

Woody Species Physiological Responses to Water Stress along Climatic Gradient in Burkina Faso

Jonas Koala¹, Kagambega O. Raymond² & Louis Sawadogo³

¹ Département Environnement et Forêt, CNRST, INERA, DRREA-Centre/Saria, BP 10 Koudougou, Burkina Faso

² Université Joseph KI ZERBO, BP 7021 Ouagadougou, Burkina Faso

³ Département Environnement et Forêt, CNRST, INERA, 03 BP 7047, Ouagadougou 03, Burkina Faso

Correspondence: Jonas Koala, Département Environnement et Forêt, CNRST, INERA, DRREA-Centre/Saria, BP 10 Koudougou, Burkina Faso. Tel: +226 70309611. E-mail: koalajonas@gmail.com

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Abstract

Drought had been increased for some decades in Burkina Faso, resulting in a reduction of ecosystems and risk to decrease provision of basic needs for vulnerable people. Different Plantation implemented these recent years had low rates of success due to lack of scientific knowledge relating to local woody species. This research was carried out to assess physiological responses along gradient of increasing aridity from south to north. Specifically, this study was to evaluate influence of climatic gradient on water potential, water content and relative water content of four woody species (*Balanites aegyptiaca*, *Pterocarpus erinaceus*, *Parkia biglobosa* and *Vitellaria paradoxa*). It appeared that climatic gradient significantly influenced differently plants water status. Water potential diurnal ranges of studied woody species were highly significant in all the sites. That means that they could cope in sites with large variation of drought. So, they could be considered in reforestation activities in the context of climate change. However, results had also shown that physiological parameters were influenced by toposequence, plants morphology and microclimate in which species could benefit in environments with unfavorable water conditions, therefore, further studies are needed before making rough recommendations.

Keywords: climate change, climatic gradient, physiological responses, adaptation, water stress, Burkina Faso

1. Introduction

There is an increased variability in rainfall pattern in West Africa during the last 30 years (Bell and Lamb 2006; Mertz, Mbow and Reeberg, 2011). In Burkina Faso, this general trend is also reflected in the shift of the 600 mm and 900 mm isohyets towards the south of the country. (UNEP 2012; Ouedraogo, et al. 2014). Besides human impact, such changes in rainfall pattern may affect that of the vegetation (Seaquist, Hickler, Eklundh, Ardo and Heumann, 2008). Indeed, water availability largely determines the distribution and function of terrestrial ecosystems (Mitlöhner 1997; Gebrekirstos, Teketay, Fetene and Mitlohner, 2006). Both climate change and human pressures, due to increasing population, contribute to woody species' habitats reduction and depletion of some woody species and non-wood products (SPCNGE and CTNCDB 1999). Such trends endanger food security for vulnerable population groups who rely on natural resources for their living.

To counteract these trends, a range of mitigation measures are implemented including afforestation, reforestation, forest management, forest products and forest tree improvement to increase biomass productivity and carbon sequestration. In these actions, priority was given to exotic species, given the lack of scientific knowledge on local species such as their adaptation to water stress (SPCNGE and CTNCDB 1999). Adaptation refers to changes in structure or function heritable, which increase the fitness of the organism in a stressful environment (Aphyllum, Persicum, Arabzadeh and Emadian, 2010; Bartlett, Sack and Baraloto, 2015). The capacity of plants to respond and cope with water deficit caused by drought depends of mechanisms or strategies developed to adapt to the environmental conditions (Turner 1986; Farooq, Wahid, Kobayashi, Fujita and Basra, 2009; Hill and Poudyal 2014). The water deficit can be defined as the internal water status that limits production of dry matter of vegetal species during a given period of its development cycle. Drought does not always cause stress or water deficit in plants. Indeed, the plant can respond to drought by implementing adaptive mechanisms that allow it either to avoid or to tolerate it without a significant reduction of yield (Hamidou 2009; Luo et al. 2016). Water stress in plants is

generally determined through water potential, water content and relative water content which are direct measurements. Water potential is an intensive thermodynamic quantity that determines the direction of the exchanges of water between two points of the set formed by soil, vegetation and atmosphere (Aphyllum et al. 2010; Luo et al. 2016). It is a good indicator of the physiological state of the plant, because photosynthesis, cell elongation, stomatal opening are strongly influenced by it (CIRAD, 2002). Furthermore, it incorporates soil water availability, climatic constraints and the intrinsic response of species to water stress (Bationo and Ouedraogo 2001). Particular attention is generally given to predawn water potential, midday water potential and diurnal range of water potential. Predawn water potential (Ψ_b) is measured when transpiration is virtually at zero. It indicates soil water potential in the rhizosphere zone (Hinckley, Lassoie and Running, 1978; Bationo and Ouedraogo 2001). This parameter provides information on the edaphic component of water stress supported by plants. In the night, plants balance their water potential with their rhizosphere zone soil humidity. Accordingly, decrease of water availability in these horizons generally results in lower predawn water potential towards more negative values. Midday water potential (Ψ_m) obtained at noon shows the maximum internal water deficit of the plant. It also provides information on the existing tension in the xylem sap during transpiration, which depends in particular on the tension of the water in the soil, the intensity of transpiration, hydraulic conductance of the soil-plant-atmosphere system. Low midday water potential provides information on the capacity of the plant to adapt to its environment because of its capacity to lower their water potential (Mitlöhner 1997). From the two variables (predawn water potential and midday water potential) diurnal range of the water potential is calculated using the following formula: $\Delta\Psi = \Psi_b - \Psi_m$. This variable indicates the daily relaxation. It is wide with the capacity of the plant to have a large ecological zone (Gebrekirstos et al. 2006). Meanwhile, it is interesting to measure leaves relative water content. Leaves relative water content (RWC) is the mass of water contained in leaves sample at the time of harvest compared to the mass of water contained in the sample at full turgor. Species that maintain high RWC are considered to be drought-resistant species (Berka and Aid 2009). However, the low success rate of plantations and the undeniable socio-economic role of local woody species have induced a shift in recent decades with more and more local species being used in vegetation restoration planting. Therefore there is an urgent need for reliable scientific data on the physiological responses of the flora in order to assess and predict its resilience in conditions of increasing drought in the context of climate change. Such knowledge is an inescapable fact to have better success of plantations in semi-arid areas (Krug 2004) to which belongs a large part of Burkina Faso. Some studies have already been carried out on physiological responses of local woody species in Burkina Faso on various aspects but in one location (Rouspard, Joly and Dreyer, 1998; Hien 2000; Bationo and Ouedraogo 2001; Bayala, Ouedraogo and Ong, 2009; Bazié 2009; Sanon 2009). The aim of this study was to assess the ability of plants to adapt to their environment along a gradient of increasing aridity from the south to the north of Burkina Faso through assessment of parameters described above. We used climatic gradient approach going from south to north and focused on the measurement of water status (water potential, stomatal conductance, transpiration) of some woody species. By adopting climatic gradient, we hypothesized that individuals of the same species in the northern part might have developed some adaptation mechanisms the reduced water availability than those from the south.

2. Methodology

2.1 Study Sites

Four sites were selected along climate gradient from North to South, so, one site by eco-geographical area (Figure 1). There are Dori in the Sahel zone, Tougouri in Sub-Saharan zone, Nobéré in the North-Sudanese zone and Orodara in South-Sudanese zone (Figure 1).

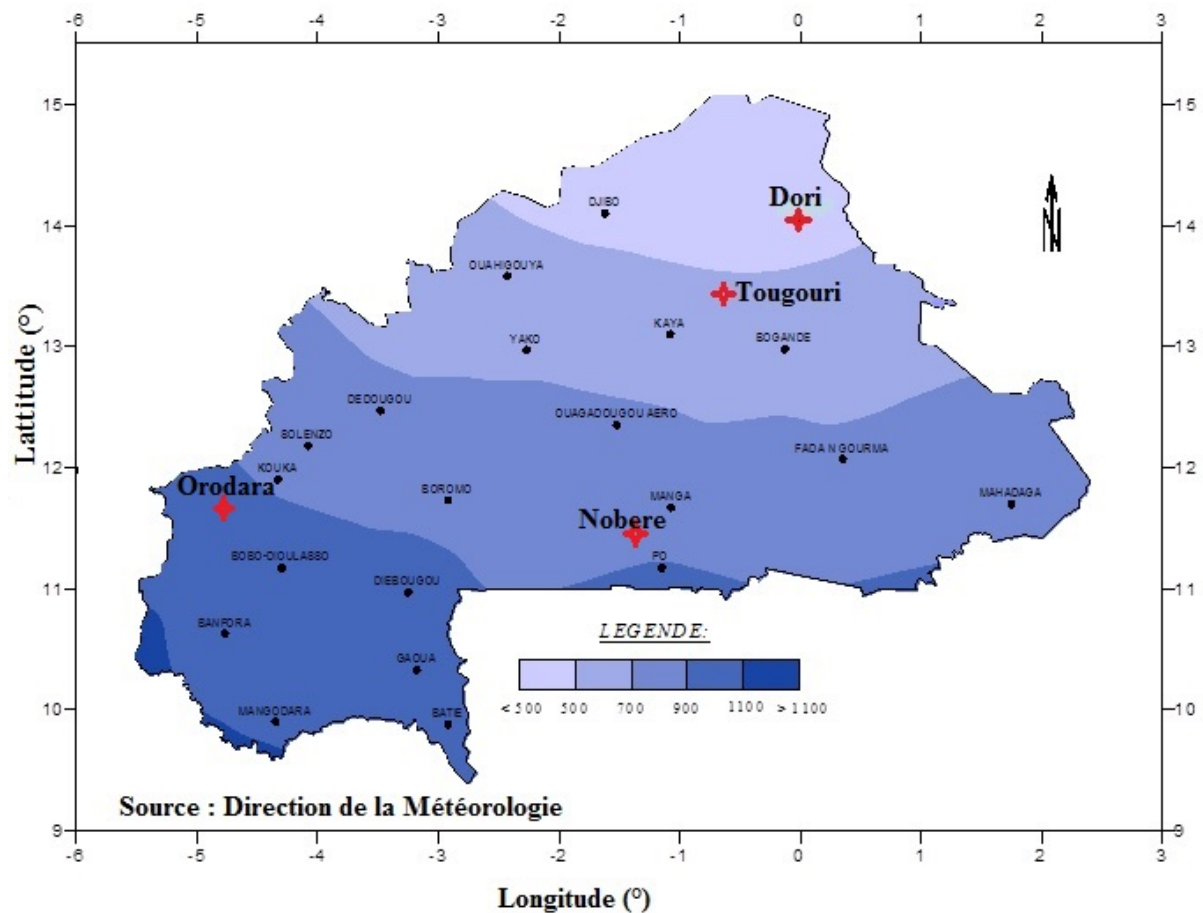


Figure 1. Location of three study sites along a climatic gradient in isohyets map of Burkina Faso (Adapted from Direction of the National Meteorology)

Rainfall and the length of the rainy season decreases from Dori to Orodara through Nobéré and Toungouri (Table 2).

Table 1. Characteristics of three study sites along a climatic gradient in Burkina Faso, West Africa

	Dori	Toungouri	Nobéré	Orodara
Location	N13 59 25.0 W0 01 41.6	N13 19 07.1 W0 30 57.0	N11 29 43.1 W1 11 41.8	N10 58 43.5 W4 51 32.6
Climate	Sahelian =>Arid	South-sahelian =>Semi-arid	North-soudanian =>Semi wet	South-soudanian =>wet
Annual rainfall (mm)	456	538	829	1065
Annual ETP (mm)	3008	4057	3042	2839
Length of rainy season (month)	3	4	5	5
Vegetation pattern	Shrub steppe	Wooded steppe	Shrublands and Woodlands	Woodlands and gallery forest

Source: Meteorological service of Burkina Faso and personal observation

2.2 Study Species

The studied species were *Balanites aegyptiaca* (L.) Del. *Parkia biglobosa* (Jacq.) Benth. *Pterocarpus erinaceus* Poir., and *Vitellaria paradoxa* CF Gaertn. Their ecologies had been described by Terrible (Terrible 1984), Soumare (Soumare et al. 1994) and Bationo & Ouédraogo (Bationo and Ouedraogo 2001).

Given the differences in the ecologies of these species, measurements of *Balanites aegyptiaca* were made in Dori, Tougouri and Nobéré, while those of *Vitellaria paradoxa*, *Parkia biglobosa* and *Pterocarpus erinaceus* were carried out in Tougouri, Nobéré and Orodara [Table 1].

Table 2. Characteristics of four woody species in three sites along a climatic gradient in Burkina Faso, West Africa

Species	Socio-economic importance	Habitat and ecology	Root system	Locality	Quality of measurement moment	Temperature		Diameter	Height	Organic form
						Midday	Predawn			
<i>Balanites aegyptiaca</i> (Balanitaceae)	-Food (fruits and leaves) - Pharmacopoeia -Fodder - Wood-fire	Rainfall <1000 mm; little leached ferruginous soils, vertisols and saline soils	Mixed (Shallow and deep)	Dori	windy and sunny	36	18	38 a	6 ab	Shrub
				Nobere	windy and sunny	35	12	39 a	5 b	Shrub
				Tougouri	Sunny but no Wind	33	19	17 b	7 a	Shrub
<i>Parkia biglobosa</i> (Mimosaceae)	- Food (fruits) - Pharmacopoeia - Wood-fire	Rainfall >700 mm ; on ferruginous soils reworked	Lateral and shallow	Nobere	windy and sunny	35	14	33 b	10 ab	Shrub
				Orodara	windy and sunny	35	19	23 b	5 b	Shrub
				Tougouri	Sunny but no Wind	33	19	76 a	17 a	Tree
<i>Pterocarpus erinaceus</i> (Papilionaceae)	- Pharmacopoeia -Fodder -Wood-fire	Rainfall>800 mm ; on leached ferruginous and armor soils	Mixed (Shallow and deep)	Nobere	windy and sunny	35	14	22 b	9 b	Small tree
				Orodara	windy and sunny	35	19	19 b	5 c	Shrub
				Tougouri	Sunny but no Wind	33	19	48 a	18 a	Tree
<i>Vitellaria paradoxa</i> (Sapotaceae)	-Food (fruits) - Pharmacopoeia -Fodder - Wood-fire	Rainfall >700 mm ; few demanding, but doesn't tolerate saline and leached ferruginous soils	Mixed (Shallow and deep)	Nobere	windy and sunny	35	12	27 b	6b	Shrub
				Orodara	windy and sunny	35	19	15 b	5b	Shrub
				Tougouri	Sunny but no Wind	33	19	49 a	18a	Tree

For each species, values of diameter and height with the same letters are not significantly different. The data were synthesized in the following sources: Aubreville, (1963); Terrible, (1984); Soumare et al, (1994), and personal observations.

2.3 Measured Variables

Six (6) representative trees of each species in each site were selected based on their accessibility. The coordinates of each plant were recorded using a Garmin GPS60, Taiwan. Then morphologic attributes such as diameter and height were measured before physiological measurement. Height was estimated with a clinometer. While diameter (D) was deduced from the circumference (C) measured with tape (precision 0.5 cm) by the following formula:

$$D = C/\pi$$

with $\pi = 3.14$

Physiological measured variables were leaf water potential (Predawn water potential (Ψ_b), Midday water potential (Ψ_m) and diurnal range of water potential ($\Delta\Psi$)), water content (WC), and relative water content (RWC). Measurements were carried in December 2009, during dry season, before leaves shedding. They were made at a time of day when there is relatively stable water potential of plants (Alexandre 1991; Mitlöhner 1997). In this study measurements were carried at dawn between 3:00 am and 5:00 am and at noon between 11:00 am and 03:00 pm.

For water potential, one leaf per plant was taken just before the measurements by breaking stalk at its insertion on the node. The petiole was cut from its end with a sharp "cutter" in order to avoid that the tissues crush. It was then introduced into the hole of the lid of the pressure chamber with the seal around the petiole using flexible rubber and the sheet placed in the chamber. The chamber is pressurized gradually. The value of water potential is noted when the exudation at the section of the petiole appears. This value corresponds to the pressure in the chamber displayed by the gauge. For measurements at midday, leaves were collected in the portion of the plant, which is the most exposed to sunlight and considered to have maximum water stress Krug (2004).

Samples used for measurements were taken from branch at almost the same height for all the sampled trees.

Leaves were collected the same branches from which leaves were sampled for water potential measurement and immediately packaged in paper envelopes and fresh weighed (FW1) on a scale PESSOLA® with precision 0.1 g. The samples were then dried in an oven at 80°C for 24 h. Dry weight of the sample (DW) was measured with the same scale. The water content (WC_d) is related to dry matter and was determined using the following formula:

$$WC_d = ((FW1 - DW) \times 100) / DW$$

Still on the same branches as described above, some other leaves were harvested and soaked in 15 l buckets filled with water to $\frac{3}{4}$. The water containers were completely covered by a dark plastic bag and kept in the shade in a house for 24 h. Thereafter, water-soaked leaves were removed and packed in paper envelopes and immediately weighted using the scales PESSOLA® with Precision 0.1 g. Resulting weight was called saturation or turgor weight (SW). Saturated sheets were then dried in an oven until constant weight and reweighed. That was called dry matter weight (DW). Fresh matter weight (FW2) was obtained here by extrapolation.

$$FW2 = MS \times X$$

with X equal to the proportion of fresh material from the dry matter in the sample used to measure the WC_d . The relative water content (RWC) was obtained using the following formula:

$$RWC = ((FW2 - DW) \times 100) / (SW - DW)$$

2.4 Data Analysis

Site was the only factor of interest in this study. Thus, differences in variables (predawn water potential, midday water potential, diurnal range of water potential, water content and relative water content) between sites were determined using analysis of variance (ANOVA). Further, when significant statistical differences were revealed, variables means were ranked using Tukey's test at 5%. The software used for this purpose is XLSTAT 2016.

In addition, we evaluated the range of daily relaxation of each species through pair-wise mean comparisons of midday water potential and predawn water potential values using paired Tukey test at 5% (Krug 2004).

Further, we used the method described by Mitlöhner (1997) and Krug (2004), to visualize the range of relaxation of each species in different sites. Midday and predawn values were used respectively as Y and X axes on an orthonormal mark. A 45° diagonal line was plotted on the graph for each species. The bisecting line is the boundary where both midday and predawn water potential have equal values. It represents permanent wilting point for the plant, in other word, the limit where no water uptake was possible. So more points or trend line was far from the bisecting line, the higher significant the range of daily relaxation was.

Pearson correlation was used to investigate the relationships between physiological and morphological variables as being influenced by the climatic gradient.

3. Results

3.1 Influence of Climatic Gradient on Water Potential of Studied Species

The difference between sites for predawn water potential was highly significant ($P < 0.01$) for *V. paradoxa* and *P. erinaceus* and very highly significant ($P < 0.001$) for *B. aegyptiaca* and *P. biglobosa*. *B. aegyptiaca* and *P. erinaceus* had their lower predawn water potential in the northern with lowest rainfall amounts which are Dori and Tougouri, respectively. In turn the lowest value for Ψ_b of *P. biglobosa* was registered in Orodara, the wettest site. Finally,

Ψ_b value of similar magnitude was measured in Tougouri (the driest site) and Orodara (the wettest site) for *V. paradoxa* (Figure 2).

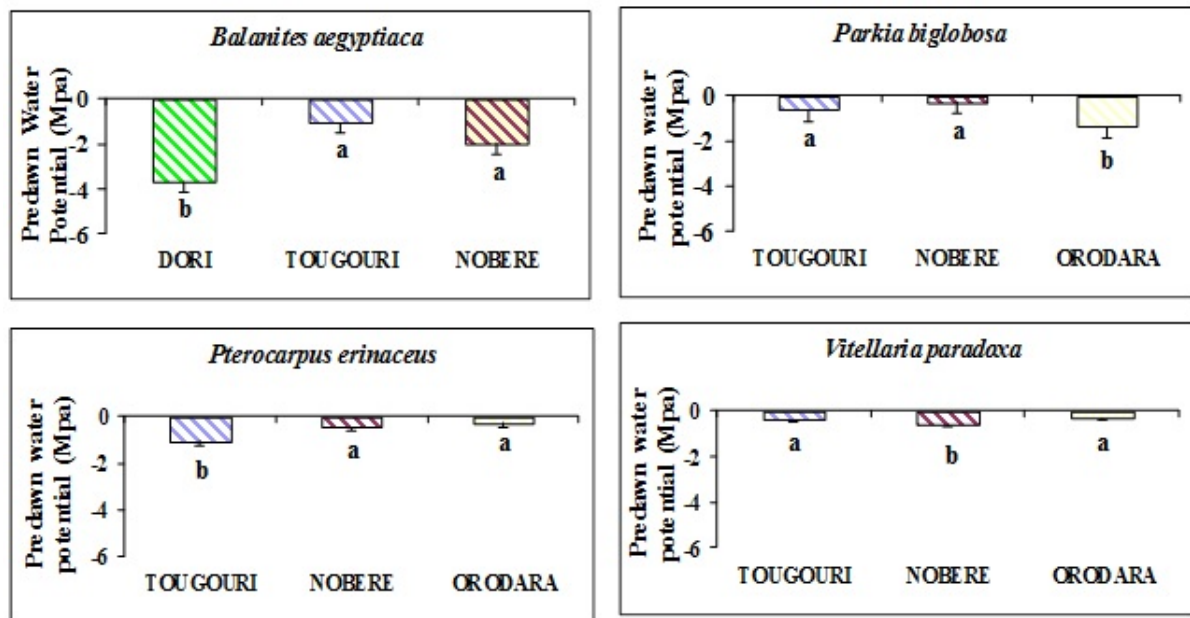


Figure 2. Predawn water potential of four woody species in three sites along a climatic gradient in Burkina Faso, West Africa

The difference between sites was highly significant ($P < 0.01$) for *P. erinaceus* and *V. paradoxa* for midday water potential. *P. erinaceus* had the lowest midday water potential at Tougouri which was not statistically difference from the value obtained in Orodara. *V. paradoxa* had the highest midday water potential in Tougouri. No significant difference was found between values of the three sites of this variable for *B. aegyptiaca* and *P. biglobosa* $P > 0.05$; (Figure 3).

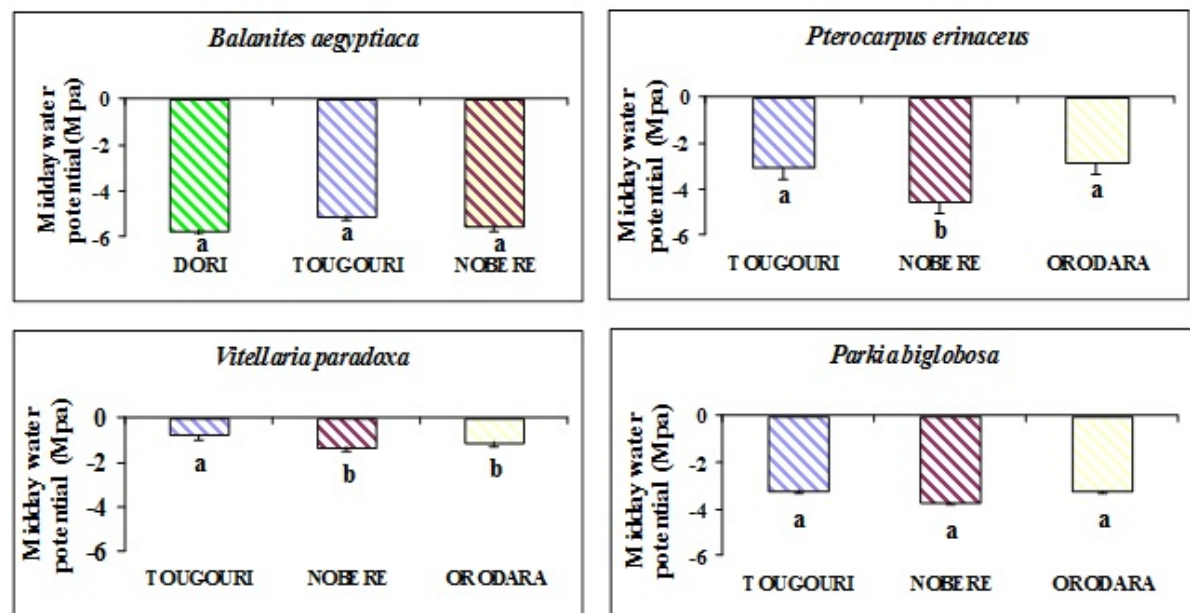


Figure 3. Midday water potential of four woody species in three sites along a climatic gradient in Burkina Faso, West Africa

Difference between the sites was highly significant ($P < 0.01$) for diurnal range of water potential for all species except *V. paradoxa*. The diurnal range of water potential of *B. aegyptiaca* was wider in Tougouri and Nobéré (Table 3).

Table 3. Result of paired Tukey-test between midday and predawn water potential values of four woody species in three sites along a climatic gradient in Burkina Faso, West Africa

	DORI	TOUGOURI	NOBERE	ORODARA
<i>Balanites aegyptiaca</i>	**	***	***	
<i>Parkia biglobosa</i>		***	***	***
<i>Pterocarpus erinaceus</i>		***	**	***
<i>Vitellaria paradoxa</i>		***	***	***

P. biglobosa had the lower diurnal range at Orodara. As for *Pterocarpus erinaceus*, it's at Nobéré that displayed the widest diurnal water potential range (Figure 4).

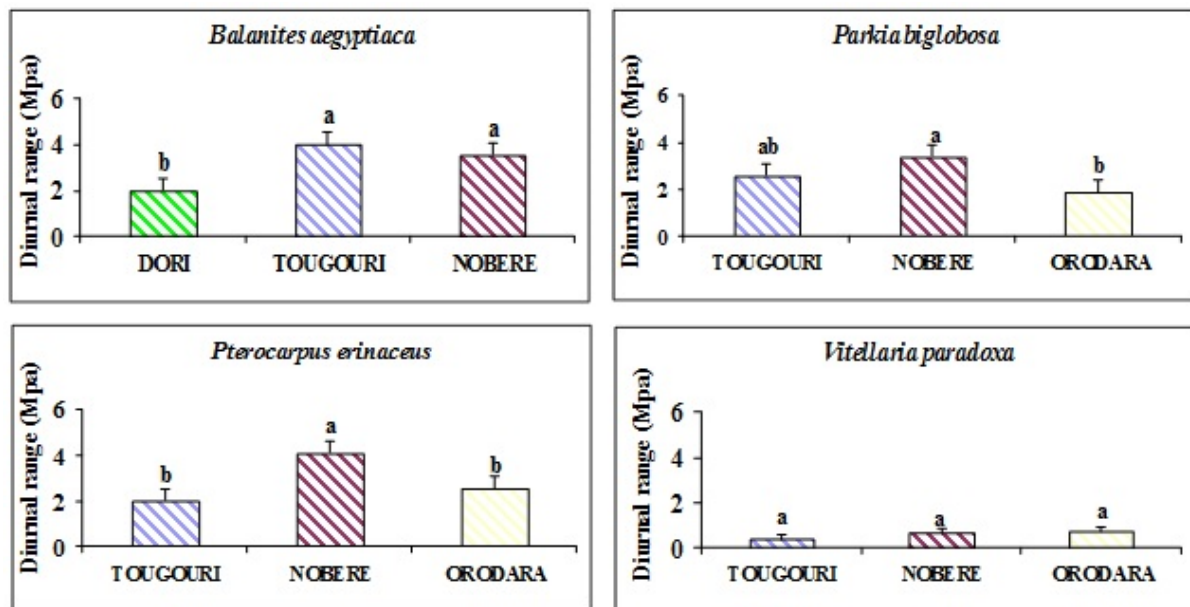


Figure 4. Diurnal range of four woody species in three sites along a climatic gradient in Burkina Faso, West Africa

B. aegyptiaca showed weaker relaxation at Dori than Tougouri and Nobéré as indicated by the points representing the Dori site, which were closer to the diagonal. *P. biglobosa* relaxation was higher at Nobéré and Tougouri. The points of these two locations are far away from the diagonal. *P. erinaceus* has a higher relaxation at Nobéré than Tougouri and Orodara. *V. paradoxa* showed similar relaxation magnitude in the three localities (Orodara, Nobéré, Tougouri). The different points of the sites are located at almost the same distance from the diagonal (Figure 5).

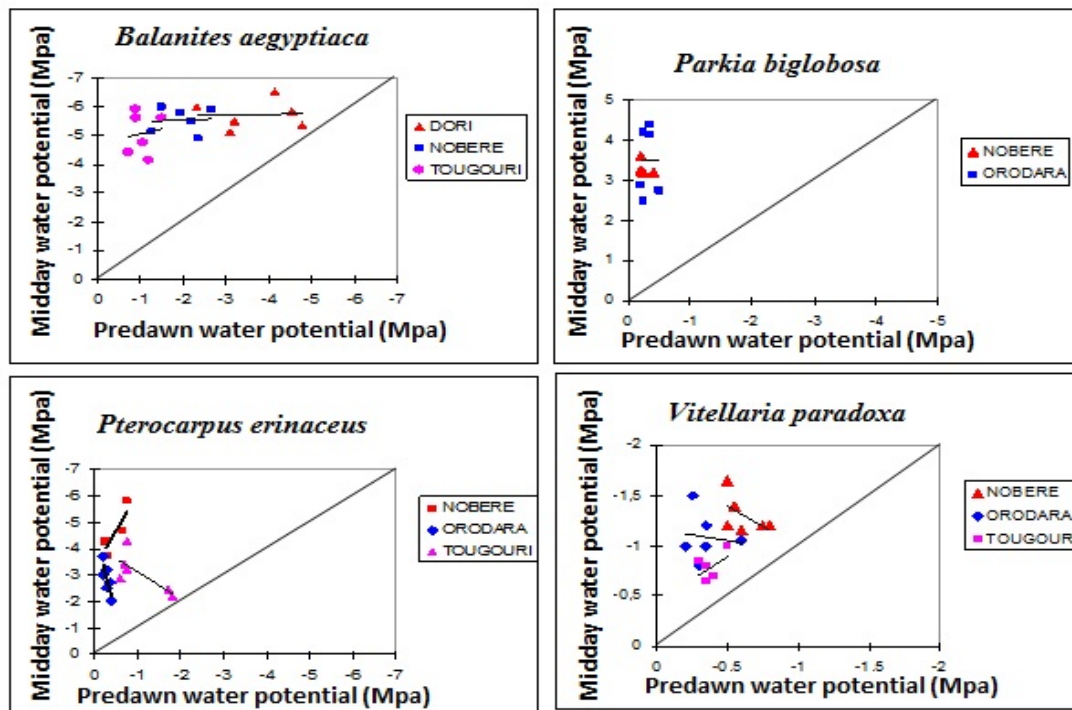


Figure 5. Predawn water potential versus midday water potential of four woody species in three sites along a climatic gradient in Burkina Faso, West Africa

3.2 Influence of Climatic Gradient on Water Contents of Studied Species

The water content (WC) increased significantly ($P < 0.05$) from Orodara to Tougouri for *V. paradoxa*. For other species (*B. aegyptiaca*, *P. biglobosa* and *P. erinaceus*), their difference between sites was not statistically significant. (Figure 6).

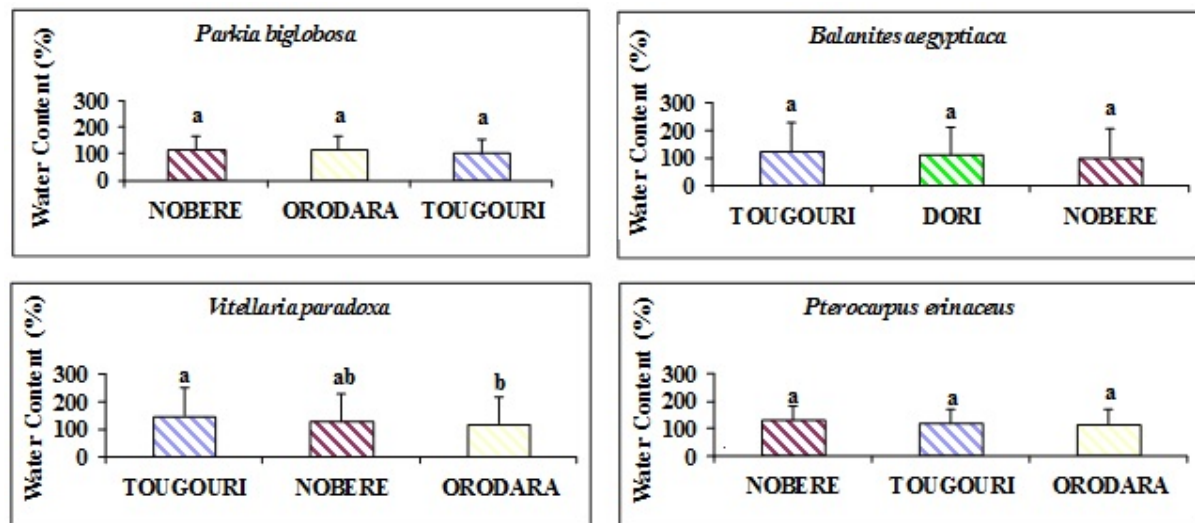


Figure 6. Water content of four woody species in three sites along a climatic gradient in Burkina Faso, West Africa

Difference of relative water content (RWC) between the three sites was significant for *V. paradoxa* and *P. biglobosa*. The value of this variable increased with increased climate aridity for *V. paradoxa*. For *P. erinaceus* difference was also highly significant between the three sites. The RWC was lower at Tougouri than the other two sites (Nobéré and Orodara), which in turn did not differ statistically from each other. No significant difference was observed

between sites (Dori, Tougouri and Nobéré) in RWC for *B. aegyptiaca* (Figure 7).

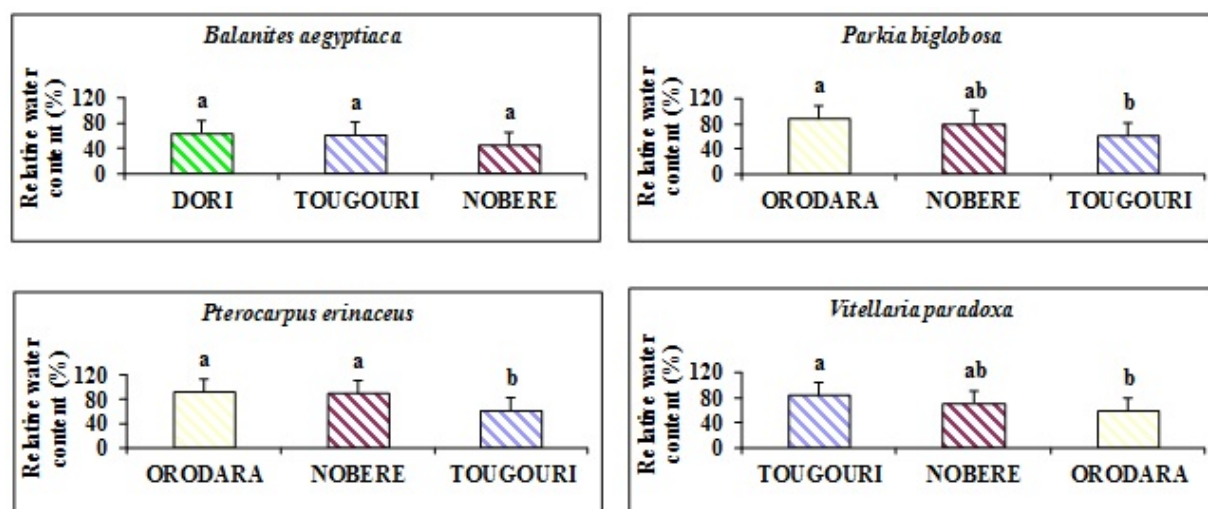


Figure 7. Relative water content of four woody species in three sites along a climatic gradient in Burkina Faso, West Africa

3.3 Correlation of Physiological and Morphological Variables Influenced by the Climatic Gradient

The linear regression and Pearson correlation test performed between the different variables, revealed that predawn leaf water potential was negatively correlated with the diameter of *B. aegyptiaca* ($P = 0.042$) and *P. erinaceus* ($P = 0.012$) and positively correlated that of *P. biglobosa* ($P = 0.022$). The correlation between predawn water potential and diurnal range was highly positive and highly significant for *B. aegyptiaca* ($P < 0.0001$), *P. biglobosa* ($P < 0.0001$) and *P. erinaceus* ($P = 0.012$). The correlation between predawn water potential and latitude was negative and highly significant ($P = 0.001$) for *P. erinaceus*. No significant correlation was observed for *V. paradoxa*.

The midday water potential was positively correlated with height of *B. aegyptiaca* ($P = 0.01$) and *V. paradoxa* ($P = 0.004$) while it was strongly negatively correlated with the diurnal range of *P. biglobosa* ($P < 0.0001$), *P. erinaceus* ($P < 0.0001$) and *V. paradoxa* ($P < 0.0001$). The correlation between midday water potential and latitude was positive and highly significant ($P = 0.005$) for *V. paradoxa*.

RWC is negatively correlated with latitude for *P. biglobosa* and *P. erinaceus* ($R^2 = -0.8$, and $R^2 = -0.9$, respectively). This correlation was positive for *V. paradoxa* ($R^2 = 0.7$). RWC is negatively correlated with height and diameter from *Parkia biglobosa* and *Pterocarpus erinaceus*.

4. Discussion

High negative correlation between predawn water potential and the gradient represented by latitude for *P. erinaceus* was observed as opposed to other species. Difference of predawn water potential recorded for *B. aegyptiaca* between Dori, Tougouri and Nobéré means that accessibility to water of the species in these three localities differed significantly. That is due to differences in environmental conditions (rainfall, soil etc.) (Hinckley et al. 1978; Mitlöhner 1997; Krug 2004) in these three sites, but moderated by the morphological differences of the studied individuals. Water access of the shrubs at Tougouri and Nobéré seems to be easier given the values of predawn water potential that are higher. *P. erinaceus* had statistically similar predawn water potential values at both Orodara and Nobéré which can be due to similar environmental conditions on these two sites. Indeed, favorable rainfall in Nobéré this last years placed it under similar environmental conditions with Orodara. In Orodara, *P. biglobosa* had the lowest predawn water potential probably due and this competition from planted trees of orchards. A second reason might be the high toposequence and the smaller diameter of individuals measured in relation to the ones of other sites. Indeed, linear regression and Pearson's test revealed firstly a negative correlation ($P < 0.001$) between the predawn water potential and altitude and secondly, a positive correlation ($P = 0.022$) between predawn water potential and diameter. The negative correlation of predawn water potential with height is consistent with the results of Krug (Krug 2004) who revealed that the topography influences negatively the predawn water potential.

Vitellaria paradoxa had inconsistent values. Predawn water potential recorded for this species was higher in Tougouri than Nobéré. It's may be because they benefit in Tougouri from favorable microclimate thus improving their accessibility to water. This could be explained the presence of *V. paradoxa* in isolated grove along the ravines and rivers. Indeed, *V. paradoxa* occurs naturally in areas where rainfall is between 750 and 1200 mm. His presence in Tougouri may be due to exceptional hydrological conditions. From the foregoing it can be argued that access to water of species varies depending on weather conditions but that can be moderated by the toposequence and morphology of woody species.

Vitellaria paradoxa and *P. erinaceus* had a higher midday water potential at Tougouri than Nobéré. This indicates that environmental conditions were more favorable at Tougouri than Nobéré (Mitlöhner 1997; Aphyllum et al. 2010; Luo et al. 2016). Indeed, local meteorological stations installed in the site gives recorded a slightly higher relative humidity at Tougouri than Nobéré. This is in agreement with the results of Mitlöhner, (Mitlöhner 1997) who showed that atmosphere humidity influences midday water potential. Moreover, midday water potential is positively correlated to morphological variables (Diameter and height) of *V. paradoxa*, whereas this species had at Tougouri the highest diameter and height than other localities. In contrast, *B. aegyptiaca* and *P. biglobosa* showed no significant difference respectively between Dori, Tougouri and Nobéré and between Tougouri, Nobéré and Orodara. This fact suggests a lack of midday water potential regulation of these species according to weather conditions or they react very slowly. This required longer studies before reaching an unequivocal conclusion. It should be added that some species in more arid sites can benefit favorable microclimates justifying their physiological functioning close to those of wetter sites (Gebrekirstos et al. 2006).

Highly significant difference between sites of diurnal range of species constitutes an indication that the species can cope with a large variation of stress levels within each site (Mitlöhner 1997, Krug 2004). So, they are physiologically adapted to the environments in which they are thriving, and may be better choices in reforestation activities in the context of climate change. When comparing diurnal range of species in different sites, we identified sites more suited physiologically for relevant species. *B. aegyptiaca* would be more suited to Tougouri and Nobéré than Dori. *P. biglobosa* and *P. erinaceus* would be more suited to Nobéré than Orodara and Tougouri. *V. paradoxa* is equally suited to Tougouri, Nobéré and Orodara.

Species did not have same strategies to adapt to environment water conditions. Adaptation strategy for *P. biglobosa* and *P. erinaceus* has involved improvement of their accessibility to water allowing them to maintain gas exchange during water stress through the maintenance of low midday water potential. Regarding *B. aegyptiaca*, adaptation to sites was done mainly through improved access to water. As for *V. paradoxa*, it maintains the gaseous exchange at midday in keeping relatively low midday water potential. However for *V. paradoxa* and *P. biglobosa*, diurnal range was influenced by other factors such as morphology of species and altitude. For these two species, adaptation to sites require more longer follow-up and consideration of these factors in order to make recommendations to policy makers for more successful reforestation with improvement of survival and growth rate in context of climate change.

Correlation between relative water content (RWC) and latitude for *P. biglobosa*, *P. erinaceus* and *V. paradoxa*, suggested that climatic gradient had influenced this variable. These species improved their RWC from north to south. The same level of RWC recorded in the three sites for *B. aegyptiaca* means that it keeps the same level of turgor of its cells despite the different climatic conditions. *P. biglobosa* and *P. erinaceus* had no correlation between their RWC and midday water potential. This could result from an osmotic adjustment of these species. Suc adjustment may come from an active accumulation of solutes (Morgan 1984; Venekamp 2008; Marechaux et al, 2015), increase of the elasticity of cell walls (Roberts, Strain and Knoerr, 2008) or increase of water content of the apoplast (Loussaief et al. 2009). On the contrary, the existence of correlation between these two variables in *V. paradoxa* could reveal a deficit of osmotic adjustment in this species (Xu, Zhou and Shimizu, 2010).

5. Conclusion

Water availability is a major environmental constraint limiting the productivity of Burkina Faso's forests. Plantation survival depends on the ability of planted species to cope with the water availability of its environment. This led us to study the physiological behavior of four woody plant species face to increasing levels of drought. The results showed that the water status of the species except *B. aegyptiaca* was influenced by the climatic gradient but the influence on physiological factors differed from one species to another.

Water deficit is positively influenced by the climatic gradient, but could be moderated by plants morphology and microclimate.

Diurnal range of species is highly significant in all sites, demonstrating their ability to cope with a large variation of water deficit levels. They are physiologically adapted to their environments in which they were are thriving,

and may be better choices in reforestation activities in the context of climate change. But the results have shown that physiological parameters are influenced by the toposequence, morphology and microclimate conditions. Further studies are required for longer follow-up and need to take into account additional factors (soil, toposequence, osmotic potential, etc.).

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Authors contributions

Sample: Dr. KJ and KOR were responsible for study design and revising. Dr KJ was responsible for data collection and drafted the manuscript and Prof. SL revised it. All authors read and approved the final manuscript.

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