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Effect of Some Antioxidants, Potassium and Arbuscular Mycorrhiza on Growth, Yield and Quality of Snap Bean Plants Grown Under Water Stress Levels

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Abstract

Two field experiments were carried out at the Experimental Farm Station of the Faculty of Agriculture Moshtohor, Benha University, Kalubia Governorate, Egypt, during 2012 and 2013 summer seasons. Drip irrigation system was used to apply the levels of water stress in the experiment. This experiment was conducted to study the effect of foliar application with ascorbic acid (200, 400 mg/L), putrescine (10, 20 mg/L) and potassium citrate (250, 500 mg/L) and adding mycorrhiza as well as two levels of water stress (50 and 35% of ETo and 100% of ETo as control) on some growth characters, yield and quality of snap bean plants cv. Bronco. The experiments were laid out in split plot design with three replications. The obtained results showed that water stress levels and applied treatments have significant effect on growth characteristics and yield of snap bean plants. The obtained results indicated that increasing water stress levels to 50% and 35% of ETo of water requirements caused significant decrease in all growth and yield characteristics (i.e., plant height, number of leaves, leaf area /plant and shoots fresh and dry weight as well as number and weights of green pods per plant and total pods yield per feddan. The same trend was obtained in photosynthetic pigments (chlorophyll a, b and carotenoids), minerals (N, P and k) and protein content in green pods of snap bean plants. Data also indicated that the application of ascorbic acid at (400 mg/L), putrescine (20 mg/L), potassium citrate (500 mg/L) and mycorrhiza gave the highest significant increase of the studied growth and yield characteristics as well as photosynthetic pigments (chlorophyll a, b and carotenoids), minerals and protein in green pods. At the highest water stress level (35% of ETo); Plants treated with putrescine (20 mg/L), ascorbic acid (400 mg/L) followed by potassium citrate (500 mg/L) and mycorrhiza , respectively gave the highest values of the previously mentioned growth characters, green pod yield/plant and chemical composition of green pods in the two growing seasons.

Generally, it could be concluded that applied antioxidants, potassium and mycorrhiza alleviated the harmful effects of high water stress levels on growth and yield of snap bean plants. So, foliar application with ascorbic acid, putrescine and potassium as well as adding mycorrhiza could be recommend in snap bean cultivation under normal and water stress conditions.

Keywords: Snap bean, *Phaseolus vulgaris* L., water stress, antioxidants, ascorbic acid, putrescine, potassium citrate, arbscular mycorrhiza (AM).

Introduction

Common bean (*Phaseolus vulgaris* L.) is considered as one of the most important vegetable legumes. Snap bean is an important vegetable economic crop grown in Egypt for local consumption and exportation. It is utilized for various purposes like fresh bean, dry pulses and edible podded type, nutritional value of beans are an excellent source of protein, carbohydrates, fibers, vitamin B_1 and antioxidants.

Common bean, a major vegetable crop with great nutritional value, accounts for higher consumption and economic importance all over the world, which is widely grown world-wide for food **(Costa França *et al.*, 2000)**.

Nowadays, Egypt face problem in amount of irrigation water. The shortage of irrigation water is the most important factor constraining agricultural production in Egypt. Common bean like many other crops is sensitive to water stress at all growth stages, it is more sensitive to drought at flowering and grain development stage **(Thaloot *et al.*, 2006).** The responses of plants to stresses depend on many factors, such as phenological stage and the time and strength of stresses **(Torres *et al.*, 2006).** Drought stress is one of the major causes for crop production losses world-wide, reducing average yield with 50% and over **(Wang *et al.*, 2003).** Drought stress in common beans reduced seed yield by 58 - 87% **(Martinez *et al.*, 2007).**

Drought, being the most important environmental stress, severely impairs plant growth and development, limits plant production and the performance of crop plants, more than any other environmental factors **(Shao *et al.*, 2009).** Water deficit is one of the major a biotic stresses, which adversely affects metabolism, crop growth and yield **(Abdul Jaleel *et al.*, 2009).**

Drought stress negatively affects almost at all aspects of plant metabolism, including a number of changes at the morphological, physiological and metabolic levels in all plant organs **(Lawlor, 2002).**

Drought stress causes oxidative damages the cellular components in plant by inducing the generation of reactive oxygen species (ROS) **(Asada, 2006).** Drought stress may lead to disturbed the balance between the production of reactive oxygen

species (ROS) and the antioxidant defense, causing accumulation of ROS which induces oxidative stress to proteins, membrane lipids and other cellular component **(Waraich *et al.*, 2011).** To alleviate these oxidative effects, plant have developed a series of enzymatic and non-enzymatic systems to counteract ROS, and protect cells from oxidative damage **(Sairam and Tyagi, 2004).**

Despite the internal resistance of the plants to drought stress, the detrimental effects of drought can be minimized by adequate and balanced supply of mineral nutrients, as well as exogenous applied antioxidants compounds such as ascorbate, α-tocopherol, glutathione, phenolic and carotenoids **(Gadalla, 2010; Waraich *et al.*, 2011; Abd-Ellatif, 2012 and Ibrahim, 2012)**.

On the other hand, antioxidants is one of new methods to assist the plant to tolerate any environmental conditions and increased plant growth, Therefore, many compounds have been applied to minimize the harmful effects of drought stress, such as ascorbic acid, putrescine and potassium citrate. These compounds can decrease the adverse effects of drought in crop plants under water stress **(El-Shayb, 2010; Gadalla, 2010; Gill and Tuteja, 2010; Abd-Ellatif, 2012 and Ibrahim, 2012).** Also, these antioxidant compounds are well known to be involved in plant adaptation to water stress and may play important roles in plant growth and development **(Farooq *et al.*, 2009 and Gadalla, 2010).**

Ascorbic acid (AsA) is one of the most important antioxidants protecting plants from oxidative stress **(Smirnoff, 2005).** It is also involved in regulating photosynthetic capacity, flowering and senescence **(Davey *et al.*, 2000)**.

AsA accelerates cell division and cell enlargement as observed in different plants such as pisum **(Cabo *et al.*, 1996)** and pea **(Citterio *et al.*, 1994)**.

Polyamines (Put, Spd, Spm) play an important role in protecting plant against various a biotic stress, they are potent ROS scavengers and inhibitors of lipid peroxidation. The diamine putrescine (Put) can alleviate harmful drought effects in plants grown under water stress. by many ways including: polyamines (PAs) may be involved in free radical scavinging **(Drolet *et al.*, 1986).** Its modulators of stress - regulated gene expression and exhibit antioxidant properties **(Kuznetsov and Shevyakova, 2007).** High accumulation of polyamines (putrescine, spermidine and spermine) in plants during a biotic stress has been well documented and is correlated with increased tolerance to a biotic stress **(Kuznetsov and Shevyakova, 2007 and Ahmad *et al.*, 2012).**

Potassium (K) plays an important role in survival of plants under environmental stress. This essential plant nutrient are not only required for better plant growth and development, but also helpful to alleviate different kinds of a biotic stresses like drought stress **(Waraich *et al.*, 2011).**

Potassium is an essential element for many physiological processes such as photosynthesis, activation of enzymes to metabolize, protein synthesis, translocation of photosynthetic into sink organs, stomatal movement (regulates opening and closing of stomata), water-relation (turgor regulation and osmotic adjustment) in plants, important of cell structure, it regulates many metabolic processes and increases drought tolerance **(Marschner, 1995 and Waraich *et al.*, 2011).**

Many investigators reported that arbuscular mycorrhizal (AM) enlarges roots areas of host plants, and improves its efficiency of water absorption, AM increased shoot-biomass, leaf water potential and enhanced proline accumulation, osmotic adjustment and soluble sugars in roots **(Porcel and Ruiz-Lozano, 2004)**. VAM enhance antioxidant levels or activities in plants **(Ruiz-Sanchez *et al.*, 2010; Baslam and Goicoechea, 2012 and Rapparini and Peñuelas, 2014).**

Therefore, the aim of this study was to investigate the effect of antioxidants (ascorbic acid and putrescine), potassium and arbuscular mycorrhiza individually or in combination with different water stress levels on growth, yield, quality as well as chemical constituents of green pods for snap bean plants cv. Bronco.

Materials and Methods

Two field experiments were carried out at the Experimental Farm Station of the Faculty of Agriculture Moshtohor, Benha University, Kalubia Gavernorate, Egypt, during two successive summer seasons of 2012 and 2013 to investigate the effect of some antioxidant materials: [ascorbic acid (AsA) and putrescine (Put)], potassium (K) and arbuscular mycorrhiza (AM) on growth, yield and chemical constituents of green pods for snap bean plants cv. Bronco grown under different water stress levels i.e., 35 , 50 and 100 % of ETo as control (Evapotranspiration).

Seeds of snap bean (*Phaseolus vulgaris* L.) cv. Bronco were obtained from Agricultural Research Center, Ministry of Agriculture, Giza, Egypt. The arbuscular mycorrhiza inoculums was obtained from Biofertilizers Unit, Faculty of Agriculture, Ain Shams University. The standard inoculums contained about 270 spores/g.

Seeds of snap bean were sown on March 15th in the two successive seasons, in open field. Four seeds / hill were sown in 3 cm deep on one side of the ridge at 25 cm apart, seeds were inoculated with root nodules bacteria (*Rhizobium phaseoli***)** and mycorrhiza treatments *(Glomus* Species). The inoculums of mycorrhiza was placed below snap bean seeds at sowing time in soil. After complete

germination plants were thinned into two plants per hill.

The experiment treatments were as follows: this experiment included 24 treatments, which were the combination between three water irrigation levels and 8 treatments of antioxidant materials, K and AM as follows:

a) Water stress levels (irrigation water quantity): drip irrigation system was used to apply the levels of water stress (quantity of irrigation water applied) in the experiment. Three irrigation levels of water quantity supply were used i.e., 100 % of ETo (control) irrigation with 3790.5 m^3 water/fed, 50 % of ETo (moderate stress) irrigation with 1895.25 m^3 water/fed and 35% of ETo (severe stress) irrigation with 1326.5 m^3 water/fed, respectively of water requirements of snap bean plants in both seasons.

The total irrigation of water requirements for bean plants 3790.5 m^3/fed in the same location of soil were taken from the previous study by **Farag (2012).** The water rate 4 L/h, discharge with 6 days intervals (water treatments were applied every 6 days) in the two seasons.

All experimental unit were received equal amounts of water until complete germination 21 days from seed sowing then irrigation and treatments were started in both seasons. one row was left between each irrigation treatment as a guard row to a void and prevent the overlapping (interactions of irrigation water).

The recommended agricultural practices of growing snap bean were applied. Phosphorus fertilizer in the form of calcium super phosphate (15.5% P_2O_5) was mixed with the soil before planting at the rate of 200 kg/fed. While, nitrogen and potassium fertilizers in the form of ammonium sulfate (21% N) and potassium sulfate (50% K_2O) were added individually with irrigation water after thinning at the rate of 200 kg/fed $(NH_4)_2SO_4$ and 100 kg/fed (K_2O) were divided into equal amounts and added five times as fertigation during the two growing seasons.

b) Applied treatments: the antioxidant materials i.e., ascorbic acid (AsA), putrescine (put), and potassium citrate (k) were used as foliar application and arbuscular mycorrhiza (AM) inoculums added to the soil below snap bean seeds immediately before cultivation (270 spores/g soil). Antioxidants used and its concentration as follows: tap water (control), ascorbic acid at 200 and 400 mg/L, putrescine at 10 and 20 mg/L, potassium citrate at 250 and 500 mg/L, arbuscular mycorrhiza at 270 spores/g soil.

Plants were sprayed with antioxidants and potassium citrate three times after 30, 40 and 50 days from sowing. The treatments were arranged in split plot design with three replicates, the main plots were assigned to water stress levels, while eight treatments of antioxidants, potassium and AM were located in subplots. The experimental area of sub plot treatment was 14.7 m^2. Each subplot contain one row (one dripper lines) of 70 cm width spacing and 21 m length.

Sampling and collecting data

1- Growth characteristics: six plants of snap bean plants from each treatment were randomly taken at 60 days after sowing to measure plant growth characteristics i.e., plant height, number of leaves/ plant, leaf area/plant, fresh and dry weights of shoots/plant. The samples of the above ground vegetative parts were dried in the oven-dried for 48 h in 75°C to a constant weight and then the dry weight per plant was calculated. These dry samples of leaves and pods were kept for chemical analysis.

2- Green pods yield and its components:

At harvest green pods that reached marketable stage were harvested and samples were taken from each treatments to determine yield characters, i.e., number and weight of green pods/plant, total green pods yield/fed, as well as green pod length and green pod diameter were determined.

3- Chemical composition in green pods:

The photosynthetic pigments i.e., chlorophyll a., b. and carotenoids in pods were determined according to **Wettestein (1957)**. Determination of N, P and K concentrations were carried out on the dry materials of green pods. Total nitrogen was determined in the dry matter using microkjeldahl method as described by **Horneck and Miller (1998)**, phosphorus **(Sandell, 1950)** and potassium (**Horneck and Hanson, 1998)**. Crude protein was calculated according to the following equation: Crude protein = Total nitrogen x 6.25 (**A.O.A.C., 2005)**.

Data obtained in this study were statistically analyzed by the methods described by **Snedecor and Cochran (1980)**.

Results and discussion

1- Vegetative growth characteristics

a- Effect of water stress

Data recorded in Tables 1 and 2 illustrate the effect of water irrigation regimes i.e., irrigation at 100%, 50% and 35% pan evapotranspiration on morphological plant growth measurements expressed as plant height, number of leaves and leaf area per plant as well as fresh and dry weights of shoots (leaves and stems)/plant during 2012 and 2013 seasons. In this respect, such data reveal that all growth traits were significantly decreased with increasing water stress conditions from 100% to 35% of plant water requirements during both seasons of study. Such decrements in all studied growth aspects as a result of decreasing the amounts of irrigation water may be attributed to the main role of water in increasing the absorption of macro and micro nutrients from the soil and in turn affect plant

vegetative growth. Also, such effect may be due to the role of water as the main constituents in photosynthetic process which consequently affect on the amounts of photosynthetic assimilates required for cells and tissues formation and in turn affect all morphological parameters of growing plants. Water stress inhibits cell enlargement more than cell division. Water stress reduces plant growth by affecting various physiological and biochemical processes, such as photosynthesis, respiration, translocation, ion uptake, carbohydrates, nutrient metabolism and growth promoters **(Farooq *et al.*, 2008 and Jalleel *et al.*, 2008).** The reduction in plant growth of oxidative stressed plants, maybe attributed to the inhibitory effect of ABA which was induced by drought on cell division and/or cell expansion **(Nabil and Coudret, 1995).** Many studies have been shown that depletion of soil moisture levels reduced plant height, number of leaves and leaf area/ plant and caused reduction in fresh and dry weights of common bean **(Farooq *et al.*, 2009)** and **Gadalla (2010)** on soybean and maize plants and **Abd-Ellatif (2012)** on snap bean. These results are in agreement with those reported by **(Hussain *et al.*, 2008; Abdul Jaleel *et al.*, 2009; El-Shayb, 2010; Emam *et al.*, 2010 and D'souza and Devaraj, 2011).**

b- Effect of applied treatments

Data in Tables 1 and 2 indicate that spraying snap bean plants with tested antioxidants (ascorbic acid at 200 and 400 mg/L, putrescine at 10 and 20 mg /L) and potassium at 250 and 500 mg/L three times during the growing season starting after 30 days from seed sowing and every 10 days intervals as well as pre-sowing soil inoculation with mycorrhiza (AM) significantly ameliorate the decrement effect of water stress and increased all measured growth aspects i.e., plant height, number of leaves and leaf area per plant as well as fresh and dry weights of shoots (leaves and stems) compared with the control treatment in both seasons. In this connection, generally the highest values were recorded as a result of spraying plants with the highest used concentration of putrescine, ascorbic acid and potassium followed by soil inoculation with AM without significant difference among them in both seasons of study compared with other tested treatments. Such increments in plant growth aspects as a result of using the tested antioxidants may be due to the main role of antioxidants on enzymatic reactions in plant metabolism and its role in catching and binding as well as scavenging of the reactive oxygen species (ROS) which affect on plant metabolism and vigor and consequently increased plant growth. Also, the increasing in plant growth traits as a result of using tested antioxidants may attributed to the increasing of photosynthetic pigments and the absorption of mineral nutrients which affect positively plant growth. Increasing plant growth aspects as a result of potassium spray may be due to the role of potassium as a macro-element in plant nutrition and its effects on different physio and chemical reactions in plant which affect positively plant growth **(Marschner, 1995 and Waraich *et al.*, 2011).** In this respect, the enhancing effect of pre-sowing soil inoculation with AM on plant foliage may be due to the main role of AM fungus on increasing the absorption through root surface for water and mineral nutrients and consequently affect positively plant growth aspects **(Porcel and Ruiz-Lozano, 2004; Safapour *et al.*, 2011 and Rapparini and Peñuelas, 2014)**. Ascorbic acid influence DNA replication, mitosis cell cycle, cell wall expansion, cell elongation and cell growth in plants **(Smirnoff and Wheeler, 2000 and Blokhina *et al.*, 2003).**

In this regard, the present results are in agreement with those of **El-Shayb (2010)** on rice plant and **Gadalla (2010)** found that applied antioxidants citric acid and ascorbic acid increased all growth parameters (plant height, stem diameter, stem fresh and dry weights, leaves fresh and dry weights, leaf area, leaves number, crop growth rate, leaf area ratio and leaf area index) and applied antioxidants could partially counteract the harmful effect of drought stress on growth of maize and soybean plants. Also, **Gharib and Hanafy Ahmed (2005)** found that spraying pea plants with putrescine at 1 or 2 ppm significantly increased plant height and shoot dry weight. The polyamines (Put, Spd, Spm) are implicated in a wide range of regulatory physiological processes such as promotion of growth, cell division, DNA replication, protein synthesis and cell differentiation **(Evans and Malmberg, 1989).**

c- Effect of the interaction

As for the interaction effect among water stress treatments and foliar spray with antioxidants and potassium as well as pre-sowing soil inoculation with AM fungus, also data in Tables 1 and 2 indicate that the highest values of all measured growth parameters were recorded as a result of irrigation snap bean plants with 100% of pan evapotranspiration and spraying the plants with the highest used concentration of putrescine and ascorbic acid during the two seasons of study. In this regard, this results are in harmony with those of **Gadalla (2010)** who mentioned that the interaction treatments of drought stress with antioxidant materials show that the applied antioxidants enhanced all growth parameter of maize and soybean under drought stress.

2. Yield and its components

2.1. Total green pods yield (marketable yield)

Data in Table 3 indicate that different water stress levels (50 and 35%) were significantly decreased the number and weight of green pods per plant and total produced yield per feddan of snap bean plant comparing with full irrigation level (100%) during 2012 and 2013 seasons. Also, the highest water stress level at 35% was the most

effective treatment which gave the highest reduction in total produced yield per plant and per feddan during the two growing seasons. In this respect, such reduction in total produced yield and its components as connected with the effect of water stress on depressing the vegetative growth measurements (Tables 1 and 2 and that is negatively affected the produced yield). Also, water stress reduced yield in soybean though number reduction of pods and seeds per unit area **(Specht *et al.*, 2001)**. Water deficit is one of the major a biotic stress, which adversely affects plant growth and yield. These changes are mainly related to the alteration of metabolic functions, such as the reduction in the synthesis of photosynthesis pigments, thereby these changes in the amount of photosynthetic pigments are closely associated to plant biomass yield **(Jalleel *et al.*, 2009).** Water stress reduced number of pods, weight of pods/ plant and ton/fed in some species, **Abd-Ellatif, (2012)** on snap bean plant and **Gadalla (2010)** on soybean and maize plants. These results are in agreement with those reported by **(Abdel-Mawgoud, 2006; Hussain *et al.*, 2008; Abdul Jaleel *et al.*, 2009 and Emam *et al.*, 2010).** Also, **Kage *et al.*, (2004) and Petropoulos *et al.*, (2008)** they mentioned that the productivity under drought stress is strongly related to the processes of dry matter partitioning and temporal biomass distribution.

As for the effect of applied treatments (antioxidants, potassium and AM), data in Table 3 indicate that all applied treatments were significantly increased number and weight of green pods per plant and total produced yield per feddan when compared with the control. Also, it could be noticed that maximum increase the number of green pods existed in case of putrescine at 20 mg/L followed by ascorbic acid at 400 mg/L, potassium citrate at 500 mg/L and AM inoculation in descending order during the two growing seasons. While, putrescine at 20 mg/L gave the highest weight of green pods per plant and feddan followed by ascorbic acid at 400 mg/L and potassium at 500 mg/L when compared with the control and other treatments during the two seasons. In this regard, the present results are in agreement with those of **El-Shayb (2010)** on rice plant and **Gadalla (2010)** on soybean and maize plants. Also, **Gharib and Hanafy Ahmed (2005)** recorded that foliar spraying of putrescine (1 or 2 ppm) significantly increased weight and number of pods/plant as well as total fresh yield/fed on pea plants.

With regard to the interaction effect, putrescine at 20 mg/L gave the highest number and weight of green pods under water stress level at 50% followed by ascorbic acid at 400 mg/L and potassium at 500 mg/L during two seasons. Also, putrescine ranked the first under water stress level at 35% followed by ascorbic acid at 400 mg/L gave the highest number and weight of green pods per plant and per feddan without significant differences between them in both seasons of study. In this respect, these results are in agreement with those of **(Mohammadi *et al.*, 2011)** they mentioned that arbuscular mycorrhizal fungi may affect host plant function on legumes and productivity under both high and low moisture conditions as well as **(Havargi, 2007)** on cotton plant. Also, **Soleimanzadeh *et al.*, (2010)** mentioned that plants with higher levels of potassium showed higher resistance to drought stress conditions and higher yield and dry matter allocation to grain filling process i.e. harvest index.

2.2. Green pods quality

As shown in Table 4 different characteristics estimated characteristics of green pods quality i.e., green pod length and green pod diameter of snap bean plants were decreased with increasing water stress to reach the level of significance during the two seasons. In this respect, water stress level at 35% gave the highest reduction in green pods quality of snap bean during 2012 and 2013 seasons when compared with water stress level at 50% and full irrigation level 100% (control).

With regard to the effect of applied treatments (ascorbic acid, putrescine, potassium and AM) data in Table 4 indicate that most applied treatments ameliorate the adverse effect of water stress and significantly increased green pods quality of snap bean compared with the control plants during the two growing seasons.

As for the interaction effect, data in Table 4 show that the putrescine at 20 mg/L gave the highest length and diameter of green pods followed by ascorbic acid at 400 mg/L without significant differences among them under water stress levels at 50% and 35% when compared with control and other treatments.

These results are in agreement with those of **(Abdel-Mawgoud, 2006 and Abd-Ellatif, 2012).**

3. Chemical composition

3.1. Photosynthetic pigments

Data in Table 5 indicate the effect of water stress levels, applied antioxidant, potassium and mycorrhiza (AM) individually or in combination on photosynthetic pigments i.e., chlorophyll a, b and carotenoids in green pods of snap bean plants at 60 days after sowing during 2013 season.

As for the effect of water stress levels, data in Table 5 show that increasing water stress levels from 50 up to 35% decreased the concentration of photosynthetic pigments i.e., chlorophyll a, b and carotenoids gradually in green pods of snap bean plants comparing with full irrigation level (100%). In this respect, water stress level at 35% gave the highest reduction in chlorophyll a, b and carotenoids in green pods of snap bean.

In this respect, water stress was found to decrease photosynthetic pigments contents and

protein in pods of snap bean plant **(Abd-Ellatif, 2012)** and in many species of plants as reported by **Havargi (2007)** on cotton, **Gadalla (2010)** on soybean in leaves, **El-Shayb (2010)** on rice and **Ibrahim (2012)** on wheat and is directly related to plant biomass yield **(Abdul Jalleel *et al.*, 2009, Farooq *et al.*, 2009).** Also, **Mafakheri *et al.*, (2010)** found that drought stress imposed during vegetative growth or anthesis on chickpea significantly decreased chlorophyll *a*, chlorophyll *b* and total chlorophyll content.

Also in the present study, it could be noticed that the reduction in chlorophyll a and b in green pods reached to 67.98%, 64.64% and 39.23%, 21.99% existed with water stress level at 50% and 35%, respectively less than the control (100%).

Concerning the effect of applied treatments, as shown in the same Table, the different applied treatments increased each of chlorophyll a, b and carotenoids in green pods of snap bean plants in 2013 season. Also, it could be noticed that maximum increase of all these pigments in green pods existed in case of putrescine at 20 mg/L followed by ascorbic acid at 400 mg/L treatments in 2013 season. Since, the putrescine at 20 mg/L gave (172.81%, 241.74% and 151.97%) and (137.73%, 110.69% and 263.08%) more than the control (100%) in chlorophyll a, b and carotenoids in green pods in case of 50 and 35% water stress respectively, in 2013 season. Also similar results were also reported by **Wu and Xia (2006)** who found that VAM seedlings had higher photosynthetic rates than in the non-VAM seedlings on tangerine. Also, **Havargi (2007)** showed that applied VAM treatments on cotton plants caused less reduction in total chlorophyll and a and b fractions where as control showed higher reduction among the treatments. Also, **Gadalla (2010)** showed that applied antioxidants of citric acid and ASA increased photosynthetic pigments content in the leaves of both maize and soybean plants under drought stress.

As for the effect of interaction, data in Table 5 clearly indicate that all the interactions effect between water stress levels and applied treatments increased the concentrations of chlorophyll a, b and carotenoids in green pods of snap bean plants in 2013 season. Also, putrescine at 20 mg/L and ascorbic acid at 400 mg/L gave the highest concentrations of chlorophyll a, b and carotenoids in green pods under water stress levels at 50 and 35% during 2013 season.

In this respect, the stimulation of photosynthetic pigments formation could be attributed to the vigorous growth obtained in Tables 1 and 2. Also, increasing of chlorophylls and carotenoids concentration in green pods may be due to enhance photosynthesis efficiency and increased dry matter production. Ascorbic acid is the major antioxidant in plant known to increase plant growth and cell cycle, through photosynthetic apparatus and plant protect any of ROS (Reactive Oxygen Species) and increased rubisco subunit, photosynthetic pigments thereby increased chlorophyll contents, photosynthetic rate and increased productivity of plants **(Chen and Gallie, 2006).** Also, this increment of photosynthetic pigment contents in response to ascorbic acid, putrescine and potassium may be due to its action as antioxidants and enhancing antioxidant enzyme activities for protecting chloroplast and photosynthetic system from oxidative damages by free radical **(Abdul Jaleel *et al.*, 2009)**. Similar results are in agreement with those reported by **Bahadur *et al.*, (2009); Gadalla (2010) and Anjum *et al.*, (2011).**

3.2. Minerals and crude protein content in green pods

Data in Table 6 indicate that water stress levels (50 and 35%) decreased the concentrations of N, P, K and crude protein in green pods of snap bean plants at 60 days after sowing during 2013 season. Also, the water stress at 35% gave the highest reduction in N (89.82%), P (93.52%), K (80.94%) and crude protein (89.81%) in green pods of snap bean when compared with the control (100% of water requirement).

As for the effect of applied treatments, applied treatments increased the concentrations of N, P, K and crude protein in green pods. The only exception was that reduction of N with mycorrhiza treatment during 2013 season. Moreover, ascorbic acid at 400 mg/L gave the highest concentrations of N and P in green pods but potassium at 500 mg/L ranked the first in potassium concentration of green pods with snap bean plants when compared with control and other treatments. While, ascorbic acid at 400 mg/L gave the highest concentration of crude protein followed by putrescine at 20 mg/L in green pods of snap bean plants during 2013 season. These results are in agreement with those reported by **El-Shayb (2010); Gadalla (2010) and Abd-Ellatif (2012).**

In addition, the interaction effects enhanced the content of N, P, K and crude protein in green pods of snap bean plants. Also, ascorbic acid at 400 mg/L gave the highest concentrations of N, P and crude protein in green pods under water stress level at 50% and 35% followed by putrescine at 20 mg/L under water stress level at 35%. But potassium at 500 mg/L ranked the first with concentration of K in this respect when compared with untreated plants and other treatments. These results are agreements with reported by **Farooq *et al.*, (2009)** showed that drought stress reduces the availability, uptake, translocation and metabolism of nutrients. A reduced transpiration rate due to water deficit reduces the nutrient absorption and efficiency of their utilization.

Table 1. Effect of water stress levels and applied antioxidants, potassium and AM as well as their interaction on plant height (cm), number of leaves and leaf area (cm^2)/plant of snap bean at 60 DAS during 2012 and 2013 seasons.

Characteristics		Plant height (cm)/plant							
		1 st season (2012)				2 nd season (2013)			
		Water levels							
Treatments (mg/l)		WL1	WL 2	WL 3	Mean	WL1	WL 2	WL 3	Mean
Control	0.0	31.23	26.4	23.4	27.01	34.42	27.67	22.33	28.14
Ascorbic Acid	200	33.25	29.76	28.63	30.55	36.17	31.17	25.00	30.78
Ascorbic Acid	400	33.67	30.77	29.57	31.34	37.20	32.07	28.33	32.53
Putrescine	10	39.67	28.76	25.33	31.25	41.67	29.83	26.27	32.59
Putrescine	20	40.33	31.33	27.00	32.89	42.06	35.87	29.33	35.75
Potassium	250	35.1	30.00	26.87	30.66	41.33	30.33	26.47	32.71
Potassium	500	44.33	34.43	29.33	36.03	42.67	36.37	29.83	36.29
Mycorrhiza		41.43	32.47	29.47	34.46	39.53	35.67	33.07	36.09
Mean		37.37	30.49	27.45		39.38	32.37	27.57	
L.S.D at 0.05		Water stress 2.303 Treatments 3.761 Interaction 6.514				Water stress 1.562 Treatments 2.550 Interaction 4.417			
Characteristics		Number of leaves/Plant							
		1 st season (2012)				2 nd season (2013)			
		Water levels							
Treatments (mg/l)		WL1	WL 2	WL 3	Mean	WL1	WL 2	WL 3	Mean
Control	0.0	9.67	8.67	7.67	8.67	7.00	6.67	6.00	6.56
Ascorbic Acid	200	12.00	11.00	10.00	11.00	8.33	7.67	6.33	7.44
Ascorbic Acid	400	14.33	13.33	12.33	13.33	12.67	10.67	8.67	10.67
Putrescine	10	15.67	10.67	9.67	12.00	9.00	9.00	6.67	8.22
Putrescine	20	16.67	13.33	11.67	13.89	12.67	11.33	8.33	10.77
Potassium	250	12.00	11.67	10.00	11.22	8.67	7.33	7.67	7.89
Potassium	500	16.33	11.67	10.67	12.89	9.33	8.33	7.67	8.44
Mycorrhiza		10.67	10.33	9.67	10.22	11.33	8.67	7.33	9.11
Mean		13.42	11.33	10.21		9.87	8.71	7.33	
L.S.D at 0.05		Water stress 1.246 Treatments 2.034 Interaction 3.524				Water stress 0.829 Treatments 1.354 Interaction 2.345			
Characteristics		Leaf Area (cm^2)/ plant							
		1 st season (2012)				2 nd season (2013)			
		Water levels							
Treatments (mg/l)		WL1	WL 2	WL 3	Mean	WL1	WL 2	WL 3	Mean
Control	0.0	83.90	76.30	68.20	76.13	79.50	68.30	51.40	66.40
Ascorbic Acid	200	122.20	119.63	104.40	115.41	110.00	76.20	60.80	82.33
Ascorbic Acid	400	156.13	151.73	126.17	152.67	165.50	169.30	82.90	139.23
Putrescine	10	115.56	102.70	83.47	100.57	120.00	89.30	70.30	93.20
Putrescine	20	192.06	145.40	116.50	151.32	180.30	177.40	90.43	149.38
Potassium	250	101.40	83.83	72.60	85.94	90.30	80.80	60.70	77.27
Potassium	500	199.33	120.70	85.60	135.21	175.50	88.50	65.40	109.80
Mycorrhiza		186.03	124.47	105.60	138.70	170.10	165.40	73.40	136.30
Mean		161.45	115.59	98.32		136.4	114.4	69.42	
L.S.D at 0.05		Water stress 2.925 Treatments 4.776 Interaction 8.272				Water stress 2.676 Treatments 4.371 Interaction 7.570			

Table 2. Effect of water stress levels and applied antioxidants, potassium and AM as well as their interaction on fresh and dry weights of shoots (leaves+ stems)/plant (g.) of snap bean at 60 DAS during 2012 and 2013 seasons.

Treatments (mg/l)		Fresh weight of shoots (leaves+ stems)/plant (g.)							
		1 st season (2012)				2 nd season (2013)			
		Water levels							
		WL1	WL 2	WL 3	Mean	WL1	WL 2	WL 3	Mean
Control	**0.0**	54.13	48.47	43.43	48.68	34.83	27.84	19.37	27.35
Ascorbic Acid	**200**	79.70	65.74	53.40	66.28	44.99	31.11	27.89	34.66
Ascorbic Acid	**400**	81.13	75.40	70.00	75.51	63.03	48.60	33.28	48.30
Putrescine	**10**	102.83	56.26	48.63	69.24	68.17	36.80	24.72	43.23
Putrescine	**20**	105.53	62.07	59.87	75.82	76.53	51.04	35.56	54.38
Potassium	**250**	72.07	61.93	55.20	63.07	45.52	31.68	27.13	34.78
Potassium	**500**	94.82	67.37	54.13	72.11	64.26	46.11	26.35	45.57
Mycorrhiza		97.20	71.87	56.80	75.29	65.38	37.86	27.40	43.55
Mean		85.93	63.63	55.18		57.84	38.88	27.71	
L.S.D at 0.05		**Water stress 5.07**				**Water stress 5.474**			
		Treatments 8.284				**Treatments 8.939**			
		Interaction 14.35				**Interaction 15.48**			
Characteristics		**Dry weight of shoots (leaves+ stems)/plant (g.)**							
		1 st season (2012)				2 nd season (2013)			
		Water levels							
Treatments (mg/l)		WL1	WL 2	WL 3	Mean	WL1	WL 2	WL 3	Mean
Control	**0.0**	8.50	7.20	6.30	7.33	9.27	8.24	6.52	8.01
Ascorbic Acid	**200**	11.37	9.13	8.10	9.53	13.13	10.23	9.60	10.99
Ascorbic Acid	**400**	15.77	11.54	9.84	12.38	15.69	13.83	11.24	13.59
Putrescine	**10**	16.50	9.23	8.03	11.25	15.26	9.92	8.89	11.36
Putrescine	**20**	17.43	13.35	8.87	13.22	16.95	14.18	10.37	13.83
Potassium	**250**	12.90	11.14	9.30	11.11	11.28	9.83	8.99	10.03
Potassium	**500**	14.10	11.54	8.87	11.50	14.49	12.92	10.91	12.77
Mycorrhiza		14.14	9.90	8.67	10.90	17.00	13.08	9.88	13.32
Mean		13.84	10.38	8.50		14.13	11.53	9.55	
L.S.D at 0.05		**Water stress 0.942**				**Water stress 1.044**			
		Treatments 1.539				**Treatments 1.705**			
		Interaction 2.665				**Interaction 2.953**			

Table 3. Effect of water stress levels and applied antioxidants, potassium and AM as well as their interaction on number and weight of green pods yield/plant and total yield ton/ feddan of snap bean plants during 2012 and 2013 seasons.

Characteristics		Number of green pods/plant							
		1 st season (2012)				2 nd season (2013)			
		Water levels							
Treatments	(mg/l)	WL1	WL 2	WL 3	Mean	WL1	WL 2	WL 3	Mean
Control	0.0	29.33	22.00	17.33	22.89	27.66	25.00	20.00	24.22
Ascorbic Acid	200	43.33	44.00	23.00	36.78	40.33	41.66	22.33	34.77
Ascorbic Acid	400	59.00	49.33	40.00	49.44	56.00	47.33	38.33	47.22
Putrescine	10	43.00	34.00	32.00	36.33	41.33	33.66	31.00	35.33
Putrescine	20	55.00	62.33	40.33	52.55	58.33	54.00	35.66	49.33
Potassium	250	45.00	45.00	26.33	38.78	43.33	42.33	24.66	36.77
Potassium	500	49.00	48.33	29.00	42.11	46.00	45.33	28.33	39.89
Mycorrhiza		52.33	43.00	37.67	44.33	50.33	44.00	29.00	41.11
Mean		46.99	43.49	30.71		45.41	41.66	28.66	
L.S.D at 0.05		Water stress 2.383				Water stress 1.176			
		Treatments 3.760				Treatments 1.920			
		Interaction 6.513				Interaction 3.325			
Characteristics		Weight of green pods/plant (g.)							
		1 st season (2012)				2 nd season (2013)			
		Water levels							
Treatments	(mg/l)	WL1	WL 2	WL 3	Mean	WL1	WL 2	WL 3	Mean
Control	0.0	91.50	71.82	60.40	74.57	88.50	67.84	55.71	70.68
Ascorbic Acid	200	137.85	134.00	68.35	113.40	135.40	131.81	66.34	111.18
Ascorbic Acid	400	219.15	171.60	115.00	168.58	210.21	165.5	94.43	156.71
Putrescine	10	140.70	104.80	95.60	113.70	137.65	98.30	70.21	102.05
Putrescine	20	209.90	194.95	120.80	175.22	202.71	185.30	85.34	157.78
Potassium	250	164.64	159.30	62.15	128.70	159.30	148.91	68.34	125.52
Potassium	500	173.30	160.30	94.85	142.82	169.83	152.70	70.23	130.92
Mycorrhiza		173.40	100.65	98.10	124.05	169.31	103.83	70.23	114.46
Mean		171.31	137.18	89.41		165.36	131.77	72.60	
L.S.D at 0.05		Water stress 10.08				Water stress 7.950			
		Treatments 16.46				Treatments 12.98			
		Interaction 28.51				Interaction 22.49			
Characteristics		Total yield ton/ feddan							
		1 st season (2012)				2 nd season (2013)			
		Water levels							
Treatments	(mg/l)	WL1	WL2	WL3	Mean	WL1	WL2	WL3	Mean
Control	0.0	4.18	3.28	2.76	3.41	4.05	3.10	2.55	3.23
Ascorbic Acid	200	6.30	6.13	3.12	5.18	6.19	6.02	3.03	5.08
Ascorbic Acid	400	10.02	7.84	5.26	7.71	9.61	7.56	4.32	7.16
Putrescine	10	6.43	4.79	4.37	5.20	6.29	4.49	3.21	4.66
Putrescine	20	9.59	8.91	5.52	8.01	9.27	8.47	3.90	7.21
Potassium	250	7.53	7.28	2.84	5.88	7.28	6.81	3.12	5.74
Potassium	500	7.92	7.33	4.33	6.53	7.76	6.98	3.21	5.98
Mycorrhiza		7.93	4.60	4.48	5.67	7.74	4.75	3.21	5.23
Mean		7.49	6.27	4.09		7.27	6.02	3.32	
L.S.D at 0.05		Water stress 0.27				Water stress 0.45			
		Treatments 0.44				Treatments 0.73			
		Interaction 0.76				Interaction 1.27			

Table 4. Effect of water stress levels and applied antioxidants, potassium and AM as well as their interaction on green pod length and diameter (cm) (marketable yield) of snap bean plants during 2012 and 2013 seasons.

Characteristics		Green pod length (cm)							
		1 st season (2012)				2 nd season (2013)			
		Water levels							
Treatments	(mg/l)	WL1	WL 2	WL 3	Mean	WL1	WL 2	WL 3	Mean
Control	0.0	11.33	11.27	11.00	11.20	10.20	9.70	8.60	9.50
Ascorbic Acid	200	11.90	11.33	11.30	11.51	12.40	11.30	10.30	11.33
Ascorbic Acid	400	13.70	13.67	11.35	12.91	13.80	13.20	12.20	13.07
Putrescine	10	13.33	11.87	12.70	12.63	13.30	13.10	12.30	12.90
Putrescine	20	13.90	13.50	13.00	13.47	14.00	13.90	12.70	13.53
Potassium	250	12.50	12.60	11.35	12.15	11.10	10.30	9.30	10.23
Potassium	500	12.97	12.77	12.77	12.84	13.30	12.90	11.30	12.50
Mycorrhiza		13.80	13.40	11.77	12.99	12.30	12.20	11.30	11.93
Mean		12.93	12.55	11.91		12.55	12.08	11.00	
L.S.D at 0.05		Water stress 0.50				Water stress 0.61			
		Treatments 0.82				Treatments 1.00			
		Interaction 1.41				Interaction 1.73			
Characteristics		Green pod diameter (cm)							
		1 st season (2012)				2 nd season (2013)			
		Water levels							
Treatments	(mg/l)	WL1	WL 2	WL 3	Mean	WL1	WL 2	WL 3	Mean
Control	0.0	0.83	0.60	0.53	0.65	0.60	0.60	0.60	0.60
Ascorbic Acid	200	0.83	0.77	0.67	0.76	0.70	0.70	0.60	0.67
Ascorbic Acid	400	0.97	0.90	0.77	0.88	0.90	0.90	0.80	0.87
Putrescine	10	0.90	0.80	0.70	0.80	0.80	0.80	0.70	0.77
Putrescine	20	0.97	0.93	0.77	0.89	0.90	0.90	0.80	0.87
Potassium	250	0.90	0.90	0.60	0.80	0.60	0.60	0.60	0.60
Potassium	500	0.93	0.90	0.67	0.83	0.90	0.80	0.70	0.80
Mycorrhiza		0.90	0.70	0.60	0.73	0.70	0.70	0.70	0.7
Mean		0.90	0.81	0.66		0.76	0.75	0.69	
L.S.D at 0.05		Water stress 0.04				Water stress 0.05			
		Treatments 0.07				Treatments 0.07			
		Interaction 0.12				Interaction 0.13			

Table 5. Effect of water stress levels and applied antioxidants, potassium and AM as well as their interaction on photosynthetic pigments (mg/g F.W.) concentration in green pods of snap bean plants at 60 DAS during 2013 season.

Characteristics		Photosynthetic pigments											
		Chlorophyll (a)				Chlorophyll (b)				Carotenoids			
Treatments (mg/L)		Water levels											
		WL1	WL2	WL 3	Mean	WL1	WL2	WL 3	Mean	WL1	WL 2	WL 3	Mean
Control	**0.0**	0.549	0.294	0.134	0.326	0.204	0.159	0.031	0.131	0.122	0.042	0.030	0.065
Ascorbic Acid	**200**	0.619	0.396	0.086	0.367	0.143	0.099	0.078	0.107	0.164	0.050	0.042	0.085
Ascorbic Acid	**400**	0.951	0.120	0.105	0.392	0.232	0.105	0.083	0.140	0.282	0.145	0.073	0.167
Putrescine	**10**	0.579	0.133	0.097	0.270	0.147	0.084	0.082	0.104	0.169	0.096	0.079	0.115
Putrescine	**20**	0.899	0.298	0.149	0.449	0.211	0.131	0.094	0.145	0.328	0.101	0.084	0.171
Potassium	**250**	0.728	0.133	0.100	0.320	0.119	0.088	0.051	0.086	0.168	0.103	0.058	0.110
Potassium	**500**	0.581	0.304	0.112	0.332	0.208	0.144	0.062	0.138	0.235	0.096	0.067	0.133
Mycorrhiza		0.724	0.116	0.088	0.309	0.187	0.127	0.084	0.133	0.175	0.095	0.079	0.116
Mean		0.291	0.224	0.064		0.181	0.117	0.071		0.291	0.119	0.064	

Table 6. Effect of water stress levels and applied antioxidants, potassium and AM as well as their interaction on mineral and crud protein content (mg/g D.W.) in green pods of snap bean plants at 60 DAS during 2013 season.

Characteristics		Minerals												Crud protein			
		N				P				K							
		Water levels															
Treatments	(mg/L)	WL_1	WL_2	WL_3	Mean	WL_1	WL_2	WL_3	Mean	WL_1	WL_2	WL_3	Mean	WL_1	WL_2	WL_3	Mean
Control	**0.0**	25.90	23.30	20.30	23.17	8.26	7.98	6.26	7.50	26.90	26.60	23.50	25.67	161.90	145.60	126.90	144.80
Ascorbic Acid	**200**	26.60	25.20	22.50	24.77	9.38	8.44	8.40	8.74	28.40	27.90	25.50	27.27	166.30	157.50	140.60	154.80
Ascorbic Acid	**400**	37.50	37.30	35.90	36.90	13.05	13.00	12.67	12.91	39.40	38.20	30.80	36.13	234.40	233.10	224.40	230.60
Putrescine	**10**	30.10	29.50	28.80	29.47	8.59	8.59	8.52	8.57	35.70	29.00	22.50	29.07	188.10	184.40	180.00	184.20
Putrescine	**20**	36.40	34.40	32.20	34.33	10.41	10.21	10.11	10.24	44.10	37.00	33.50	38.20	227.50	215.00	201.30	214.60
Potassium	**250**	28.00	27.30	26.60	27.30	8.75	8.72	8.66	8.71	38.70	36.60	31.00	35.43	175.00	170.60	166.30	170.60
Potassium	**500**	34.30	31.00	29.40	31.57	9.90	9.88	9.15	9.64	45.50	43.40	38.80	42.57	214.40	193.80	183.80	197.30
Mycorrhiza		31.00	30.80	28.70	30.17	10.72	10.26	10.15	10.38	40.10	42.20	36.20	39.50	193.80	192.50	179.40	188.50
Mean		31.23	29.85	28.05		9.88	9.64	9.24		37.35	35.11	30.23		195.20	186.50	175.30	

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تأثير بعض مضادات الأكسدة والبوتاسيوم والميكورهيزا على النمو والمحصول والجودة لنبات الفاصوليا النامى تحت مستويات من الإجهاد المائى

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أجريت تجربتان حقيتان بمزرعة كلية الزراعة بمشتهر – جامعة بنها – محافظة القليوبية – مصر خلال الموسم الصيفى لعامى 2012 و 2013 تحت نظام الرى بالتنقيط لدراسة تأثير الرش بحمض الأسكوربيك (بتركيز 200 و400 ملجم/لتر) والبترسين بتركير10 و 20 ملجم/لتر) وسترات البوتاسيوم (بتركيز 250 و500 ملجم/لتر) و الميكورهيزا المضافة للتربة (270 جرثومه/جم تربة) بإستخدام مستويين من الإجهاد المائى (50% ، 35% بخر نتح بالأضافة إلى كنترول 100% بخر نتح من الإحتياج المائى) على بعض صفات النمو الخضرى ومحصول وجودة قرون نبات الفاصوليا صنف برونكو ومن النتائج المتحصل عليها :

1- أدت المعاملة بمستويات الإجهاد ومعاملات الرش إلى تأثير معنوى على صفات النمو الخضرى والمحصول لنبات الفاصوليا.

2- أدت الزيادة فى مستويات الإجهاد المائى إلى نقص معنوى فى كلاً من صفات النمو الخضرى (طول النبات – عدد الأوراق ومساحة الأوراق – الوزن الخضرى والجاف للمجموع الخضرى) وأيضاً نقص محصول القرون الخضراء (عدد القرون و وزن القرون للنبات وللفدان – ونقص جودة القرون من حيث طول وسمك القرن) وأيضاً نقص فى محتوى الكلوروفيل أ ، ب والكاروتين وأيضاً نقص فى محتوى العناصر (نيتروجين وفوسفور وبوتاسيوم) ومحتوى البروتين بالقرون الخضراء .

3- أدى الرش بالتركيز العالى من حمض الأسكوربيك 400 ملجم/لتر والبترسين 20 ملجم/لتر وسترات البوتاسيوم 500 ملجم/لتر وإضافة الميكورهيزا إلى زيادة معنوية فى صفات النمو الخضرى السابقة ومحصول وجوده القرون لنبات الفاصوليا صنف برونكو وكانت معاملة البترسين 20 ملجم/لتر يليه حمض الأسكوربيك 400 ملجم/لتر ثم البوتاسيوم 500 ملجم/لتر و الميكورهيزا أعطت أعلى زيادة فى الصفات السابقة. ومحتوى القرون من الكلوروفيل أ ، ب و العناصر نيتروجين وفوسفور وبوتاسيوم ومحتوى البروتين بالقرون الخضراء.

4- أدى الرش بالبترسين 20 ملجم/لتر ثم حمض الأسكوربيك 400 ملجم/لتر تحت مستوي 50% و 35% أعلى إستجابة لصفات النمو الخضرى والمحصول ومحتوى القرون من صبغات البناء الضوئى والعناصر مثل النيتروجين والفوسفور والبوتاسيوم والبروتين مقارنة بالكنترول والمعاملات الأخرى.

أظهرت الدراسة أن الرش بكل من حمض الأسكوربيك والبترسين وسترات البوتاسيوم وإضافة الميكورهيزا أدى إلى تقليل التأثير الضار للإجهاد المائى على نمو ومحصول الفاصوليا ويمكن التوصيه بالرش الورقى بمضادات الأكسدة والبوتاسيوم وإضافة الميكورهيزا إلى التربة تحت ظروف الإجهاد المائى (مستويات الرى المنخفضة) 50% من البخر نتح من الإحتياج المائى لتحسين النمو وزيادة المحصول لنبات الفاصوليا.