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Research Article

ANALYSIS OF EARLY PHYSIOLOGICAL CRITERIA TO SCREEN FOUR FABACEAE PLANTS FOR THEIR TOLERANCE TO WATER STRESS

Tsoata, E[1]*., Temegne Nono, C[2] and Youmbi, E[3]

[1,2,3]Department of Plant Biology, Faculty of Science, University of Yaoundé 1, Cameroon

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ABSTRACT

Early physiological indicators of Fabaceae plants were studied, in rain shelter, under water stress, in pots, with seedlings having two threeleaflets leaves. Experimental design used was randomized factorial with: four species, four levels of water stress and five replications. Parameters measured after 15 days of water stress, on each species were: relative water content, water stress resistance index, water consumption, water use efficiency, water content and hydration degree. Broadly, results obtained showed that water stress inhibits all parameters for studied plants. These parameters could be used as early indicators and relevant criteria of drought tolerance, useful in varietal selection and like yield improvement parameters in areas victims of water starvation. Results obtained, concerning water status: management and water use efficient, allowed to adduce that *C. cajan* and *T. vogelii* would be more tolerant to water stress than *V. subterranea* and *P. lunatus*.

INTRODUCTION

Growth, development and production of plants, are affected by biotic and abiotic stresses, among which water stress (Rahdari and Hosseini, 2012). Water stress influences greatly plants production (Abdolla and El-Khoshiban, 2007). Lack of water limits agricultural production everywhere in world, in spite of its abundance on the surface of earth: 2/3 of globe surface is covered by water (Baghizadeh and Hajmohammadrezaei, 2011). Water stress determines success or failure of plants establishment in a given habitat (Gamze *et al*, 2005). It is one of major factors, limiting all aspects of growth and crop production in several countries of the world (Ahmad, 2015).

Drought is imposing itself with acuity in many areas of terrestrial globe practicing rainfed agriculture (Passioura, 2007) because of sporadic rains that can stop suddenly during farming period (Tsoata *et al*, 2015a), but also because of total climatic warming (Sun *et al*, 2011). Approximately 36 % of terrestrial surface are classified arid or semi-arid, receiving only 13 to 78 cm of rain per year in period where rains are not significant (Baghizadeh and Hajmohammadrezaei, 2011).

Water stress settles when quantities of water available in soil are reduced and atmospheric conditions favorable to a continuous water loss by evapotranspiration (Khajeh Hosseini *et al*, 2003), but also when absence of rains or irrigation had a sufficient time to lower soil moisture and damage plants (John *et al*, 2011). In humid zone drought occurs after 15 days without rain (Radhari and Hosseini, 2012).

When water is scare, plants change their metabolism to adapt to new conditions of their environment (Baghizadeh and Hajmohammadrezaei, 2011). Young plants growth, is the part of plant life cycle which depends greatly on environmental conditions; Sadeghian and Yavari (2004), showed that drought inhibits growth of sugar beet seedlings and consequently, constitutes a significant constraint in agricultural production (Gamze *et al*, 2005).Thus study of water stress tolerance during early plants growth could allow determination of tolerance limits at this stage of development.

Leguminous plants seem to play significant and multipurpose role (Talukdar, 2013), this role was clarified in previous works (Akedrin *et al*, 2010; Jensen *et al*, 2012, Anonyme, 2013; Bahadoran and Mirmiran, 2015; Tsoata *et al*, 2015a). But their hydrodynamic answers to attenuate or tolerate water stress remain little known (Talukdar, 2013); because ecophysiologic mechanisms induced by water deficit are variable according to plants. Research concerning water stress tolerance of leguminous plants is scare, furthermore those concerning early vegetative growth phase.

However growing of plants tolerant to water stress can constitute a significant means to boost crop yield in drought prone zones (Ennajeh, 2010).This work concerns study of effects of water stress applied during vegetative phase, on some physiological parameters of four Fabaceae leguminous plants.

Corresponding author:* ***Tsoata, E*
Department of Plant Biology, Faculty of Science, University of Yaoundé 1, Cameroon

It is necessary because of huge importance of leguminous plants in society and scarcity of information on their physiological responses in environmental stress conditions.

MATERIALS AND METHODS

Very young seedlings from germination of healthy and disinfected seeds of each specie, are shown in plastic container on river sand regularly humidified until stage two threeleaflets leaves. Then transferred in plastic pots of 3 l, containing a substrate made of ¾ ground and ¼ sand and various levels of water stress are applied immediately.

Experimental design is randomized factorial with: 4 leguminous plants (*C. cajan*, *P. lunatus*, *T. vogelii* and *V. subterranea*); 4 levels of watering: 90(control), 60, 30 and 15 % of field capacity; that is to say 900, 600, 300 and 150 ml of water for 2,4 kg of dry substrate respectively; five replications for each treatment. At the end of water stress period (15 days) following physiological parameters: relative water content (RWC), water stress resistance index (WSRI), water consumption(WCs), water use efficiency (WUE), water contents(WC) and hydration degree (H°) are determined (Tsoata *et al*, 2016a).

Data analysis

Data collected for various parameters are subjected to analysis of variance (ANOVA), and Student Newman-Keuls and Duncan test at 5 % significance level for comparison of averages, thanks to software SAS or SPSS 18.0. The Microsoft Excel software 2007 is used for graphs representation (Tsoata *et al*, 2016a).

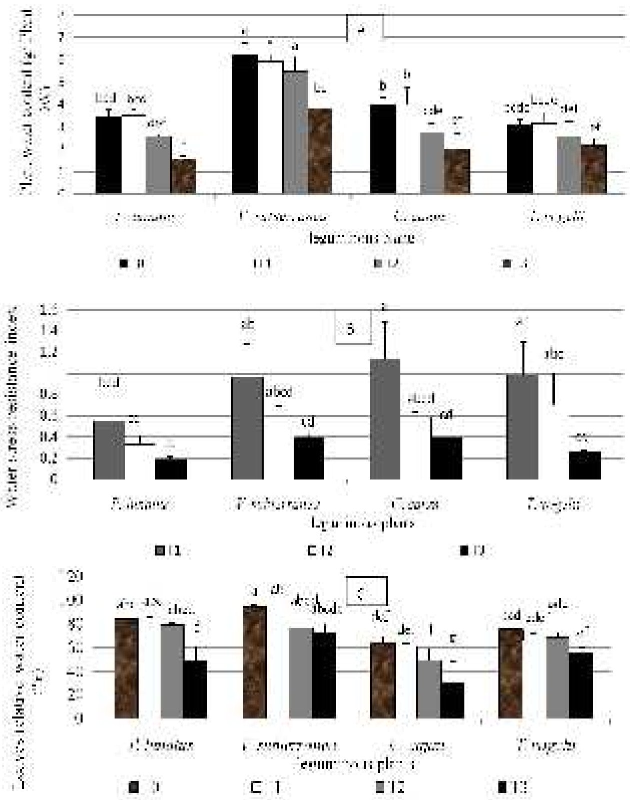

Fig 1 Relative water content (A), water content (B) and water stress resistance index (C) of studied leguminous plants

RESULTS

Relative water content

For controls, *V. subterranean* had highest leaves relative water content (RWC) and *C. cajan* lowest (Fig 1A).With T1, variations of RWC were not significant for *C. cajan* and *P. lunatus*; for *T. vogelii* and *V. subterranea*, RWC was respectively. At T2 and T3, RWC was decreased significantly, this decrement rose with water stress level for all studied species.

Water content

Water content was decreased significantly for studied species when water stress level rose, but this decrement was not significant at T1 for *P. lunatus*, *C. cajan* and *T. vogelii*, for T1 and T2 for *V. subterranea*. At T0, *V. subterranea* had highest water content and *T. vogelii* lowest (Fig 1B). This parameter was lessened significantly at T3 for studied species, this lessening was high for *V. subterranea* and weak for *T. vogelii.*

Water stress resistance index

Water stress resistance index of studied species was relatively weak for *P. lunatus* and high for *C. cajan* despite water stress level. A significant reduction in this index was observed for *V. subterranea*, *C. cajan* and *T. vogelii* in condition of water stress (Fig 1C); for *P. lunatus* decrease was not significant. *Cajanus cajan* had best WSRI at T1 (1.14), followed by *T. vogelii* (0.99) and of *V. subterranea* (0.97). With T2, *T. vogelii* (0.70) had best WSRI.

Water use efficiency and water consumption

Water stress had reduced significantly ($p < 0.05$) compared to T0, water use efficiency for four studied leguminous plants (Table 1). For *C. cajan*, reduction was 26.21 and 48.12 g/l at T1 and T2 respectively. In *P. lunatus*, the decrement of WUE was 49.37 and 232.79 g/l at T1 and T2 respectively. At *T. vogelii*, WUE was decreased of 35.74 g/l at T1 and 163.35 g/l for T2, for *V. subterranea*, it was reduced of 68.07 g/l at T1.

Water stress had reduced significantly ($P < 0.05$) compared to T0, WCs for studied leguminous plant species (Table 1). For *C. cajan*, reduction was 7 ml for T1, T2 and T3; whereas for *P. lunatus*, it was 20 ml for T1, 33 ml for T2 and T3. Water consumption although very low for *C. cajan* was not zero at T3. For *T. vogelii*, water consumption was decreased by 3 ml at T1, 7 ml at T2. *C. cajan* and *T. vogelii* water consumption was less compared to *V. subterranea* and *P. lunatus*.

Hydration degree

Hydration degree was decreased compared to T0 as water stress level increases for *P. lunatus* (Table 2). This reduction in H° for *P. lunatus* was 0.83 % at T1 and 2.35 % at T2, it was not significant; with T3, H° was decreased significantly ($p < 0.05$) by 19.34 %. For *C. cajan*, *T. vogelii* and *V. subterranea*, variations of H° compared to T0 weren't significant.

DISCUSSION

For four studied leguminous plants, water stress involves variation of physiological parameters: RWC, WCs, WUE, WSRI and WC.

Table 1 Water use efficiency and water consumption for studied leguminous plants

Parameters	Treatments	T0 (90 % FC)	T1 (60 % FC)	T2 (30 % FC)	T3 (15 % FC)
Water use efficiency (g/l)	*C. cajan*	94.47± 45.20 abc	68.26 ± 26.57 bcd	46.35± 20.31 bcd	12.91 ±0.10 cd
	P. lunatus	253.29 ±105.13 a	203.92 ± 54.24 ab	46.10 ±20.50 bcd	178.27± 22.51 e
	T. vogelii	196.94± 71.17 ab	161.20 ± 38.68 abc	57.99 ±33.39 bcd	10.27± 9.30 cd
	V. subterranea	116.42±40.64abc	48.35 ± 15.28 bcd	67.66 ±9.39 cd	118.49± 102.14 de
Water consumption (ml)	*C. cajan*	6.67 ± 5.77 bc	0.01 ± 0.01 bcd	0.01 ± 0.01 bcd	0.01 ± 0.00 bcd
	P. lunatus	33.33 ± 11.55 a	13.33 ± 5.77 b	0.01 ± 0.00 bcd	5.77 ± 3.33bcd
	T. vogelii	6.67 ± 5.77 bc	5.77 ± 3.33 bcd	0.01 ± 0.01 bcd	13.33 ± 5.77 d
	V. subterranea	10.00 ± 10.00 bc	5.77 ± 3.33 bcd	11.55± 6.67 cd	0.01 ± 0.00 bcd

Values follow by same letter on one line are not significant at $p < 0.05$ %.

Table 2 Hydration degree of studied leguminous plants

Species \ Treatments	T0 (90 % FC)	T1 (60 % FC)	T2 (30 % FC)	T3 (15 % FC)
C. cajan	66.93 ± 1.37 b	69.39 ± 0.66 b	64.67 ± 3.78 b	63.61±5.91 b
P. lunatus	82.45 ± 1.33 a	81.62 ± 0.80 a	80.10 ± 1.11 a	63.11± 8.75 b
T. vogelii	70.36 ± 1.77 b	72.07 ± 2.53 b	70.29 ± 0.95 b	66.17 ± 2.67 b
V. subterranea	80.79 ± 0.71 a	79.25 ± 0.91 a	77.74 ± 1.14a	76.23 ± 3.33 a

Values follow by same letter on one line are not significant at $p < 0.05$ %.

Water is important for plants growth, particularly in arid and semi arid areas. Water starvation induced in stressed plants reduction in RWC (Albouchi *et al*, 2000). Clavel *et al* (2005) observed it on groundnut; Li *et al* (2009) on *S. davidii*.

Water content of durum wheat leaves decreases proportionally with soil water reduction (Bajji *et al*, 2001). Reduction in RWC is faster for non tolerant species than for tolerant ones, *Phaseolus lunatus* would be thus the most susceptible specie. Genotypes which maintain high RWC in presence of water stress are tolerant (Nouri, 2002). Maintenance high RWC at T1 would be related to a good capacity of osmotic adjustment allowing safeguarding of structural and functional integrity of tissues. RWC would be an early indicator of water state of plants under water stress.

Reduction of water consumption for four leguminous plants according to water stress level would be explained by reduction in the volume of water in rhizosphere because of drought. Result obtained in this work is similar to those of Li *et al* (2009) on *S. davidii*, Anyia and Herzog (2004) on *Vigna unguicula*. Water stress also decreases WUE for the four leguminous plant species. This result is similar to those obtained by Singh and Singh (2003) on *Dalbergia sissoo*, Li *et al* (2009) on *S. davidii*.

WUE is a functional character related to growth and performance of plant in water stress condition (Li *et al*, 2009). It depends on quantity of water consumed for growth and biomass production (Monclus *et al*, 2006). In this study WUE was decreased with water consumption and biomass production. Under severe water stress, weak CO_2 conductance and activity of photosynthetic enzymes in leaves decrease photosynthesis and biomass, and consequently WUE decreases. Some authors confirm the fact that plant WUE is decreased by water stress (Monclus *et al*, 2006), but others disagree (Rodiyati *et al*, 2005; Martin and Stephens, 2006).

Reduction in WSRI for water stress leguminous plants would be related to reduction in their dry biomasses and their water consumption. This result is similar to those obtained by Guissou *et al* (2001) on four fruit-trees and Kinfack Dongmo (2006) on banana tree.

Reduction in water content of leguminous plants under water stress would result from reduction of water consumption. This result is similar to those obtained by Bajji *et al* (2001) on durum wheat under water stress induced by polyethylene glycol.

In water stress condition hydration degree of *C. cajan* and *T. vogeli* remains unchanged; this two species would have preserved in their leaves tissues, same quantity of water under water stress as in normal watering condition. This aptitude to conserve H° under water stress could be considered as an adaptive mechanism which confers to them a better stress tolerance (Blum and Ebercon, 1981) compared to *P. lunatus* which shows a reduction of its H°).

CONCLUSION

The objective of this work was to analyze early physiological indicators for tolerance to water stress of four Fabaceae leguminous plants. Broadly, results obtained show that water stress inhibits all physiological parameters for studied plants. These parameters can be used as early indicators and relevant criteria of tolerance to drought, useful in varietal selection and like parameter of improvement of yield in areas victims of water starvation. Results obtained, concerning water status: management and water use efficient, allow to say that *C. cajan* and *T. vogelii* would be more tolerant to water stress than *V. subterranea* and *P. lunatus*.

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