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Research Article

The Combined Effect of Drought Stress and Culture Substrate on Water Nutrition, Growth and Yield of *Vicia faba* L.

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ABSTRACT

In order to evaluate the effects of the substrate on the resistance of faba bean (*Vicia faba* L.) to drought stress, an essay is carried in a greenhouse of Oran1 University at Algeria. Three types of substrates were introduced: Substrate 1 (sand), Substrate 2 (peat) and Substrate 3 (soil). Drought stress at 10% of field capacity (FC) was imposed at the vegetative stage from the 36th day after sowing in a simple randomized design for 56 days. The response to water stress is evaluated through water status, growth parameters (plant height, collar diameter, branching number, aerial and root dry biomass) as well as plant pod yield. The obtained results show that the substrate 2 allows a better resistance to water stress, the analyzed parameters were positively influenced by the contribution of the organic matter which plays not only a role in the slow and regular release of the mineral elements but also in the retention of the water.

Key words: Substrate, Drought stress, *Vicia faba* L., Organic matter, Resistance, Yield.

INTRODUCTION

Satisfying the water needs of the plant is certainly the most important factor in plant growth and crop productivity. Growth, as a set of irreversible quantitative changes in organs, is very sensitive to water deficit because of its dependence on turgor (Ferreira *et al.*, 2015). A water deficit usually has reducing effects on plant growth, resulting in lower yield (Chaves, 2002; Aldesuquy *et al.*, 2014). The plant response to water shortages is complex and depends both on the stage of plant development, severity of stress, duration of stress and the state in which was the plant when stress took place (Aziadekey *et al.*, 2014). In arid and semi-arid zones, although the availability of water is one of the main factors limiting agricultural production, there has been little work on the prediction of soil water retention properties (Dridi and Dilmi, 2011; Wosten *et al.*, 2013). The knowledge of these properties is necessary to describe the transfer of water and solutes (Morvan *et al.*, 2004). In fact, soil plays a fundamental role in water retention since it is the substrate for crops and thus conditions water and nutrient removal. It is also the site of adsorption phenomena, physical filtration and biological degradation (Laurent and Rossignol, 2003). It also stores the free water and solutes before they are absorbed by the vegetation; it thus forms an essential compartment of retention (Laurent and Rossignol, 2003). For plants, the water effectively available depends primarily on the energy with which it is retained (Tessier *et al.*, 1996). The soil water retention properties are strongly influenced by soil texture. In fact, water retention is higher in fine-textured soils containing clay levels and finely divided constituents (Aoubouazza, 2018). This is due to the presence of a textural porosity responsible for almost all of the water retained in the soil at low potentials (Bigorre, 2000). Moreover, Balbino *et al.*, (2002) reported that water retention properties are dependent on the nature of the mineral and organic constituents. Many studies have shown that organic matter tends to increase water retention, both in field capacity and at wilting point, so that the effect on the useful reserve can be considered negligible (Bauer and Black, 1992). Its influence on the water regime remains decisive for improving plants resistance to water stress (Diallo *et al.*, 2010). The bean (*Vicia faba* L.) is an important legume crop worldwide, ranking as the fourth most important grain legume after dry beans, dry peas and chickpeas (Lopez Bellido *et al.*, 2005). It is one of the oldest and most important grain legumes grown in the Mediterranean region, where it is used for human consumption and animal feed (Abid *et al.*, 2017).

Drought is one of the most deleterious environmental conditions affecting crop growth and productivity

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(Galeano *et al.*, 2019). Drought stress affects faba bean growth, reduces grain yield and quality, and causes morphological, physiological, biochemical and molecular alterations (Alghamdi *et al.*, 2014; Zarafshar *et al.*, 2014).The objective of our present study is to study the interaction of two factors, water and soil, and to evaluate the water stress sensitivity of *Vicia faba* L. plants grown in different substrates.

MATERIALS AND METHODS

Plant material

The experiment was conducted in a greenhouse under controlled conditions at Oran1 University, Algeria. We used bean seeds (*Vicia faba* L.) belonging to a foreign variety (Spanish) marketed in Algeria: Reina Mora.

Methods

Seeds of *Vicia faba* were surface disinfected by soaking them in a 5% sodium hypochlorite solution for 5 min and rinsed 3 times with sterile distilled water. The seeds were then sown individually into plastic pots (21cm diameter and 18 cm depth) filled with one of the three substrates introduced:

- Substrate 1 (S1): Composed of fine sea sand, previously washed and dried.
- Substrate 2 (S2): made of peat and contains 85-90% of dry organic matter and some mineral elements (nitrogen, phosphorus and potassium).
- Substrate 3 (S3): Consists of soil.

The substrate 3 granulometric study shows the presence of coarse sand, fine sand and clay. The clay percentage is estimated by the “pudding test” (Ridremont *et al*., 2012): it's about trying to roll the wet fine soil sample to form a pudding of 5 to 10 mm in diameter. The result obtained shows that the collected soil contains more than 25-30% of clay (Fig.1). Watering seedlings is done every two days with tap water. The Hoagland nutrient solution is added every two weeks until water stress application (Hoagland and Arnon, 1938).

At the 36th day, the seedlings are subjected to severe drought stress at 10% FC for 56 days until the end of the cycle and the production of pods (Fig. 2). For the field capacity calculation, the following protocol was undertaken: a sample of 100 g (weight P1) of each substrate was placed in a pot and then watered abundantly until water leaching (saturation phase). The pot is kept in a dry place for 24 hours to drain the excess water, then reweighed (weight P2). It is expressed as a percentage (gram of water retained in 100 g of dry soil). The samples show 25%, 193% and 30% field retention capacities for substrates 1, 2 and 3, respectively. Therefore, our pots that weigh 3004.16 g (S1); 1104.5g (S2) and 1199.5g (S3), will have by deduction a retention capacity of 751; 2132 and 360 g respectively.

Measured traits

Relative water content (RWC)

Relative water content was determined as described by Ladiges, (1975). It is determined according to the equation:
RWC (%) = [(FW-DW)/ (TW-DW)] X 100

FW: fresh weight; TW: turgid weight; DW: dry weight

Growth parameters

The length of the main stem, the number of branches, the collar diameter and aerial and root biomass were evaluated. Height measurements were made using the decimeter from the collar to the apex. The number of branches is determined by counting the stems from the primary and secondary branches. The collar diameter of the plants was measured with calipers. For the evaluation of dry biomass, the aerial and root parts of the plants were cut and dried and weighed.

Yield Parameters

This parameter is studied through the measurement of the number and weight of pods per plant.

Statistical analyzes

The obtained results are analyzed using SPSS software (version 20.0). A multivariate analysis of variance (MANOVA) is carried out to evaluate the effect of the culture substrate on the water stress resistance of the bean plants through the analysis of some morpho-physiological parameters according to Pillai criteria. All parameters were subjected then to a one-way analysis ($p<0.05$) and compared using Turkey’s test at 5% of probability. Similarly, Pearson correlation coefficients were calculated to determine the relationships between the retained variables.

RESULTS

The study of the statistical results of the MANOVA test shows that the drought stress (DS) and the substrate (S) as well as the interaction between these two factors (DS x S) have a highly significant effect on all the measured parameters ($p=0.000$ at $\alpha <0.05$), which reflects a variability of plant response to water stress according to the culture substrate (Table 1). ANOVA statistical analysis showed a highly significant effect of drought stress and substrate on the expression of all measured parameters (RWC, stem height, collar diameter, branching number, aerial and root dry weight, number and weight of pods/plant). The effect of the interaction (DS x S) is significant in all studied parameters except for the number of branching character (Table 2).

Effect of substrate and drought stress on water retention (RWC)

The effect of drought stress on leaf relative water content (RWC) is shown in figure 3. Under control conditions, substrate 1 (sand) had the lowest value of RWC (88.47% ±0.41). The highest values were found in culture substrates 2 and 3 which are rich in hydrophilic compounds such as organic matter and clay with respectively 91.52% ±0.7 and 91.80% ± 0.98. Under drought stress, the RWC of leaves was significantly reduced in faba beans plants grown on substrate 2 and 3 compared to substrate 1. The lowest value of RWC, causing a marked turgor loss, was recorded in substrate 3 with 86.15% ± 0.23. A negative and highly significant correlation is recorded between RWC and drought stress (r= -0.677, Table 3). Tukey test at 5% of probability shows four distinct homogeneous groups (Fig.3).

Table 1: Significant multivariate effects (at p<0.05).

Effect	Trace of Pillai	ddl	F	Sig.
Drought stress (DS)	0.999	8,000	843,635	0.000**
Substrate (S)	1.949	16,000	28,432	0.000**
Drought stress x Substrate (DS X S)	1.943	16,000	25,629	0.000**

** highly significant

Table 2: Effects of drought stress and substrate on different variables

Treatment	Dependent variable	ddl	F	Sig.
Drought stress (DS)	Stem height	1	510,682	0,000**
	Collar diameter	1	20,167	0,001**
	Branching number	1	40,579	0,000**
	Air dry weight	1	362,228	0,000**
	Root Dry weight	1	112,069	0,000**
	Pods number	1	124,000	0,000**
	Pods weight	1	144,650	0,000**
	RWC	1	94,550	0,000**
Substrate (S)	Stem height	2	311,902	0,000**
	Collar diameter	2	70,167	0,000**
	Branching number	2	64,194	0,000**
	Air dry weight	2	242,116	0,000**
	Root Dry weight	2	113,312	0,000**
	Pods number	2	57,323	0,000**
	Pods weight	2	172,501	0,000**
	RWC	2	26,935	0,000**
Drought stress x Substrate (DS x S)	Stem height	2	13,989	0,001**
	Collar diameter	2	1,167	0,344
	Branching number	2	6,452	0,013*
	Air dry weight	2	33,500	0,000**
	Root Dry weight	2	19,310	0,000**
	Pods number	2	12,806	0,001**
	Pods weight	2	25,411	0,000**
	RWC	2	28,749	0,000**

* significant, ** highly significant

Fig. 1: Pudding test

Fig. 2: Faba bean 36 days old seedlings (*Vicia faba* L.) before water stress; S1: substrate 1 (sand); S2: substrate 2 (peat); S3: substrate 3 (soil)

Effect of substrate and drought stress on growth parameters

Main stem height

The height main stem height showed differences between control and treated plants due to the substrate and drought stress (Fig. 4). In well-watered conditions, the highest stem length was observed on substrate 2 rich in organic matter with value of 129.66 ± 3.51 cm.

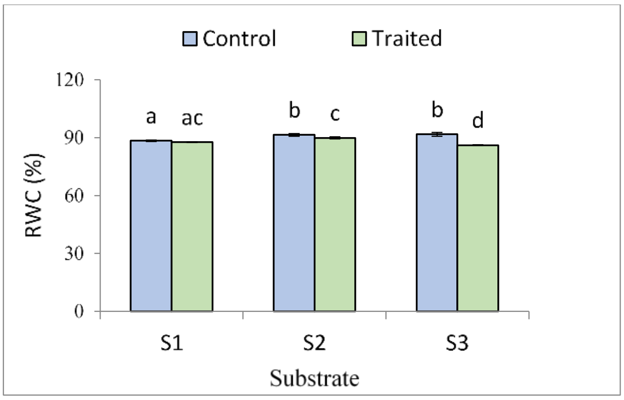

Fig. 3: Relative water content (RWC) of *Vicia faba* L. plants at the end of drought stress; Different letters denote significant differences (Tukey test p<0.05)

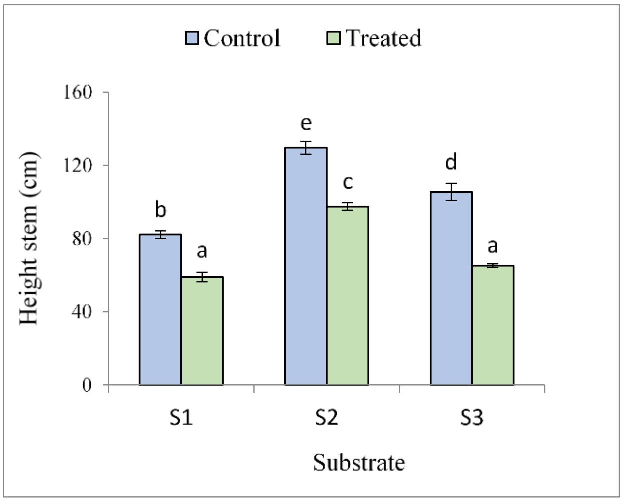

Fig. 4: Height stems of *Vicia faba* L. plants at the end of drought stress; Different letters denote significant differences (Tukey test <0.05)

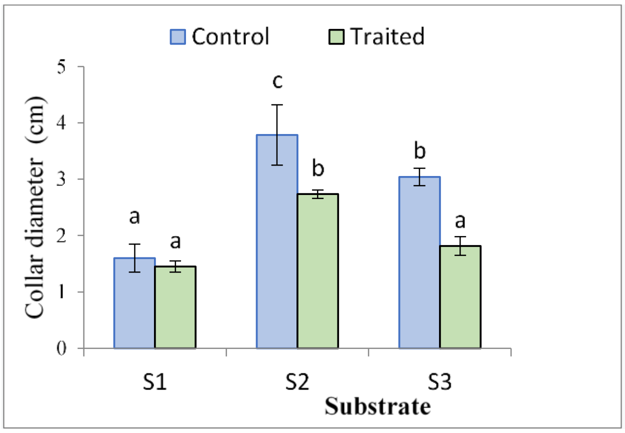

Fig. 5: Collar diameter of *Vicia faba* L. plants at the end of drought stress; Different letters denote significant differences (Tukey test P<0.05)

Drought stress caused a decrease of stem height for all plants; statistically translated by the existence of a highly significant negative correlation between the two variables (r=-0,649, Table 3). The largest decrease of stem height was found in substrate 2 (97.5 ± 2.08 cm), while the lowest decrease occurred in substrate 1 (59 ± 2.64 cm).

Table 3: Pearson correlation between mesured physiological parameters

		DS	SUB	SH	NR	DC	ADW	RDW	NPP	WPP
SUB	Corrélation de Pearson	-,044								
	Sig. (bilatérale)	,820								
SH	Corrélation de Pearson	-,649**	,200							
	Sig. (bilatérale)	,001	,384							
NR	Corrélation de Pearson	-,261	,814**	,763**						
	Sig. (bilatérale)	,240	,000	,000						
DC	Corrélation de Pearson	-,543**	,456*	,918**	,874**					
	Sig. (bilatérale)	,009	,033	,000	,000					
ADW	Corrélation de Pearson	-,604**	,411	,953**	,835**	,938**				
	Sig. (bilatérale)	,006	,080	,000	,000	,000				
RDW	Corrélation de Pearson	-,537*	,320	,944**	,772**	,927**	,959**			
	Sig. (bilatérale)	,022	,195	,000	,000	,000	,000			
NPP	Corrélation de Pearson	-,656**	,245	,975**	,736**	,897**	,931**	,925**		
	Sig. (bilatérale)	,000	,228	,000	,000	,000	,000	,000		
WPP	Corrélation de Pearson	-,469*	,154	,924**	,677**	,872**	,886**	,947**	,895**	
	Sig. (bilatérale)	,043	,528	,000	,001	,000	,000	,000	,000	
RWC	Corrélation de Pearson	-,677**	,150	,877**	,596**	,774**	,865**	,815**	,896**	,739**
	Sig. (bilatérale)	,001	,540	,000	,009	,000	,000	,000	,000	,000

* significant, ** highly significant; DS : Drought stress; SUB : Substrate; SH: Stem height; CD: Collar diameter; NR: Number ramification; ADB: Aerial dry biomass; RDB: Root dry biomass; NPP: Number of pods per plant; WPP: Weight of pods per plant; RWC: Relative content water

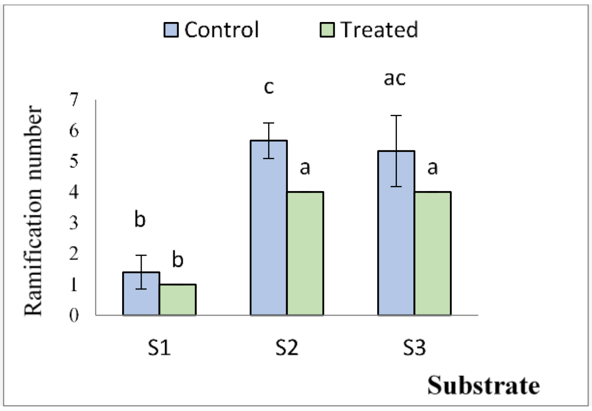

Fig. 6: Stem ramifications number of *Vicia faba* L. plants at the end of water stress; Different letters denote significant differences (Tukey test P<0.05)

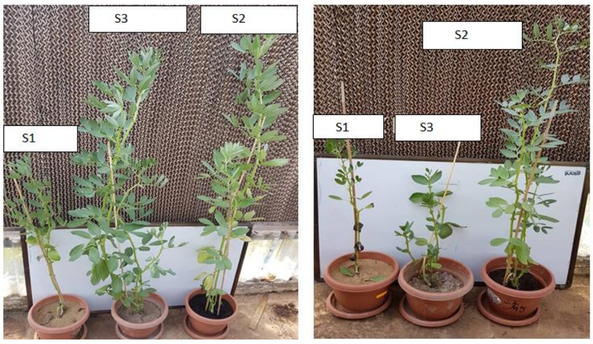

Fig. 7: Control (left) and stressed (right) plants of *Vicia faba* L. plants, grown in different substrates (S1, S3 and S2) after 13 weeks of drought stress.

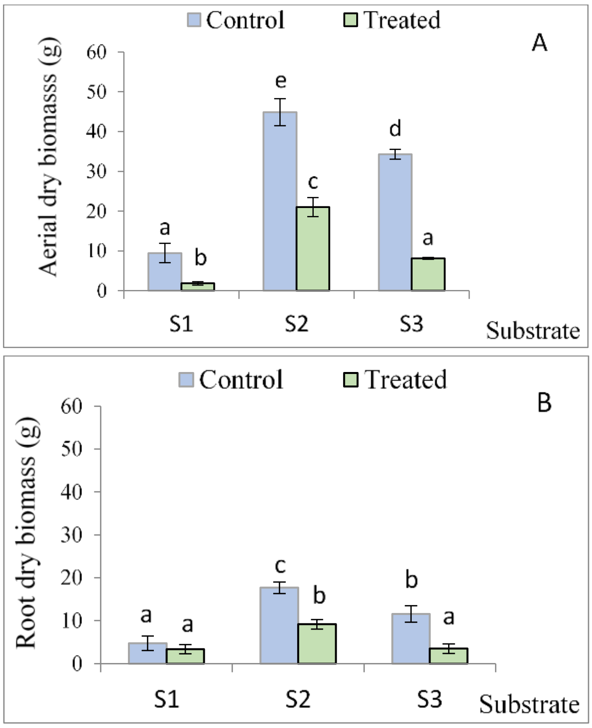

Fig. 8: Variation of aerial (A) and root (B) dry biomass of *Vicia faba* L. plants, at the end of drought stress; Different letters denote significant differences (Tukey test P<0.05)

Collar diameter

Collar diameter evolution of plants varies according to drought stress and culture substrate type (Fig. 5). Under control conditions, substrate 2 shows a maximum collar growth of 3.78 ± 0.53 cm. This value drops to 3.03 ± 0.15 cm in substrate 3 and reaches 1.6 ± 0.25 cm in substrate 1. A significant positive correlation is recorded between the substrate and the diameter of the collar (r = 0.456, Table 3).

Drought stress did not affect the collar diameter of substrate 1 plants (sand), but significantly reduced that of plants cultivated on substrates 2 and 3 from 27.78% to 40% respectively. This result is translated by highly significant negative correlation existence between water stress and collar diameter (r=-0.543, Table 3).

Stem ramifications number

The effects of substrate and water deficit on the number of branches of faba bean plants are presented in Fig.6 and 7. The substrate 1 is the least favorable medium for the development of the plants under all watering conditions. The average number of ramifications of the stem

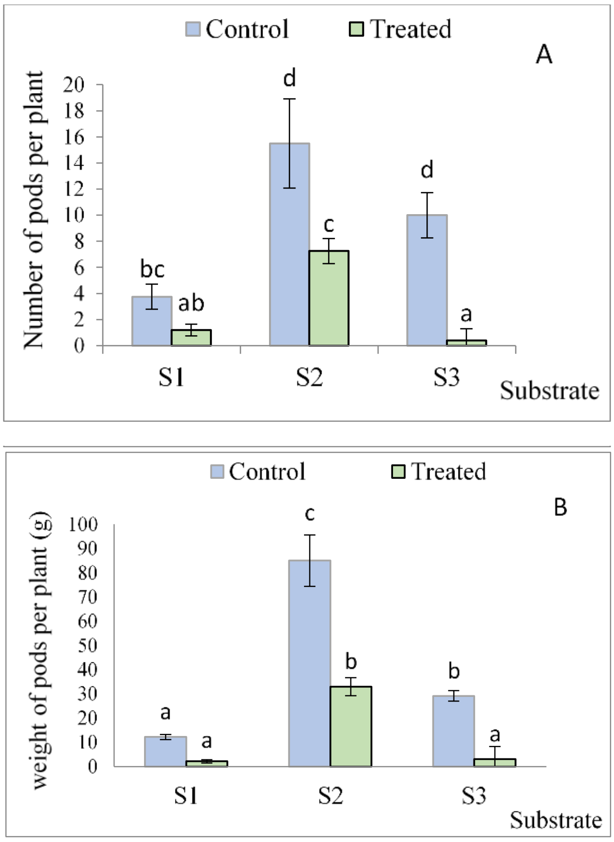

Fig. 9: Number (A) and weight (B) of pods per plant at the end of drought stress; Different letters denote significant differences (Tukey test P<0.05)

Fig. 10: Pods yield of control (left) and stressed (right) plants of *Vicia faba* L., harvested from S1, S2 and S3 substrates, after 13 weeks of water stress.

is near to unity. The plants of substrates 2 and 3 are more branched and come first with five branches under well-watered conditions. During stress, this number decreases and reaches four. A highly significant positive correlation is recorded between the substrate and stem ramification number (r=0.814, Table 3).

Effect of substrate and drought stress on aerial and root dry biomass (Fig. 8, A and B)

Drought stress significantly reduced aerial dry biomass of all faba bean plants (Fig. 8 A) compared to control. This reduction is all the more important as the culture medium is poor in hydrophilic elements retaining water. The highest decrease was observed in substrate 1 (80.36%) and the lowest in substrate 2 (53%). A highly significant positive correlations are recorded on the one hand between the aerial dry biomass and the RWC (r= 0.856) and on the other hand between the aerial dry biomass and stem ramification number (r=0.835) (Table3). The plants more branched are those which produce more dry matter favored mainly by a good water supply.

The effect of drought stress on root dry biomass is shown in Fig.8 B. In unstressed plants, the highest value of root dry mass was recorded in substrate 2 (17.65 g ± 1.31). In contrast, the lowest value was noted in substrate 1 (4.73g ± 1.66). Drought stress significantly reduced the root dry biomass of all plants. This reduction is very clear for the substrate 3 (sandy-clay) plants, which recorded the highest percentage of damage (70%) compared to control. On the substrate 1 (sand), the values recorded did not differ significantly compared to control; a difference of 29.39% was noted. On peat (substrate 2), drought stress reduced root dry biomass by 48%. However, it realized that this dry matter remains the most important. A significant negative correlation is recorded between root dry biomass and drought stress (r=-0.537, Table 3).

Effect of substrate and drought stress on yield parameters

Figure 9 (A and B) shows variations in number and weight of pods per plant at the end of the experiment. Under well-watered conditions, plants in substrate 2 develop well and are the most productive with an average pod count of 15.5 ± 3.42. Drought stress causes a decrease in this parameter in all substrates. However, the highest mean number was found in plants of substrate 2 with 7.25 ± 0.96 and the lowest in plants of substrate 3 with 0.4 ± 0.08.

The mean pod weight per plant followed the same trend as the mean pods number per plant (Fig. 9 B and Fig. 10). Substrate 2 has large pods; it comes first with the highest weight as well for the controls (84.98g ± 10.60) as for the drought-stressed (32.93g ±3.71) plants. The existence of highly significant positive correlations between different parameters: the water content, growth and yield in plants implies that in these plants the height, the collar diameter, the aerial vegetative part, the underground root part are closely linked and interact with each other for the harmonious development of the plant while influencing the yield pods yield (Tab. 3).

DISCUSSION

The study of the combined effect of water stress and culture substrate on some morphological and physiological parameters (water retention, growth and yield of pods) of bean seedlings (*Vicia faba* L.) showed a variable response.

The plants water content evolution on three culture substrates shows a greater plant capacity to mobilize water in the culture substrates rich in organic matter and clay compared to the sandy substrate. Indeed, under control conditions, substrates 2 and 3 maintained the highest values of the RWC. This could be explained on the one hand by the hydrophilic character of organic matter, which contributes to enriching the soil with water and subsequently to increase its resistance to drought (Demolon, 1968 ; Citeau *et al*., 2008) and on the other hand, by the presence of a clay fraction which is characterized by several physicochemical properties which give it a high adsorption capacity thanks to the large surface area, high cation exchange capacity and the ability to trap water molecules (Yukselen and Kaya, 2008). This is in agreement with the results of Benkhelifa and Daoud (1998) which showed that bentonite (clay) improves the water retention capacity when applied to a sandy soil, this increase becomes important from 10% of bentonite. Our results also reveal that the leaves of the control plants on the culture substrate 1 (sand) show a significant decrease in their relative water content compared to the previous substrates. These results can be attributed to the texture of the soil containing coarse particles engendering to very rapid drainage, therefore a small amount of water is retained by the substrate which will be made available to the roots (Koffi *et al*., 2013). Huber and de Parcevaux, (2007) admit that the range of soil moisture that can be used by plants or useful reserve is about 2 millimeters of water (2 l. m^{-2} or 20 m^3. ha^{-1}) for 1 centimeter thick loamy soil. This value will fall to 0.7 millimeters per centimeter or less in sandy soil. It can be twice as high in very clay soil.

However, the results obtained show that water stress does not seem to affect the water content of plants in the same way. The plants of the substrate 3 (sandy-clay) have varied in behavior with respect to the substrates 1 and 2, this attitude being expressed by a significant drop in the water content. This is in agreement with the results obtained by (Abid *et al*., (2017) on faba bean cultivars under water stress. Huber and de Parcevaux, (2007) state that the more percentage of fine elements in a soil increases, the more its capacity for water retention increases, and the more its wilting point rises. If the soil reaches its wilting point, the plant can no longer absorb water from the soil which implies wilting and plant death. On soil containing clay, moisture values at the wilting point range between 6% on loam- clay- sand and 20% on loam-clay, while for sand, this value does not exceed 2.5% (Duchaufour and *Souchier,* 1979). The RWC of stressed plant leaves of substrates 1 and 2 remain close to that of their respective controls. Numerous studies have shown that organic matter tends to increase water retention, as much to field capacity as to wilting point (Bauer and Black, 1992). Moreover, Durand (2007) and Aqtbouz *et al*., (2016) report that the maintenance of a sufficient quantity of water during a water deficit can delay the closure of stomata and maintain photosynthesis which offers sugars necessary for osmotic adjustment and maintenance of deep roots.

The decrease in vegetative growth is the most characteristic incidence of low water availability. The Results analysis shows a decrease in heights and collar diameters of the plants in the three substrate variants (S1, S2 and S3) under water stress. These data are in agreement with those obtained by Siddiqui *et al*., (2015), revealing a decrease of stem growth of faba bean under drought stress. This reduction in stem height can be explained by a delay in vegetative growth following a decrease in cell divisions induced by a water deficit that prevents the absorption of water by the roots (Oukara *et al*., 2017). According to Bidai *et al*., (2016), the reduction of seedling growth can be linked to a reduction in photosynthetic capacity following a decrease in the stomatal conductance of CO_2 under water stress and the decrease in cell expansion due to the loss of turgor of the cell. Dugo, (2002) stipulate that the drought stress induces a deficiency of mineral nutrition (nitrogen and phosphate) which is mainly due to reductions in the flow of elements towards the roots, which has the consequence a reduction in plant growth. However, this decrease in growth remains low for the plants of the substrate 2 (sand), compared to the other substrates. Indeed, plants that have evolved on a substrate rich in organic matter record the best results in the absence and in the presence of water stress. In the same logic, Diallo *et al*., (2010) state that the height of rice plants increases with organic manure due to improved nitrogen nutrition. Konate *et al*., (2016) have shown that the height growth of okra (*Abelmoschus esculentus*) plant stems is accelerated on the organic manure enriched substrate during all water treatments compared to controls.

Concerning the number of branches, substrate 1 (sand) is the least favorable medium for the development of plants under both watering conditions; the mean number of ramifications of the stem remains close to unity. This reduction is attributed to several causes among which the sandy texture which is the primary cause of the damage; it is poor in organic matter, light, very filtering, very dry and whose mineral fixing capacities are relatively weak. Thus, the plants are struggling to develop (Duchaufour, 1984). The plants of the substrates (2 and 3) react differently; they are more branched and have a large aboveground biomass favored mainly by a good water supply. However, it would be interesting to emphasize that the reduction in height growth, collar diameter and number of branches that characterized the plants of the sandy substrate 1 would constitute an abiotic stress adaptation strategy. It allows plants to reduce energy and resource expenditure and thus avoid stress (Diallo *et al*., 2016).

On the other hand, the aerial and root dry biomass evaluation made it possible to deduce that all seedlings, regardless of the type of growing medium, respond to water stress by reducing these parameters. Similar results have been published by authors such as Shahbaz *et al*., (2010) and Belfakih *et al*., (2013) who argue that stem and root biomass production is negatively affected by increased osmotic stress. It should be remembered that the plants of substrate 2, characterized by vigorous roots, gave the best yields of aerial dry matter under different conditions. This is statistically translated by the existence of a highly significant positive correlation between aerial dry biomass and dry root biomass (r = 0.959). To this end, Ganry and Thuriès, (2010) show that the organic matter brought to the soil promotes the drought resistance of plants. The more the vegetable matter is humified, the more it retains water. At the plant level, Ganry and Guiraud (1979) specify that organic matter has a double action: on the one hand, it increases the porosity of the soil and promotes rooting (physical action) and on the other hand, it releases growth factors and increases the absorption and cell permeability (biochemical action). Flaig *et al*., (1976) indicate clearly a physiological influence of the active substances resulting from the organic matter and the humus (in particular phenols and quinones) all the more important that the environmental conditions (humidity first) middle-sol deviate from their optimum. Davet (1996) explains that the absorption of phenolic substances modifies the metabolism of the plant; it induces the formation of reducing sugars in the plant; consequently, the osmotic pressure increases, which induces greater resistance to the dryness of the plant. Ozores-Hampton *et al*., (2011) showed that organic amendments significantly increased (35%) soil moisture to field capacity.

The results obtained on the sandy substrate showed that the production of aerial biomass is more affected by water stress than that of the roots (80.36% for the aerial part and 29.39% for the root part). According to Monneveux and This, (1997), the sustained growth of the root system under water stress conditions is a factor of resistance to water stress. Roots tend to sink deeper into the soil in search of water. Furthermore, Araújo *et al.*, 2015 reveal that plants must limit water loss by transpiration, reduce leaf area and activate the senescence of older leaves to invest in the organs of absorption and maximize the absorption of water. In this sense, De Souza and Da Silva (1987) show that the dry weight ratio of the root to that of the aerial part (RDW/ADW) tends to increase under severe stress where the plant will promote the growth of the root to better exploit the soil in search of water.

Compared with previous substrates, substrate 3 (sandy-clay) seems to be the most affected by water stress. The dry biomass production of the aerial and root parts is considerably reduced (76.35% for aerial dry biomass and 70% for root dry biomass). These results can be attributed to soil texture containing a high percentage of clay which in the dry state develops a strong suction tension for water that can oppose that of plant roots. In this sense, Halitim *et al.*, (2016) report that the easily usable reserve is all the weaker as the drying of the soil is intense, that the soil has a fine texture and that the pore size is small.

The imposition of water stress on different substrates from the vegetative stage to the pod formation stage caused a significant reduction in the number and weight of pods for faba bean plants. Similar results are obtained in several legume species such as, the bean (Mouhouche, 1998), chickpea (Singh *et al.*, 1987), cowpea (Suliman and Ahmed, 2010), lentil (Idrissi *et al.*, 2012). The decrease in the number and weight of capsules under water stress could be explained by the concomitant decrease in plant size, branching numbers and flower drop (Son *et al.*, 2011). However, Substrate 2 plants have the best results during all water treatments compared to other substrates because they are on a soil rich in organic matter that holds not only the nutrients but also the water that can be taken by plants (Van Duijvenbodden, 1998).

CONCLUSION

This study showed the close bond between the culture substrates and the water supply conditions, translated by variable effects on the physiological behavior of the bean plants *Vicia faba* L.

In the peat (substrate 2), the plants grow well and reach a maximum growth translated by a good yield of pods compared to other cultivation substrates. This can be explained by the richness of organic matter in hydrophilic substances retaining several times its weight in water and its ability to fix ions. All the mechanisms of the rhizosphere supply as well as the transfers of the mineral elements in the plant are thus facilitated. However, this aspect is more important in conditions of favorable water supply than in crops less well supplied with water, probably resulting from the reduced effect of organic matter on the retention of water at low potentials.

The culture in the sand (substrate 1) is interesting under water stress thanks to its very filtering and very light texture which allows the roots to sink deep to better exploit the soil in search of water. However, its low organic matter content and low water holding capacity result in low mineral retention capacity and low cation exchange capacity, making it unfavorable to agricultural production unless if a clay amendment at appropriate doses is made. However, its low organic matter content and low water retention capacity result in low mineral retention capacity and low cation exchange capacity, which makes it unfavorable for agricultural production unless an amendment of clay at appropriate doses is performed.

In soil (sandy-clay), the results show that the fraction of the clay that composes substrate 3 significantly improved water retention, growth, and plant yield in the absence of water stress. This results from the presence of fine particles that play an important role in the fixation of water molecules, thanks to their hydrophilic properties, and in plant nutrition because of their electronegative action. Nevertheless, when the clay dries out, it develops an important suction tension for the water which can oppose that of the roots of the plants. Nevertheless, when the clay dries out, it develops a significant suction tension for the water which can oppose that of the roots of the plants.

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