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Responses of Physiological Traits of Two un-or Mycorrhizal Leguminous Plants [*Tephrosia vogelii* Hook F. *and Vigna subterranean* (L.) Verdcourt] Under Drought Stress at an Early Growth Phase

Esaïe TSOATA[1], siméon Raphaël Njock [2], Youmbi Emmanuel[3], Dieudonné Nwaga[4]

1,2,3 Department of Plant Biology, Faculty of Science, University of Yaoundé 1, PO Box 812 Yaoundé, Cameroon
4 Department of Microbiology, Faculty of Science, University of Yaoundé 1, PO Box 812 Yaoundé, Cameroon

Abstract

Physiological traits of un-or mycorrhizal *Tephrosia vogelii* and *Vigna subterranea* was evaluated in glasshouse under natural light. Completely randomized block design with three factors: two leguminous species, two treatments, four water stress levels were used. Parameters evaluated after 31 days of water stress are: relative water content, hydration degree, water use efficiency, water stress resistance index, plant water content and plant water use. Results obtained show that mycorhization of plants, improves almost all physiological parameters studied in drought condition. The mycorrhizea thank to its multiple beneficial functions for host plants, allows the two species to maintain their water status, to better tolerate water constraint and to function as in well watered condition. The arbuscular mycorrhizal fungi would be thus a material of choice to mitigate negative effects of water stress on crops, to boost agricultural production and consequently consolidate food safety in area where water is scare.

Key words: *Arbuscular mycorrhizal fungi (AMF), water stress, physiological traits, early stage, symbiosis*

1. Introduction

Stress is regarded as a life situation which deviates significantly of the normal conditions of life (Larcher, 2003). Water stress is one of the environmental constraints most significant, affecting the outputs of agricultural everywhere in the world (Boyer, 1982;Wang and al., 2003; Al-Karaki et al., 2004; Araus and al., 2008; Shahbaz and al., 2011; Hamrouni and al., 2012; Tsoata and al., 2015). Areas where this stress prevails account for 36% of the emerged grounds (Nouaim and Chaussod, 1996). Water stress is prevalent particularly in zones where water is scare, arid and semi-arid regions (Al-Karaki et al., 2004) and represents the major cause of the loss of more than 50% of the output of plants in world (Wang and al., 2003). Moreover 1/3 of arable lands in the world are touched by frequent and unforeseeable conditions of dryness, allotted to the total climatic adjustment. Recent forecasts indicate that the annual and total average temperature on earth surface will increase by 1.7 to 3.8°C from here to years 2100 (Sun and al., 2011). Such increases in temperature could compromise the agricultural production radically and act negatively on food safety.

Effects of total climatic warming affect all the areas of the world, but the developing countries seem more predisposed because many of them are in arid or semi-arid regions where the cultivable lands are already marginal, vulnerable to the annual climatic fluctuations (Bavec & Mlakar, 2002) and population pressure on the arable lands is already strong (Moran & Showeler, 2005). Water deficit reduces leaves water potential, water use efficiency and consequently decreases leaf stomatal conductance, leaf area, roots biomass and plants total biomass (Schneider et al., 1993).The increase in plants productivity in water deficit condition requires a comprehension of physiological mechanisms by which this stress affects plants growth (Prabawardani et al., 2012).

Several methods were used to mitigate effect of water stress on plants growth and thus to improve their output in drought stress condition (Dixon and al., 1993; Hu and al., 2010; Sassi and al., 2010; Aown and al., 2012; Kassap and al., 2012; Kadian and al., 2013; Hussain and al., 2013; Abdelmoneim and al., 2014; Shabbir and al., 2015); among them, the use of AMF biofertilizers (Dixon and al., 1993; Sassi and al., 2010; Kadian and al., 2013; Abdelmoneim and al., 2014). Mycorrhizae formed by the AMF on roots of some plants permits them to gain several advantages: (i) increase in resistance/tolerance to abiotic stresses (Parabawardani and al., 2012; Tsoata et al., 2015; Habibzadeh and Abedi, 2014; Mawardi and Djasuli, 2006), including water stress (Hapsoh and al., 2006); (ii) improvement of the absorption of nutrients (Mawardi and Djasuli, 2006). Nevertheless, under well watered conditions, the effectiveness of mycorrhizal symbiosis depends on the implied fungi species (Zézé and al., 2007), but especially on the genotype of the plant concerned (herbaceous, shrub or tree). It is then useful to intensify research on stressed plants physiology, because AMF are ubiquists in the environment.

Leguminous plants in general are plants having significant potential on several areas: economic (Westphal and al., 1985), commercial (Bertrand, 2009), agricultural (Akédrin, 2010; Thiébeau and al., 2010), food (Vance and al., 2000; Duke, 1981; Visitpanich and al., 1985a; Anonyme, 2013), Medicinal (El-Sohaimy, 2012; Makoshi and Arowolo, 2011; Bahadoran and Mirmiran, 2015; Tsoata et al., 2015), attenuation of the effects of climatic change (Jensen and al., 2012). Considering significant services rendered to living things and environment, Jensen et al. (2012), think that leguminous plants could be regarded as significant components in the development of futures agroecosystems. *T. vogelii* which is shrubby perennial leguminous plants, exploited primarily to enrich fallow, poor and degraded soils and also as firewood and insecticidal plant (Makoshi and Arowolo, 2011; Tsoata et al., 2015). *V subterranea* is a herbaceous papilionaceae cultivated for its seeds (Hillocks and al., 2012) and used in various rotations with cultivated gramineae (Ncube and Twomlow, 2007; Tsoata et al., 2015).

Research related to the physiology of *T. vogelii* and *V. subterranea* in water stress condition is scare, particularly those bearing on their first development stages. Therefore it is pressing need to intensify studies aiming to unveil plants behavior under water stress and highlight measures of attenuation of negative impact of this abiotic stress on crops yield. The goal of this experimentation was to evaluate the physiological response of un-or mycorrhizal *T. vogelii* and *V. subterranea* according to increasing levels of water stress.

2. Material and methods

2.1. Plant material

Seeds of *T. vogelii* and *V. subterranea* selected, sterilized, germinated, are transferred in pots of development placed in glasshouse, according to an experimental design block randomized with three factors (i) two leguminous plant species; (ii) two treatments [un-and inoculated (iii) four levels of water stress according to field capacity of culture substrate: control (zero stress), soft, average, severe stress and five replicates (Tsoata and al., 2015).

2.2. Measured parameters

Relative water content of leaves (RWC in %): The state of turgidity is estimated by the calculation of RWC: Eq. (1) (Clarck and Mac-Caig, 1982), which represent the fraction of turgid weight that remaining in the tissue. Leaves are cut and weighed immediately to obtain their fresh weight (FW), put thereafter in test tubes filled with distilled water and placed in darkness. After 24 h, leaves are withdrawn, surface dry, then weighed again to obtain the fresh weight at full turgidity (FWT).The samples are finally oven dry 48 h at 80 °C and weighed to have their dry weight (DW).

$$\text{RWC (\%)}=(\text{FW-DW/FWT-DW}).100 \qquad (1)$$

Hydration degree (H° in %): H° is the quantity of water present in a tissue (El Jaafari et al., 1993). It is determined using Eq. (2).

$$H° = 100 - 100\ (DW/FW) \qquad (2)$$

With (DW = dry weight, FW = fresh weight).

Water use efficiency (WUE): WUE is calculated using Eq. (3) (Anyia and Herzog, 2004; Monclus and al., 2006).

$$WUE=PTDM/WU \qquad (3)$$

Where WUE: water use efficiency; PTDM: plant total dry mass (g); WU: water used (ml).

Water stress resistance index (WSRI): WSRI is calculated with Eq. (4) Fisher and Maurer (1978).

WSRI = TDWSP / TDWNSP (4)

Where TDWSP: total dry weight of stressed plant; TDWNSP: total dry weight of not stressed plant.

Plant water content (PWC in g of water/ g DW): PWC is obtained with Eq. (5) below (Bajji et al., 2001).

PWC= (PFW-PDW)/PDW (5)

Where PWC= **plant water content (g)** PFW = plant fresh weight and PDW = plant dry weight)

Plant water used (PWU in ml): PWU is evaluated by the difference between the total quantity of water lost in each pot and the average quantity of water evaporated by substrate (Guissou and al., 2001).

2.3. Data analyses

Data are treated statistically by the procedure of ANOVA using SPSS 18.0 software. The comparison of means is carried out using the test of Duncan, with an experimental error of 5 %).The means are compared according to the irrigation level within each treatment (un-or mycorrhizal), then between treatments having received mycorrhizal inoculum and control according to the level of water supply.

3. Results

3.1 Relative water content

RWC of *T. vogelii* is always lower than that of *V. subterranea*, whatever the level of water stress or mycorhization (Fig. 1A), it decreases in leaves with the increase in level of water stress for the two species, un-or mycorrhizal. For *T. vogelii* the decline of RWC is significant ($P < 0.05$) for all the levels of water stress and for un-or mycorrhizal seedlings. The fall is not significant for soft, average stress and soft and control, respectively for unmycorrhizal and mycorrhizal seedlings of the two species. The reduction is significantly high for *T. vogelii* compared to *V. subterranea*. When level of stress increases, the inhibition is 7-69 % and 17-63 % for *T. vogelii*; 9-40 % and 10-37 % for *V. subterranea* respectively for unmycorrhizal or mycorrhizal seedlings. However mycorhization improved RWC of the two species; the stimulation is significant for *T. vogelii*: 15, 5, 25 and 27 % respectively for control, soft, average and severe stress, compared with *V. subterranea*: 1, 7, 6 and 5 % respectively for the same stress levels. The correlation between root colonization (RC) and RWC for *T. vogelii* (r_{Tv}) and *V. subterranea* (r_{Vs}) exhibits following correlation coefficients: r_{Tv} = 0.585 ** and r_{Vs} = 0.231, unveiling a more significant effect of the AMF on this parameter for *T. vogelii* (Table 1 and 2). Thus, the mycorhization improves RWC of water stressed plants.

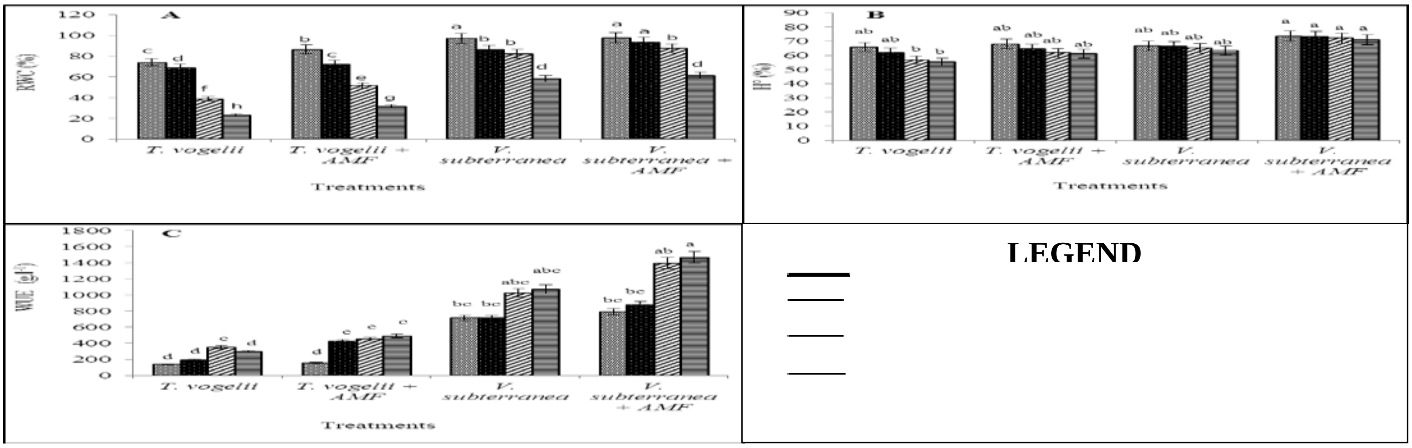

Fig. 1 Relative water content: RWC (A); Hydration degree: H° (B); Water use efficiency: WUE (C) of mycorrhizal and unmycorhizal *T. vogelii* and *V.*

Table 1. Pearson correlation of evaluated parameters of *T. vogelii*: Root colonization (RC); water used efficiency (WUE); water relative content (RWC); plant water content (PWC) and plant water used (PWU).

	RC	WUE	RWC	PWC	PWU	H°
RC	1	-0.255	0.585**	0.176	0.422**	0.213
WUE		1	-0.341*	-0.288	-0.626**	-0.285
RWC			1	0.310	0.538**	0.330*
PWC				1	0.218	0.709**
PWU					1	0.271
H°						1

Note: * significant effect at 5 %, ** significant effect at 1 %

Tableau 2. Pearson correlation of evaluated parameters of *V. subterranea*: Root colonization (RC); water used efficiency (WUE); water relative content (RWC); plant water content (PWC) and plant water used (PWU).

	RC	WUE	RWC	PWC	PWU	H°
RC	1	-0.023	0.231	0.477**	0.302	0.309
WUE		1	-0.102	-0.166	-0.528**	-0.165
RWC			1	0.115	0.375*	0.075
PWC				1	0.055	0.52**
PWU					1	0.271
H°						1

Note: * significant effect at 5 %, ** significant effect at 1 %.

3.2 Hydration degree

The H° of *V. subterranea* leaves is always higher than that of *T. vogelii* whatever the level of stress for unmycorrhizal or mycorrhizal seedlings. It decreases independently of mycorhization when water stress level increases for the two species. This relatively weak reduction is not significant for *V. subterranea* compared to *T. vogelii*. This inhibition for the soft, average and severe stress is not significant ($p < 0.05$) for *V. subterranea*: 0.5; 2.4; 5.0 % and 0.4; 2.0; 3.5 % respectively for unmycorrhizal and mycorrhizal seedlings. For *T. vogelii*, the fall for the same levels of stress: 6, 14, 16 % and 5, 9, 10 % respectively for unmycorrhizal and mycorrhizal seedlings, is significant compared to control only for average and severe stress. However, for *T. vogelii* and for levels of stress: control, soft, average and severe, mycorhization increased H° of: 3, 4, 8 and 9 %, the increment being not significant ($p < 0.05$) for average and severe stress; for *V. subterranea* and according to same levels of stress, it significantly improved H° of 9, 9, 10 and 11 %. The correlation coefficients of r_{Tv} = 0.213 and r_{Vs} = 0.309 (Table 1 and 2) obtained between RC and H° show that AMF have definitely positive effect on the improvement of H° of two leguminous plants studied in drought stress conditions (Fig. 1B).

3.3 Water use efficiency

WUE of *V. subterranea* is always higher than that of *T. vogelii* independently of the level of stress and mycorhization (Fig. 1C) and increases with the increase in level of water stress for the two species. Increase in WUE for stress levels: blank, soft, average and severe is: 40, 156, 116 % and 174, 190, 216 % respectively for unmycorrhizal and mycorrhizal seedlings of *T. vogelii*; 0, 44, 50 % and 11, 76, 85 % for same stress levels respectively for the seedlings of unmycorrhizal and mycorrhizal *V. subterranea*. *T. vogelii* records the most significant increases compared to *V. subterranea* in water stress conditions. Under water stress mycorhization of seedlings improves WUE for stress levels: blank, soft, average and severe, of 13, 121, 28, 66 % and 11, 23, 36, 37 % respectively for *T. vogelii* and *V. subterranea*. The improvement is increasingly more significant for *T. vogelii* compared to *V. subterranea*. If for *V. subterranea* increase grows with level of stress, for *T. vogelii* the most significant increase is observed for soft stress. The correlation coefficients of $r_{Tv} = -0.255$ and $r_{Vs} = -0.023$ between RC and WUE (Table 1 and 2) show in this case that evolution of root colonization is inversely proportional to the improvement of WUE of the two Leguminous plants. Thus a reduction in RC in drought conditions drops WUE.

3.4 water stress resistance index

The WSRI (Fig. 2A) for the two species studied is lower than one and decreases independently of the mycorhization when level of water stress increases. The WSRI of *T. vogelii* and *V. subterranea* mycorrhizal or not are not significantly different for soft water stress, like for severe water stress for *T. vogelii*. Significant differences ($p < 0.05$) are noticed for average stress for the two species mycorrhizal or not and for *V. subterranea* for severe stress. The mycorhization slightly improves the WSRI for the two species; *V. subterranea* presents weak WSRI under average and severe water stress compared to *T. vogelii*.

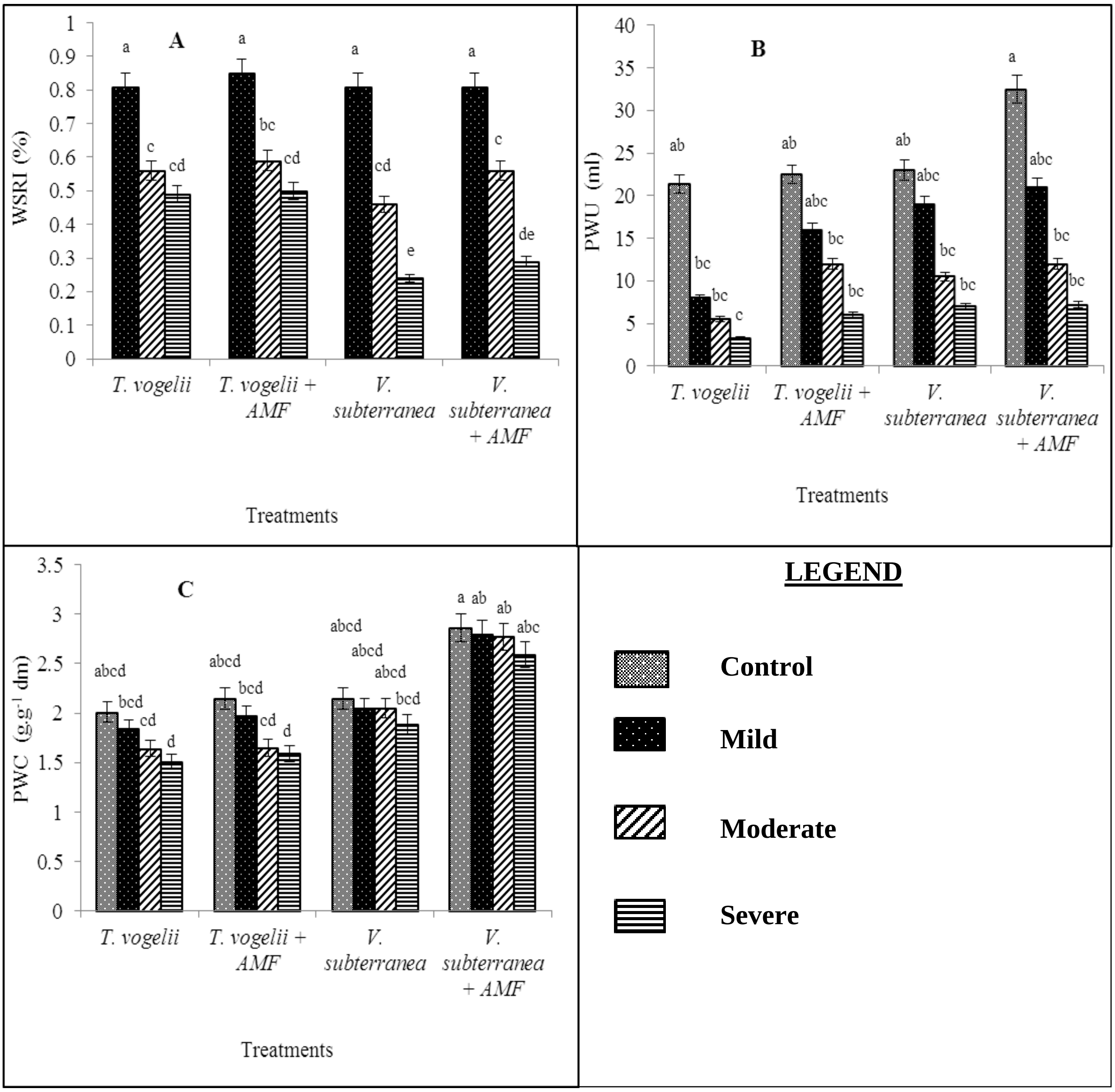

Fig. 2 Water stress resistance index: WSRI (A); plant water used: PWU (B); plant water content: PWC (C) of mycorrhizal and unmycorrhizal *T. vogelii* and *V. subterranea* plants under severe, moderate, mild and well-watered stress.

3.5 Plant water content

The PWC (Fig. 2B) of the two species studied is significantly high for *V. subterranea* compared to *T. vogelii*, except for unmycorrhizal control seedlings. It drops significantly ($p<0.05$) compared to control for the two species mycorrhizal or not when the drought level grows, except *V. subterranea* mycorrhizal or not for soft and average stress. The mycorhization does not significantly improve PWC for *T. vogelii* whatever the water stress on one hand; on the other hand for *V. subterranea*, one notes a significant improvement of this parameter: 33, 37, 35 and 37 % respectively for blank, soft, average and severe stress. The correlation coefficients of r_{Tv} = 0.176 and r_{Vs} = 0.477 ** between RC and PWC (Table 1 and 2) show in this case that the evolution of root colonization is proportional to that of water contents of two leguminous plants. Thus a reduction in RC in water stress conditions may lessen PWC.

3.6 Plant water used

The PWU (Fig. 2C) of the two studied species is significantly high for *V. subterranean* compared to *T. vogelii* whatever the treatment and water stress level, that of mycorrhizal seedlings being increasingly higher. One notes a general fall of PWU when the level of stress raises for the two species whatever the treatment. This reduction is not significant ($p<0.05$) for *T. vogelii* mycorrhizal or not for soft and average stress, and for unmycorrhizal *V. subterranea* for average and severe stress. However the reduction of PWU is significant for *T. vogelii* mycorrhizal or not for severe water stress; whereas for *V. subterranea*, it is significant for unmycorrhizal seedlings only for soft stress and mycorrhizal seedlings for all levels of water stress. The mycorhization improves PWU for the two species and for all levels of water stress; this improvement is: 5, 100, 118, 85 % for *T. vogelii*; 41, 11, 14, 3 % for *V. subterranea* respectively for blank, soft, average and severe stress. The correlation coefficients of r_{Tv} = 0.422** and r_{Vs} = 0.302 between RC and (Table 1 and 2) show in this case that the evolution of root colonization is proportional to that of water use of the two leguminous plants. Thus lessen RC in water stress conditions may impair PWU.

4. Discussion

The RWC or foliar turgidity is a genotypic characteristic of plant enabling him to maintain leaves cells water content, in order to guarantee the continuity of a normal metabolic activity (Auraus and al., 1991 in Bouzerzour and al., 1998; Taiz and Zeiger, 2006). It is for a giving tissue the fraction of turgid weight remaining in it (Chatterjee and Solankey, 2015).The RWC can be regarded as a useful indicator of water balance for a plant as it indicates absolute quantity of water required by the plant to restore its full turgidity (Qariani and al., 2000; Moinuddin and Khanna, 2004; Chatterjee and Solankey, 2015). The maintenance of cellular turgidity and thus high RWC is a physiological feature by which plant manages to express a certain membrane plasticity to avoid plasmolysis. It is an effective mean to tolerate water stress, through raise of osmotic potential, thanks to accumulation of osmolyte in the cytoplasm (Smirnoff, 1998; Cushman and Bohnert, 2001). Osmoregulation is frequently observed in plants and is regarded as one of adaptive strategies to face effects of water stress (Acevedo and al., 1989). This feature of adaptation can constitute an interesting predictive tool in early selection of tolerant species or genotypes to water stress because dryness resistance of a plant is related to its skill to maintain high leaves RWC in conditions of water stress (Faraloni and al., 2011).
In the present study, the RWC of *T. vogelii* is lower than that of *V. subterranea*; this result is in agreement with those of Mbarek et al. (2011) on *Cicer arietinum*. It may be considered as a genotypic characteristic; RWC raised in water stress conditions are associated with resistance to dryness (Shaw and al., 2002; Nouri, 2002).Thus *V.*

subterranea, herbaceous leguminous plant, would be more tolerant to water stress than *T. vogelii* papilionaceae shrubby. The RWC lessen when water stress level increases for the two studied species. This decline was already observed in several former works (Lizana and al., 2006; Mbarek and al., 2011; Fu and Huang, 2001; Shaw and al., 2002; Toumi and al., 2014; Bahadur and al., 2009 and 2010; Subramanian and al., 2006). This reduction in RWC would be correlated with differences on the level of skill to absorb ground water by these genotypes, skill to control transpiration water losses at the level of stomata, as well as the variability of the amount of osmolyte accumulated for osmotic adjustment of the two species and consequently normal physiological activity (Baraowa and Gogoi, 2016). In the present experiment *V. subterranea* maintained high % of RWC in all the treatments, this would indicate its best capacity of tolerance against the dryness.
The strong inhibition of RWC observed for *T. vogelii* compared to *V. subterranea,* was already noticed for pea genotypes (Upreti and al., 2000) and could be due to the differences in water stress tolerance of the two species. Indeed *T. vogelii* which has a weak RWC would be more sensitive to negatives effects of water deficit (Toumi and al., 2014) than *V. subterranea*. The RWC is improved for the two studied mycorrhizal species. This result is similar to that of Subramanian et al. (2006) on the tomato (*Lycopersicon esculentum)*; Subramanian and Charest (1997) on corn (*Zea mays*); Qiao et al. (2011) on soya (*Glycine max*); Karti et al. (2012) on *Stylosanthes seabrana*. The maintenance of high water statu for inoculated plants could be allotted to the multiple beneficial effects of the mycorhization. Indeed mycorrhizae functions like a bridge ensuring flow of energy and matter, between the plant and the ground (Cardon and Whitbeck, 2007; Naher and al., 2013); it plays several beneficial roles for the plant like: solubilization of phosphates (Panhwar and al., 2009); increase of active absorbing surfaces and stimulation of the absorption of water as well as nutriments, even in water stress conditions (Naher and al., 2009). It confers to the plant host: better tolerance to drought stress (Abdelmoneim and al., 2014); a better exploration of the soil thanks to the mycorrhizosphere (Porcel and Ruiz-Lozano, 2004).
The differences of H° observed for the two studied species independently to treatment and water stress level would be due to the genotypic differences (Auraus and al., 1991 in Bouzerzour and al., 1998); *V. subterranea* which has high H° would be more tolerant to water stress than *T. vogelii* which have low H° in water stress conditions (Shaw and al., 2002).The decline of this parameter observed with the raise of water stress for the two species would be due: to differences in soil water absorption by the two genotypes; to differences in the control of stomata water losses; to different amounts of osmolytes accumulated for the osmotic adjustment (Baraowa and Gogoi, 2016). The improvement of H° for the two mycorrhizal species could be allotted to the mycorhization which increases active absorbing surfaces, stimulates absorption of water and nutrients even in water stress condition (Naher and al., 2009).
A broad variability in WUE was reported between species (Condon and al., 2002). WUE of *V. subterranea* is higher than that of *T. vogelii* whatever the treatment and the level of water stress. For Chartterjee and Solankey (2015), high WUE constitutes a critical characteristic of the tolerant species to dryness. The difference of WUE observed for the two species would be due to their difference in water stress tolerance; *V. subterranea* having high WUE would be more tolerant to drought stress than *T. vogelii* which exhibit weak one. This parameter increases with rise in water stress level for the studied species; similar results were obtained for: corn (Abbate and al., 2004), *Trifolium alexandrinum* (Lazaridou and Koutroubas, 2004), *Pinus ponderosa* and *Artemisia tridentata* (Delucia and al., 1989); alfalfa (*Medicago sativa*) (Lazaridou and al., 2003); tomato (Subramanian and al., 2006); Martin et Stephen (2006).The increment observed under water stress would be correlated with: the stomata closing to reduce transpiration (Lazaridou and Koutroubas, 2004) in one hand, to the fast fall of stomatal conductance with the rise in water deficit in another hand (Delucia and al., 1989; Chaves and al., 2004). However former works announce a reduction in WUE in water stress conditions: Costa et al. (1997) on the potato; Sarr et al. (2001) on niébé (*Vigna unguiculata*); Singh and Singh (2003) on *Dalbergia sisso*; Egilla et al. (2005) on *Hibiscus rosa-sinensis*; Li et al. (2009) on *Sophora davidii*. The tolerant species stabilize WUE, by reducing water losses, but if the growth of the plant is

strongly broken, WUE is significantly reduced (Farooq and al., 2009).

The mycorhization of seedlings of the two studied species improves WUE for all levels of water stress compared to control. This result corroborates those of Subramanian et al. (2006), which noted a significant improvement and increasing of WUE in mycorrhizal tomato plants, with the severity of water stress. However the yield rise under water limited conditions is generally associated to WUE reduction, mainly because water is used in great quantity (Chartterjee and Solankey, 2015). We can therefore think that mycorhization improved the degree of tolerance to drought stress and water status of the species studied in stress condition and consequently, the quantity of water used reduced. For a large number of plant species indeed a reduced water use is associated to high WUE, thus constituting a saving water strategy for plants growing where water is scare (Chartterjee and Solankey, 2015).

The values of WSRI are lower than one and decrease when the level of water stress rise for the two studied species, which show that the total dry biomass of the stressed plants is always higher than that of not stressed one. The water stress inhibits dry matter production of *V. subterranea* and *T. vogelii*, this inhibition is proportional to the level of stress. This result is in agreement with those of former works (Liu and al., 2012; Zokaee-Khosroshahi and al., 2014). This decrement of dry matter production for stressed plants would be the consequence of a considerable lessen of photosynthesis and growth of plant (Shao and al., 2008), inducing consequently the fall of the photosynthetic activity. The difference of WSRI observed for *V. subterranea* and *T. vogelii* would be due to their different sensitivity to this stress. Thus with average and severe water stress *V. subterranea*, presenting weak WSRI would be more sensitive to drought stress than *T. vogelii* which has high WSRI (Fischer and al., 1983). The mycorhization improves the WSRI of the stressed host plants, surely by its multiple beneficial effects like: improvement of water status and tolerance to the stress (Smith and Smith, 2012), enrichment in mineral nutrients (Abdelmoneim and al., 2014) as well as the role of biofertilizer, and can reduces diseases incidence, importance of root diseases through biological processes (Hindumathi and Reddy, 2012; Gao and al., 2012).

The difference of PWC observed between *V. subterranea*, herbaceous plant and *T. vogelii*, woody plant could be due to the fact that water requirements of the two genotypes are different. The PWC drops for the two studied species when the water stress level rise. In previous works, under water stress, a decline of water potential was observed for corn and rice (Siddique and al., 2001), a reduction of 57 % of the total water contents for *Opuntia ficus-indica* (Nerd and Nobel, 1991), a reduction of turgidity potential for *Hibiscus rosa-sinensis* (Egilla and al., 2005). This result could be correlated with the fact that under water stress almost all the plants close their stomata (Cornic and Massacci, 1996) to reduce transpirational water losses (Mansfield and Atkinson, 1990), consequently leaves turgidity and /or water potential fall (Ludlow and Muchow, 1990; Bajji and al., 2001).

The improvement of PWC at the level of mycorrhizal plants for the two species is noted. This result is in agreement with those of Qiao et al. (2011) on soya bean. It could be justified by the capacity of AMF to raise tolerance of plants to water deficit. Indeed plants colonized by the AMF improve active absorbing surfaces, thus contributing to increase the absorption of water and nutrients (Porcel and Ruiz-Lozano, 2004). The improvement of PWC is not significant for mycorrhizal *T. vogelii*; this difference could be due to the fact that the mycorrhizae settles and becomes fully functional for *V. subterranea* faster than for *T. vogelii*.

The PWU are different for the two studied species independently of the level of stress. This difference would be justified by the fact that requirements of water are different for the two genotypes; *V. subterranea* would require more water for its growth and development than *T. vogelii*. The increase of water stress levels, significantly lower PWU for *T. vogelii* and *V. subterranea*. This result is in consistent to those of Li et al. (2009) on *Sophora davidii*; Anyia and Herzog (2004) on *Vigna unguiculata*. This fall would be explained by the reduction in the volume of water in the rhizosphere, because of the various levels of stress applied. The mycorhization improves the PWU of *T. vogelii* and *V. subterranea* in this work. This result is in agreement others works which showed that water consumption increases for mycorrhizal plants (Kothari and al., 1990; Davies and al., 1996; Porcel and Ruiz-Lozano, 2004; Asrar et al., 2012). This increase in the water consumption of the plant host would be due to the increase in their tolerance to water stress, improvement of water and mineral absorption following mycorrhizae establishment (Abdelmoneim and al., 2014).

5. Conclusion

The goal of this work was to study the response to water stress of physiological traits of two leguminous plants un-or mycorrhizal. Results obtained show that mycorhization of the two leguminous plants, improves almost all physiological parameters studied in water stress conditions. Mycorrhizae thanks to its multiple beneficial functions for host plants, allows the two species to maintain their water status, to better tolerate water constraint and to function as in well watered conditions. AMF would be thus considering as choice material to mitigate negative effects of drought stress on crops, in order to booster agricultural production and consequently consolidate food safety everywhere where water is scare.

References

[1] P. E. Abbate, J. L. Dardanellib, M. G. Cantareroc, M. Maturanoc, R. J. M. Melchiorid, E. E. Sueroa, "Climatic and water availability effects on water-use efficiency in wheat", Crop. Sci., Vol. 44, 2004, pp. 474-483.

[2] T. S. Abdelmoneim, A. A. Tarek Moussa, O. A. Almaghrabi, S. Hassan Alzahrani, I. Abdelbagi, "Increasing plant tolerance to drought stress by inoculation with arbuscular mycorrhizal fungi", Life Science Journal, Vol. 11, No. 1, 2014, pp. 10-17.

[3] E. Acevedo, A. Conesa, P. Monneveux, A. Srivastav, "Physiology breeding of winter creats for stressed mediterranean environments", in Colloque July 3-6, Montpellier, France, No. 55, 1989, pp. 449-458.

[4] T. N. Akédrin, K. N'guessan, E. Aké-Assi, & S. Ake , "Effet de Légumineuses herbacées ou subligneuses sur la productivité du maïs", J. of Animal & Plant Sci., Vo. 8, No. 2, 2010, pp. 953-963.

[5] G. B. Al-karaki, McMichael, and J. Zak "Field response of wheat to arbuscular mycorrhizal fungi and drought stress", Mycorrhiza, Vol. 14, 2004, pp. 263-269.

[6] Anonyme, "Année international des légumineuses", Organisation des Nations Unies pour l'Alimentation et l'Agriculture, 2013, p. 4.

[7] A. O. Anyia & H. Herzog, "Water-use efficiency, leaf area and leaf gas exchange of cowpeas under mid-season drought", Eur. J. Agron., Vol. 20, 2004, pp. 237-339.

[8] M. Awon, S. Raza, M. F. Saleem, S. A. Anjum, T. Khalia and M. A. Wahid, "Foliar application of potassium under water deficit conditions improved the growth and yield of wheat (*Triticum aestivum* L.)", J. Anim. Plant Sci., Vol. 22, No. 2, 2012, pp. 431-437.

[9] J. L. Araus, G. A. Slafer, C. Royo, M. D. Serret, "Breeding for yield potential and stress adaptation in cereals", Critical Reviews in Plant Sciences, Vol. 27, 2008, pp. 377-412.

[10] A. A. Asrar, G. M. Abdel-Fattah and K. M. Elhindi, "Improving growth, flowers yield and water relations of snapdragon (*Antirhinum majus* L.) plants grown under well-watered and water-stress conditions using arbuscular mycorrhizal fungi", Photosynthetica, Vol. 50, 2012, pp. 305-316.

[11] Z. Bahadoran and P. Mirmiran, "Potential properties of legumes as important functional foods for management of type 2 diabetes: A short review: Functional Foods and nutraceuticals for management of type 2 diabetes", International Journal of nutrition and Food Sciences, Vol. 4, No. 1-2, 2015, pp. 6-9.

[12] A. Bahadur, K.P. Sing, A. Rai, A. Verma, & M. Rai, "Physiological and yield response of okra (*Albelmoschus esculentus* Moench) to irrigation scheduling and organic mulching", Indian J. Agric. Sci., Vol. 79, 2009, pp. 813-815.

[13] A. Bahadur, R. Kumar, U. Mishra, A. Rai, & M. Singh, "Physiological approaches for screening of tomato genotypes for moisture stress tolerance ", in National Conference of

Plants Physiology(NCPP) BHU, Varanasi during Nov. 25-27, 2010, pp. 142.

[14] M. Bajji, S. Lutts, & J-M. Kinet, "Water deficit effects on solute contribution to osmotic adjustment as a function of leaf ageing in three durum wheat (*Triticum durum* Desf.) cultivars performing differently in arid conditions", Plant Sci., Vol. 160, 2001, pp. 669-681.

[15] B. Baraowa, and N. Gogoi, "Morpho-physiological and yield responses of black gram (*Vigna mungo* L.) and green gram(*Vigna radiata* L.) genotypes under Drought at different growth stages", Research Journal of Recent Sciences, Vol. 5, No. 2, 2016, pp. 43-50.

[16] T. Bavec, & S. G. Mlakar, "Effects of soil and climate condition on emergence of grain *Amaranthus"*, Journal of Agronomy, Vol.17, 2002, pp. 93-103.

[17] G. Bertrand, "Caractéristiques des réponses adaptatives à la contrainte hydrique dans le Sud-Est de l'Amazonie chez trois espèces fourragères cultivées en monoculture et en association: *Brachiarra brizantha*, *Leuceana leucocephala* et *Arachis pintoï*", Thèse Doctorat de Sciences de l'Univers et de l'environnement, Univer. Paris Est, France, 2009.

[18] H. Bouzerzour, A. Djekoune, A. Benmahammed, L. K. Hassous, "Contribution de la biomasse aérienne, de l'indice de récolte et de la précocité à l'épiaison au rendement grain de l'orge (*Hordeum vulgare* L.) en zone semi-aride d'altitude", Cahier d'Agriculture, Vol. 8, 1998, pp. 133-137.

[19] J. S. Boyer, "Plant productivity and environment", Science, Vol. 218, 1982, pp. 443-449.

[20] Z. G. Cardon and J. L. Whitbeck, The rhizosphere, Amsterdam Netherlands: Elsevier Academic Press. 2007.

[21] A. Chatterjee and S. S. Solankey, Functional physiology in drought tolerance of vegetable crops-An approach to mitigate climate change impact Chapter 9, Canada: Apple Academic Press, 2015.

[22] M. M. Chaves, M. M. Oliveira, "Mechanisms underlying plant resilience to water deficits: prospects for water-saving agriculture", J. Exp. Bot., Vol. 55, 2004, pp. 2365-2384.

[23] Clarck and Mac-Caig, "Excised leaf water relation capability and as indicator of drought resistance of *Triticum* genotypes", Can. J. Plant Sci., Vol. 62, 1982, pp. 571-576.

[24] A. G. Condon, R. A. Richards, G. J. Rebetzke, & G. D. Farquhar, "Improving intrinsic water-use efficiency and crop yield", Crop Sci., Vol. 42, 2002, pp. 122-131.

[25] G. Cornic, A. Massacci, "Leaf photosynthesis under drought stress", in: Baker N. R. (Ed.), photosynthesis and Environment, Berlin, Germany: Kluwer Academic Publishers, 1996.

[26] L. D. Costa, G. D. Vedove, G. Gianquinto, R. Giovanardi , A. Perssotti, "Yield, water use efficiency and nitrogen uptake in potato: influence of drought stress", Potato Res., Vol. 40, 1997, pp. 19-34.

[27] J. C. Cushman, "Osmoregulation in plants: implications for agriculture", Amer. Zool., Vol. 41, 2001, pp. 758-769.

[28] F. T. J. R. Davies, S. E. Svenson, J. C. Cole, L. Phavaphutanon, S. A. Duray, V. Olalde-Portugal, C. E. Meier and S. H. Bo, "Non-nutritional stress acclimation of mycorrhizal woody plants exposed to drought", Tree Physiology, Vol. 16, 1996, pp. 985-993.

[29] E. H. DeLucia, and S. A. Heckathorn, "The effect of soil drought on water-use efficiency in a contrasting Great Basin desert and Sierra montane species", Plant Cell Environ., Vol. 12, 1989, pp. 935-940.

[30] R. K. Dixon, V. K. Garg, M. V. Rao, "Inoculation of *Leuceaena* and *Prosopis* seedlings with *Glomus* and *Rhizobium* species in saline soil: rhizosphere relation and seedlings growth", Arid Soil Res. Rehab., Vol. 7, 1993, pp. 133-144.

[31] J. A. Duke, Handbook of legume of world economic importance, New York and London: Plenum Press, 1981.

[32] J. N. Egilla, Jr. F. T. Davies, T. W. Boutton, "Drought stress influences leaf water content, photosynthesis and water-use efficiency of *Hibiscus rosa-sinensis* at three potassium concentrations", Photosynthetica, Vol. 43, 2005, pp. 135-140.

[33] S. El Jaafari, R. Paul, P. Lepoivre, J. Semal et E. Laitat, "Résistance à la sécheresse et réponses à l'acide abscissique : analyse d'une

approche synthétique", Cahiers Agric., Vol. 2, 1993, pp. 256-263.

[34] S. A. El Sohaimy, "Functional foods and nutraceuticals-modern approach to food science", World Appl. Sci. J., Vol. 20, No. 5, 2012, pp. 691-708.

[35] C. I. Faraloni, R. Cutino, A. R. Petruccelli, S. Leva, Lazzeri and G. Torzillo, "Chlorophyll fluorescence technique as a rapid tool for In vitro screening of Olive cultivars (*Olea europaea* L.) Tolerant to drought stress", Environ. Exp. Bot., Vol. 73, 2011, pp. 49-56.

[36] M. Farooq, A. Wahid, N. Kobayashi, D. Fujita, S. M. A. Basra, "Plant drought stress: effects, mechanisms and management", Agron. Sustain. Dev., Vol. 29, 2009, pp. 185-212.

[37] K. S. Fischer, E. C. Johnson, G. O. Edmeades, "Breeding and selection for drought resistance in tropical maize", Centro Internacional de Mejoramiento de Maiz; CIMMYT, El Batan, Mexico, 1983.

[38] R. A. Fisher et R. Maurer, "Drought resistance in spring wheat cultivars. Grain yield responses", Aust. J. Agric. Res., Vol. 29, 1978, pp. 897-903.

[39] J. Fu, B. Huang, "Involvement of antioxydants and lipid peroxidation in the adaptation of two cool-season grasses to localized drought stress", Environ. Exp. Bot., Vol. 45, 2001, pp. 105-114.

[40] X. Gao, X. Lu, M. Wu, H. Zhang, R. Pan, "Co-Inoculation with *Rhizobia* and AMF inhibited soybean red crown root: from field study to plant defense-related gene expression analysis", PLOSONE, Vol.7, No. 3, 2012, pp. 33-97.

[41] T. Guissou, A. M. Ba, C. Plenchette, S. Guinko et R. Duponnois, "Effet des mycorhizes à arbuscules sur la tolérance à un stress hydrique de quatre arbres fruitiers : *Balanites, aegyptiaca* (L.) Del., *Parkia Biglobosa* (Jacq.) Benth., *Tamarindus indica* L. et *Zyziphus mauritania* Lam", Secheresse, Vol. 12, No. 2, 2001, pp. 121-127.

[42] Y. Habibzadeh, and M. Abedi, "The effects of arbuscular mycorrhizal fungi on morphological characteristics and grain yield of Mung bean (*Vigna radiata* L.) plants under water deficit stress", Peak Journal of Agricultural Sciences, Vol. 2, No. 1, 2014, pp. 9-14.

[43] L. Hamrouni, N. Souayah, M. L. khouja, & M. N. Rejeb, "Effect of osmotic stress on *Myrtus communis* germination", Biologia, Vol. 67, No. 1, 2012, pp. 132-136.

[44] S. Hapsoh, T. Yahya, M. H. Oelim, and B. S. Purwoko, "The physiological response of several soybean genotypes to vesicular arbuscular mycorrhizal (VAM) symbiosis with different levels of drought stress", J. Hayati, Vol. 13, No. 2, 2006, pp. 43-48.

[45] R. J. Hillocks, C. Bennett, and M. O. Mponda, "Bambara nut: A review of utilization market potential and crop improvement", African Crop Science Journal, Vol. 20, No. 1, 2012, pp. 1-16.

[46] A. Hindumathi, B. N. Reddy, "Synergistic effect of arbuscular mycorrhizal fungi and *Rhizobium* on the growth and charcoal root of soybean [*Glycine max* (L.) Merr.]", World Journal of Science and Technolog , Vol. 2, No. 7, 2012, pp. 63-70.

[47] L. X. Hu, Z. L. Wang, H. M. Du, B. R. Huang, "Differential accumulation of dehydrins in response to water stress for hybrid and common Bermuda grass genotypes differing in drought tolerance", J. Plant Physiol., Vol. 167, 2010, pp. 103-109.

[48] I. Hussain, R. Ahmad, M. Farooq, A. Wahid, "Seed priming improves the performance of poor quality wheat seed", Int. J. Agric. Biol., Vol. 15, 2013, pp. 1343-1348.

[49] E. S. Jensen, M. B. Peoples, R. M. Boddey, P. M. Gresshoff, H. Hauggaard Nielsen, J. R. A. Bruno, M. J. Morrison, "Legumes for mitigation of climate change and the provision of feedstock for biofuels and biorefineries", Agron. Sustain. Dev., Vol. 32, 2012, pp. 329-364.

[50] N. Kadian, K. Yadav, A. Aggarawal, "Signification of bioinoculants in promoting growth, nutrient uptake and yield of *Cyamopsis tetragonoloba* (L.)"Tub.4" ", Europ. J. Soil Biol., Vol. 58, 2013, pp. 66-72.

[51] P. D. M. H. Karti, D. A. Astuti, and Nofyangtri, "The role of arbuscular mycorrhizal fungi in enhancing productivity, nutritional quality, and drought tolerance

mechanism of *Stylosanthes seabrana*", Media Peternakan, 2012, pp. 67-72.

[52] O. M. Kassab, S. A. Orabi, and A. A. Abo Ellil, "Physiological response to potassium application in six folder Beet plant grown under water stress", Aust. J. Basic & Appl. Sci., Vol. 6, No. 13, 2012, pp. 566-574.

[53] S. K. Kothari, H. Marschner, and E. George, "Effects of VA-mycorrhizal fungi and rhizosphere microorganisms on root and shoot morphology, growth and water relations in maize", New Phytol., Vol. 131, 1990, pp. 17-85.

[54] W. Larcher, Physiological plant ecology: Ecophysiology and stress physiology of functional groups, Berlin Heidelberg, Germany: Springer-Verlag. (4th Ed.), 2003.

[55] M. Lazaridou, A. Kirilov, B. Noitsakis, N. Todorov, I. Katerov, "The effect of water deficit on yield and water use efficiency of Lucerne. Optimal forage systems for animal production and the environment", in Proceedings of the 12th Symposium of the European Grassland Federation, Pleven, Bulgaria , 2003, pp. 26 - 28.

[56] M. Lazaridou, S. D. Koutroubas, "Drought effect on water use efficiency of berseem clover at various growth stages. New directions for a diverse planet", in Proceedings of the 4th International Crop Science Congress, Brisbane, Australia, 2004.

[57] F. L. Li, W. K. Bao, & N. Wu, "Effects of water stress on growth, dry matter allocation and water-use efficiency of a leguminous species, *Sophora davidii*", Agrofor. Syst., Vol. 77, 2009, pp. 193-201.

[58] B. Liu, L. Cheng, F. Ma, Y. Zou, and D. Liang, "Growth, biomass allocation, and water use efficiency of 31 apple cultivars grown under two water regimes", Agrofor. Sys., Vol. 84, No. 2, 2012, pp.117-129.

[59] C. Lizana, M. Wentworth, J. P. Martinez, D. Villegas, R. Meneses, E. H. Murchie, C. Pastenes, B. Lercari, P. Vernieri, P. Horton, and M. Pinto, "Diffferential adaptation of two varieties of common bean to abiotic stress, I. Effects of drought on yield and photosynthesis", Journal of Experimental Botany, Vol. 57, No. 3, 2006, pp. 685-697.

[60] M. M. Ludlow, R. C. Muchow, "A critical evaluation of traits for improving crop yields in water-limited environments", Adv. Agron., Vol. 43, 1990, pp. 107-153.

[61] M. S. Makoshi, & R. O. A. Arowolo, "Therapeutic effects of *Tephrosia vogelii* ointement, in the treatment of bovine dermatophilosis", Journal of Veterinary Medicine and Animal Health, Vol. 3, No. 4, 2011, pp. 51-55.

[62] T. J. Mansfield, and C. J. Atkinson, "Stomatal behavior in water stressed plants", in: Alscher R. G., Cumming J. R. (Eds.), "stress responses in plants: adaptation and acclimation mechanisms", New York: Wiley-Liss, 1990.

[63] P. J. Martin, & W. Stephens, "growth in response to nutrients and moisture on a clay landfill cap soil. II. Water use", Bioresour. Technol., Vol. 97, 2006, pp. 449-458.

[64] Mawardi, and M. Djasuli, "Biological fertilizer utilization of mycorrhizae to increase drought tolerance in Nilam plants", J. Litri., Vol., 12, No. 1, 2006, pp. 38-43.

[65] K. B. Mbarek, M. Boubaker, and T. Mehoichi, "Early tests on tolerant kabuli chickpea (*Cicer arietinum* L.) genotypes selection for drought stress", African Journal of Plant Science, Vol. 5, No. 14, 2011, pp. 794-808.

[66] K. H. M. Moinuddin, R. Khannu-Chopra, "Osmotic adjustment in chickpea in relation to seed yield and yield parameters", Crop Sci., Vol. 44, 2004, pp. 449-455.

[67] R. Monclus, E. Dreyer, M. Villar, F. M. Delmotte, D. Delay, J. M. Petit, C. Barbaroux, D. L. Thiec, C. Bréchet, F. Brignolas, "Impact of drought on productivity and water use efficiency in 29 genotypes of *Populus deltoids* X *Populus nigra*", New Phytol., Vol. 169, 2006, pp. 765-777.

[68] P. J. Moran, & A. T. Showeler, "Response to water deficit and shade stresses in pigweed and their influences on feeding and oviposition by waterhemp", Environmental Entomology, Vol. 34, 2005, pp. 929-939.

[69] U. A. Naher, O. Radziah, Z. H. Shamsuddin, M. S. Halimi, and I. Mohd Razi, "Growth enhancement and root colonization of rice seedlings by *Rhizobium* and *Corynebacterium*

spp, Int. J. Agric. Biol., Vol. 11, 2009, pp. 586-590.

[70] U. A. Naher, R. Othman, and Q. A. Panhwar, "Beneficial effects of mycorrhizal association for crop production in the tropics", Int. J. Agric. Biol., Vol. 15, 2013, pp. 1021-1028.

[71] A. Nerd, P. S. Nobel, "Effects of drought on water relations and nonstructural carbohydrates in cladodes of *Optunia fiscus-indica*", Physiol. Plant., Vol. 81, 1991, pp. 495-500.

[72] B. Ncube, & S. J. Twomlow, "Productivity and residual benefit of grain legumes to sorghum under semi-arid conditions in southwestern Zimbabwe", Plant and Soil, Vol. 299, 2007, pp. 1-15.

[73] R. Nouaïm, et R. Chaussod, "Rôle des mycorhizes dans l'alimentation hydrique et minérale des plantes, notamment des ligneux de zones arides", Cahiers options Méditerranéennes, Séminaire, Vol. 20, 1996, pp. 9-20.

[74] L. Nouri, "Ajustement osmotique et maintien de l'activité photosynthétique chez le blé dur (*Triticum durum*, Desf), en condition de déficit hydrique", Thèse de Magistère en Biologie végétale, Univ. Mentouri, Constantine, Algérie, 2002.

[75] Q. A. Panhwar, O. Radziah, M. Sariah, and I. Mohd Razi, "Solubilization of phosphate forms by phosphate solubilizing bacteria isolated from aerobic rice", Int. J. Agric. Biol., Vol. 11, 2009, pp. 667-673.

[76] R. Porcel, and J. M. Ruiz-Lozano, "Arbuscular mycorrhizal influence on leaf water potential, solute accumulation, and oxidative stress in soybean plants subjected to drought stress", Journal of Experimental Botany, Vol. 55, 2004, pp.1743-1750.

[77] S. Prabawardani, P. D. Wasgito, and L. M. Nouke, "The effectiveness of AM fungal in improving the tolerance of sweet potato plants to drought stress", in International Conference on Agricultural, Environment and Biological Science, 2012, pp. 55-58.

[78] L. Qariani, S. El-Jaafari, M. Dekkaki, J. L. Araus, "Cuticular conductance, water use efficiency and drought tolerance of durum wheat isolines of differing glaucousness in Durum wheat improvement in the Mediterranean region", Zaragoza: CIHEAM-IAMZ; option Méditérranéennes: Série A. Séminaires Mediterraneens, Vol. 40, 2000, pp. 315-318.

[79] Q. Qiao, X. P. Wen, L. F. Yu, and X. B. Ji, "The enhancement of drought tolerance for pigeon pea inoculated by arbuscular mycorrhizae fungi", Plant Soil Environ., Vol. 57, No. 12, 2011, pp. 541-546.

[80] B. Saar, O. Diouf, M. Diouf, H. Roy-Macauley, & C. Brou, "Utilisation de paramètres agronomiques comme critère de résistance à la sécheresse chez trois variétés de niébé cultivées au Sénégal et au Niger", Sécheresse, vol. 12, No. 4, 2001, pp. 259-266.

[81] S. Sassi, S. Ayadi, E. M. Gonzalez, C. Arrese-Tgor, C. Abdelly, "Understanding osmotic stress tolerance in leaves and nodules of two *Phaseolus vulgaris* cultivars with contrasting drought tolerance", Symbiosis, Vol. 52, 2010, pp. 1-10.

[82] J. Schneider, C. A. Widyastuti, and M. Djazuli, "Sweet potato in the Baliem Valley area, Irian Jaya". In A report on collection and study of sweet potato germplasm, April-May 1993. International Potato Center (CIP), ESEAP-Region; Bogor, Indonesia, 1993.

[83] R. N. Shabbir, M. Y. Ashraf, E. A. Waraich, R. Ahmad, and M. Shahbaz, "Combined effects of drought stress and NPK foliar spray on growth, physiological processes and nutrients uptake in wheat", Pak. J. Bot., Vol. 47, No. 4, 2015, pp. 1207-1216.

[84] M. M. Shahbaz, M. Iqbal, and M. Ashraf, "Response of differently adapted populations of blue panic grass (*Panicum antidotale* Retz.) to water deficit conditions", J. Appl. Bot. Food Qual., Vol. 84, No. 2, 2011, pp. 134-141.

[85] H. B. Shao, L. Y. Chu, M. A. Shao, C. Abdul Jaleel, and M. Hong-Mei, "Higher plant antioxidants and redox signaling under environmental stresses", Comp. Rend. Biol., Vol. 331, 2008, pp. 433-441.

[86] B. Shaw, T. H. Thomas, & D. T. Cooke, "Response of sugar beet (*Beta vulgaris* L.) to drought and nutrient deficiency stress", Plant Growth Regulation, Vol. 37, 2002, pp. 77-83.

[87] M. R. B. Siddique, A. Hamid, M. S. Islam, "Stress effects on water relations of wheat",

Bot. Bull. Acad. Sinica, Vol. 41, 2001, pp. 35-39.

[88] B. Singh, & G. Singh, "Biomass partitioning and gas exchange in *Dalbergia sissoo* seedlings", 2003, in A. Slama, M. Ben Salem, M. Ben Naceur, & E. Zid, "Les céréales en Tunisie : production, effet de la sécheresse et mécanismes de résistance", Sécheresse, Vol. 16, No. 3, 2005, pp. 225 -229.

[89] N. Smirnoff, "Plant resistance to environmental stress", Current Opinion in Biotechnology, vol. 9, 1998, pp. 214-219.

[90] S. E. Smith, and F. A. Smith, "Fresh perspectives on the roles of arbuscular mycorrhizal fungi in plant nutrition and growth", Mycologia, Vol. 104, No. 1, 2012, pp. 1-13.

[91] K. S. Subramanian, P. Santhanakrishnan, and P. Balasubramanian, "Responses of field grown tomato plants to arbuscular mycorrhizal fungal colonization under varying intensities of drought stress, Scientia Horticulturae, Vol. 107, 2006, pp. 245-253.

[92] K. S. Subramanian, and C. Charest, "Nutritional, growth and reproductive responses of maize (*Zea mays* L.) to arbuscular mycorrhizal inoculation during and after drought stress at tasseling", Mycorrhiza, Vol. 7, 1997, pp. 25-32.

[93] Y. Sun, X. Du, W. Zhang & R. Li, "Seed germination and physiological characteristic of *Amaranthus* L. under drought stress", Advanced Material Research, Vol. 1071, 2011, pp. 183-185.

[94] L. Taiz, E. Zeiger, Plant physiology, 4th Ed., Sunderland, Massachustts USA:Sinauer Associates Inc, Publishers, 2006.

[95] P. Thiébeau, I. Badenhausser, H. Meiss, V. Bretagnolle, P. Carrère, J. Chagué, A. Decourtye, T. Maleplate, S. Médiène, P. Lecompte, S. Plantureux, & F. Vertès, "Contribution des légumineuses à la biodiversité des paysages ruraux", Innov. Agron., Vol. 11, 2010, pp. 187-204.

[96] M. Toumi, S. Barris, & F. Aid, "Effects of water and osmotic stress on the accumulation of proline and malondialdehyde (MDA) in two varieties of colza (*Brassica napus* L.)", Bulletin de l'Institut Scientifique, Rabat, Section Science de la Vie, Vol. 36, 2014, pp. 17-24.

[97] E. Tsoata, S. R. Njock, E. Youmbi, D. Nwaga, "Effects of water stress on: mycorrhizal root colonization, chlorophyll pigment, number of spore, mycorrhizal dependency and nodules of two leguminous plants (*Tephrosia vogelii* and *Vigna subterranea*) at an early stage of growth", J. Bio. & Env. Sci., Vol. 7, No. 5, 2015, pp. 96-108.

[98] K. K. Upreti, G. S. R. Murti, R. M. Bhatt, "Response of pea cultivars to water stress: changes in morphophysiological characters, endogenous hormones and yield", Veg. Sci. Vol. 27, 2000, pp. 57–61.

[99] C. P. Vance, P. H. Graham, D. L. Allan, "Biological nitrogen fixation. Phosphorous: a critical future need", in F. O. Pedrosa, M. Hungria, M. G. Yates,W. E. Newton, eds, nitrogen fixation: from molecules to crop productivity. Dordrecht, The Netherlands: Kluwer Academic Publishers, 2000.

[100] T. Visitpanich, E. S. Batterham, and B. W. Norton, "Nutritional value of chickpea (*Cicer arictinum*) and pigeon pea (*Cajanus cajan*) meals for growing pigs and rats. 1. Energy content and protein quality", Austral. J. Agrie. Res., Vol. 36, 1985a, pp. 327–335.

[101] W. Wang, B. Vinocur, and A. Altman, "Plant responses to drought, salinity and extreme temperatures: towards genetic engineering for stress tolerance", Planta, Vol. 218, 2003, pp. 1–14.

[102] E. Westphal, J. D. Ferwerda, H. A. E. Van Gils-Meeus, H. J. W. Mustsaers, & J. M. C. Westphal-Stevels, "Cultures vivrières tropicales avec référence spéciale au Cameroun", Wageningen, Netherlands: Pudoc, 1985.

[103] A. Zeghida, R. Amrani, F. Djennadi, R. Ameroun, A. A. Khldoun, & M. Belloucif, "Etude de la variabilité de réponse des plantules de blé dur (*Triticum durum* Desf) à la salinité", Céréaliculture, ITGC, Constantine, Vol. 42, 2004, p. 5.

[104] A. Zézé, C. B. Yao, M. Abelilah, and M. Francis, "Molecular characterization of a mycorrhizal inoculants that enhances *Trifolium alexandrium* resistance under water stress conditions", African Journal of

Biotechnology, Vol. 6, No. 13, 2007, pp. 1524-1528.

[105] M. Zokaee-Khosroshahi, M. Esna-Ashari, A. Ershadi, "Morphological changes in response to drought stress in cultivated and wild Almond species", International Journal of Horticultural Science and Technology, Vol. 1, No. 1, 2014, pp. 79-92.

First Author Biography

TSOATA Esaïe, is graduated from University of Yaoundé 1: BSc (1985) in Botany, "Maîtrise" in Biological Science (1986), "Doctorat 3è Cycle" in plant ecophysiology (1990). He has been working in Cameroon, University of Yaoundé 1, Faculty of Science, Department of Plant Biology, as teacher and researcher since 1991. Ten scientific publication up till now; he is currently interested in effects of drought on crop production and attenuation measures, for sustainable agriculture and adaptation to climate change in Cameroon.

Others authors Biographies

NJOCK Siméon Raphaël, is graduated from University of Yaoundé 1: BSs (2011), MSc (2013), DIPES II (2016) in computer science and instructional technology of Higher Teacher's Training College. He is Ph D student in Faculty of Sciences since 2015.

YOUMBI Emmanuel is graduated from University Bretagne Sud, France HDR (2004) in Biological Science. He has been working in Cameroon, University of Yaoundé 1, Faculty of Science, Department of Plant Biology, as teacher and researcher since 1998.

Nwaga Dieudonné is graduated from University of Rennes I/ENSAR, France, Ph. D (1988) in Biological Science. He has been working in Cameroon, as teacher and researcher, University of Yaoundé 1, Faculty of Science, since 1990, Head of Soil Microbiology laboratory, Biotechnology Centre since 1999. He beneficiates: IITA funding 2003-2006 for biocontrol of Cowpea flower thrips using mycorrhizal/metarhizobium fungi and nitrogen fixing bacteria.