA/GB/KPM); thus, this product becomes very promising and can be used in a preventive way during droughts of up to 14 days in the common bean crop, referred to as "dry spells", which are common in the Midwest region, more specifically in the Southwest region of the Goiás state.

The results obtained in the present study contribute to new perspectives of studies using osmoprotectants based on

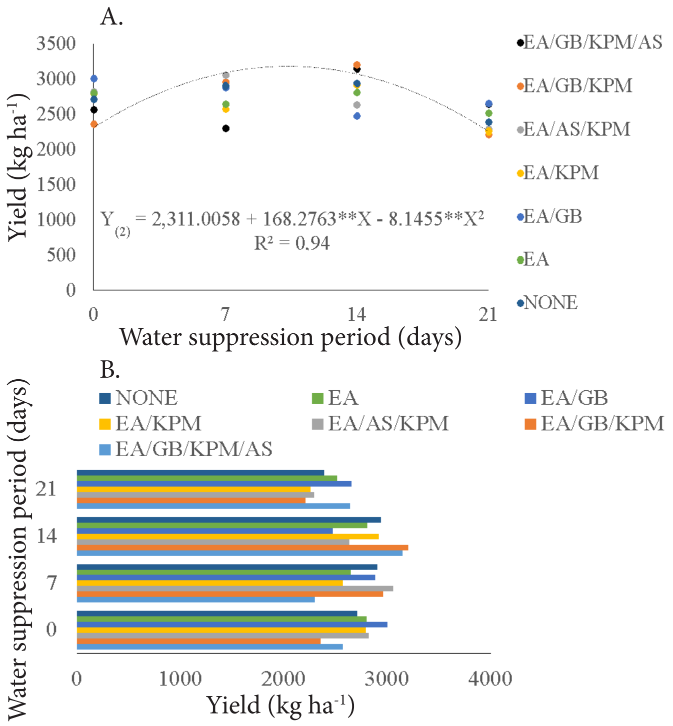

Figure 5. Follow-up analysis of common bean yield for the water suppression period in each type of osmoprotectant (A) and two types of osmoprotectants in each water suppression period (B)

extracts of marine algae of the genus *Durvillaea potatorum*, especially regarding the agronomic development, such as effective plant survival, tolerance to lodging, reaction to insects and diseases, accumulation of dry matter in the plant, grain yield at different doses and in different types of soil and edaphoclimatic conditions.

Conclusions

1. The use of osmoprotectants based on algae of the genus *Durvillaea potatorum* does not affect growth characteristics or yield components of common bean (*Phaseolus vulgaris* L.) cultivated with and without the occurrence of water suppression.

2. Under water restriction conditions, common bean plants show lower leaf and shoot dry matter and lower number of leaves and 100-grain weight.

3. The application of osmoprotectants promotes higher harvest indices and the grain yield of the common bean is influenced by the type of osmoprotectant and the period of water suppression.

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