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Evaluating the effects of water stress and irrigation on three cashew origins at juvenile stage for adaptation of agroforestry systems to drought under climate change in Burkina Faso (West Africa)

Yacouba Noël COULIBALY[1*] and Gérard ZOMBRE[2]

[1]*Institut de l'Environnement et de Recherches Agricoles (INERA), station de recherches environnementales et agricoles de Farako-Bâ, 01 BP 910, Bobo-Dioulasso, Burkina Faso.*
[2]*Université Joseph Ki-Zerbo, Ecole Doctorale Sciences et Techniques, 03 BP 7021, Ouagadougou 03, Burkina Faso.*
[*]*Corresponding author; E-mail: yacoubacoulibaly2002@yahoo.fr; Phone: (00226) 78 87 34 75.*

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ABSTRACT

The Drought threatens cashew-based agroforestry systems productivity in Burkina Faso. The objective of this research was to study the effects of water stress and irrigation on 03 cashew origins for recommendations to maintain and/or improve cashew based agroforestry systems productivity. The experiment was conducted in a semi-controlled environment using randomised complete blocks, studying the factors water regime and origin at 03 levels. The number of replication was 4 and the experimental unit was 4 pots. Total dry biomass, height and survival percentage were measured. The effect of water regime, origin and their interaction were highly significant (P<0,0001) on total dry biomass and height. The effect of water regime was highly significant (P<0,0001) while the effect of origin and the interaction were very significant (P=0,004) on survival percentage. Diakadougou origin performed better and the parameters measured were reduced under water stress and increased under irrigation. Diakadougou origin was the most drought tolerant and Ouessa origin the most demanding in water. Irrigation and use of drought tolerant origin Diakadougou could contribute in adaptation to drought of cashew based agroforestry systems. Further research to study drought and irrigation effects on physiological parameters of the cashew origins studied is required.

Keywords : Growth, Survival, Drought, Adaptation, Agriculture.

INTRODUCTION

The cashew (*Anacardium occidentale* L.) based agroforestry systems are increasing in the agricultural production systems in Burkina Faso (Somé, 2014; Belem, 2017) because of the socio-economic value of cashew nuts (Nugawela et al., 2006; Marlos et al., 2007; Sarah, 2014; Sali et al., 2020; Kambaye et al., 2021; Assih and Nenonene, 2022). Climate change in Burkina Faso is characterized by an increase in temperature with a multiplication of extreme climatic events such as droughts and floods with droughts being more frequent and intense

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(Traore et al., 2013). Temperature rise, droughts and floods under climate change are likely to have negative impacts on cashew performance reducing the cashew based agroforestry systems productivity. Several relevant research studies have reported negative effects of drought on cashew (Mbow et al., 2009; Bambara et al., 2013; Bello et al., 2017; Djighaly et al., 2021; Grüter et al., 2022). The difference of gas exchange rates between irrigated and unirrigated cashew, 3 or 4 months after the end of the rainy season was reported with a better gas exchange rate observed for irrigated cashew (Carr et al., 2014). The literature review did not allow to identify research currently implemented in Burkina Faso for selecting cashew drought tolerant varieties and studying the effect of irrigation on cashew. The objective of this research was to study the effects of water stress and irrigation on 3 cashew origins for formulating recommendations to maintain and/or improve cashew based agroforestry systems productivity to drought under climate change.

MATERIALS AND METHODS

Site description

The 3 cashew origins studied were collected in the South West Region of Burkina Faso. The South West Region is a major region of cashew production with about 884 farmers, 2663 ha of land under cashew conventional production and with a productivity about 379 t/ha (UNPA, 2014). The South West Region is located between 10°67' and 12°11' latitude north and 2°84' and 5°49' longitude west. The average temperatures of the South West Region are between 21°C and 32°C and the average annual rainfalls between 900 mm and 1200 mm (Belem, 2017). The soils of the South West Region are tropical eutrophic brown on clay material, ferralitic medium desaturated on sandy-clay material and mineral hydromorphic (Belem, 2017).

Plant material

The Diakadougou, Ouessa and Niceo cashew origins used for this experiment were those that performed better among 9 origins to the temperature, precipitation and soil conditions of the South West Region during a preliminary research. These 3 origins were collected from the elite cashew identified in the best cashew plantations jointly selected with producers of the South West Region. The elite cashew were those with the best yields in nuts per tree, the best dendrometric performances, the best sanitary performances, the best qualities of nuts and the best length of production times. The characteristics of the nuts from the 3 origins studied are in the Table 1.

Experimental design

The experimental design used was randomised complete blocks, studying the water regime factor at 3 levels (ETM, ETM1 and STR) and the origin factor at 3 levels (Diakadougou, Niceo and Ouessa). The number of replication was 4 and the experimental unit consisted of 4 blacks nursery pots. The water regime factor ETM corresponds to the water supply to maintain the soil at field capacity and this was our first irrigation level. The water regime factor ETM1 corresponds to the water supply of 1.25 ETM and this was our second irrigation level. The water stress factor STR corresponds to the pots which have been subjected to water stress where no water was supplied.

Experimental procedure

The experiment was carried out at Ouagadougou in semi-controlled conditions during the dry season for 4.5 months. The conventional plastic pots with the same amount of soil material composed of sand and manure were used. The soil material in the pots was watered at field capacity. We did not use fertilisers in the pots to be closer to the peasant

environment. The addition of manure would certainly have changed the current results (Faye, 2004) but was necessary to accelerate the plant development. Also, the manure is recommended as a good production practice for cashew plantations establishment (Coulibaly et al., 2022). The cashew seedlings were produced through direct sowing in the pots. For the ETM watering a control pot with the soil at field capacity was placed under the same conditions as the other pots to estimate the water losses by evaporation. The control pot was weighed every 02 days to measure the water loss by evaporation which was compensated through the supply of water in weight equivalent to all the pots in the aim to maintain them at constant weight and the soil at field capacity during 30 days to allow seedlings to be robust. For the ETM1 watering, 1.25% water in weight equivalent at ETM was supplied to the seedlings. This methodology used to maintain the soil of the pots at field capacity neglected the amount of water lossed by the transpiration of the plant due to the volume of the pots, the age of the plants and the duration of the experiment. The water regimes ETM, ETM1 and STR were applied from the 30th day after sowing. The application of the water regime STR consisted in stopping the supply of water to the plants in the pots.

Parameters measured

The parameters measured were the total dry biomass, the height and the survival percentage. The total dry biomass was measured by harvesting the stems and the leaves of all the plants in the experimental unit for each treatment at the end of the experiment. The harvested stems and leaves were dried under the sun for one month and weighed with a precision balance (accuracy 0.1 mg). The plant height was measured with a graduated ruler at the end of the experiment on a randomly selected plant in the experimental unit for each treatment. The survival percentage was measured by dividing the number of the living plants by the total number of the plants multiplied by 100 in the experimental unit of the ETM and STR treatments.

Data analysis

The ANOVA test was used to test the effects of origin, water regime and their interactions on cashew total dry biomass, height and survival percentage using the software XLSTAT 2022. When the differences among the means were significant with ANOVA, they were separated by the test of Student-Newman Keuils at 5%.

Table 1: Characteristics of the nuts for the 3 cashew origins studied.

Origins	Sizes (mm)	Weight (g)	KOR (lbs)
Diakadougou	3	6	45
Ouessa	2	5	44
Niceo	2	5	44

RESULTS

The results of ANOVA showed a highly significant effect of origin on total dry biomass and height and a very significant effect of origin on survival percentage (Table 2). The total dry biomass, height and survival percentage were significantly higher for cashew of Diakadougou and Ouessa origins (Figures 1A, 1B, 1C). The results of ANOVA showed a highly significant effect of water regime on total dry biomass, height and survival percentage (Table 2). The total dry biomass was significantly reduced in STR compared to ETM (Figure 2A). The total dry biomass in ETM1 was significantly higher compared to ETM and STR (Figure 2A). The same trends were observed for the height (Figure 2B). The survival percentage was significantly reduced in STR compared to ETM (Figure 2C). The results of ANOVA showed a highly significant interaction effect on total dry biomass, height and a very significant interaction effect on survival percentage (Table 2). For the cashew of Diakadougou origin, the total dry biomass and height were significantly higher in ETM and ETM1 compared to STR (Figure 3A). Also, the total dry biomass and height were not significantly different in ETM compared to ETM1 (Figure 3A). As for the cashew of Niceo and Ouessa origins, the total dry biomass and height were significantly higher in ETM and ETM1 compared to STR (Figures 3A, 3B). The total dry biomass and height were significantly higher in ETM1 compared to ETM for cashew of Niceo and Ouessa origins (Figures 3A, 3B). In ETM the total dry biomass was significantly higher for cashew of Diakadougou origin (Figure 3A). In STR the total dry biomass was significantly higher for cashew of Diakadougou origin (Figure 3A). In ETM1, the total dry biomass was significantly higher for cashew of Ouessa origin (Figure 3A). The same trends were observed for the height (Figure 3B). The survival percentage was significantly higher in ETM compared to STR for all the origins (Figure 3C). In ETM the survival percentage was not significantly different between the origins while in STR it was significantly higher for cashew of Diakadougou origin (Figure 3C).

Table 2: The results of ANOVA test for the effects of cashew origins, water regimes and their interactions on total dry biomass, height and survival percentage.

Parameters	Source	DDL	Sum of squares	Mean of squares	F	Pr > F
Biomass	Origins	2,000	30,949	15,474	59,648	**<0,0001**
	Water regime	2,000	70,355	35,177	135,596	**<0,0001**
	Origins*Water regime	4,000	24,904	6,226	23,999	**<0,0001**
Height	Origins	2,000	2020,597	1010,299	218,771	**<0,0001**
	Water regime	2,000	4775,514	2387,757	517,048	**<0,0001**
	Origins*Water regime	4,000	1115,444	278,861	60,385	**<0,0001**
Survival percentage	Origins	2,000	2031,250	1015,625	7,800	**0,004**
	Water regime	1,000	5859,375	5859,375	45,000	**<0,0001**
	Origins*Water regime	2,000	2031,250	1015,625	7,800	**0,004**

Significant = P < 0.05 Very significant = P < 0.01 Highly significant = P < 0.001

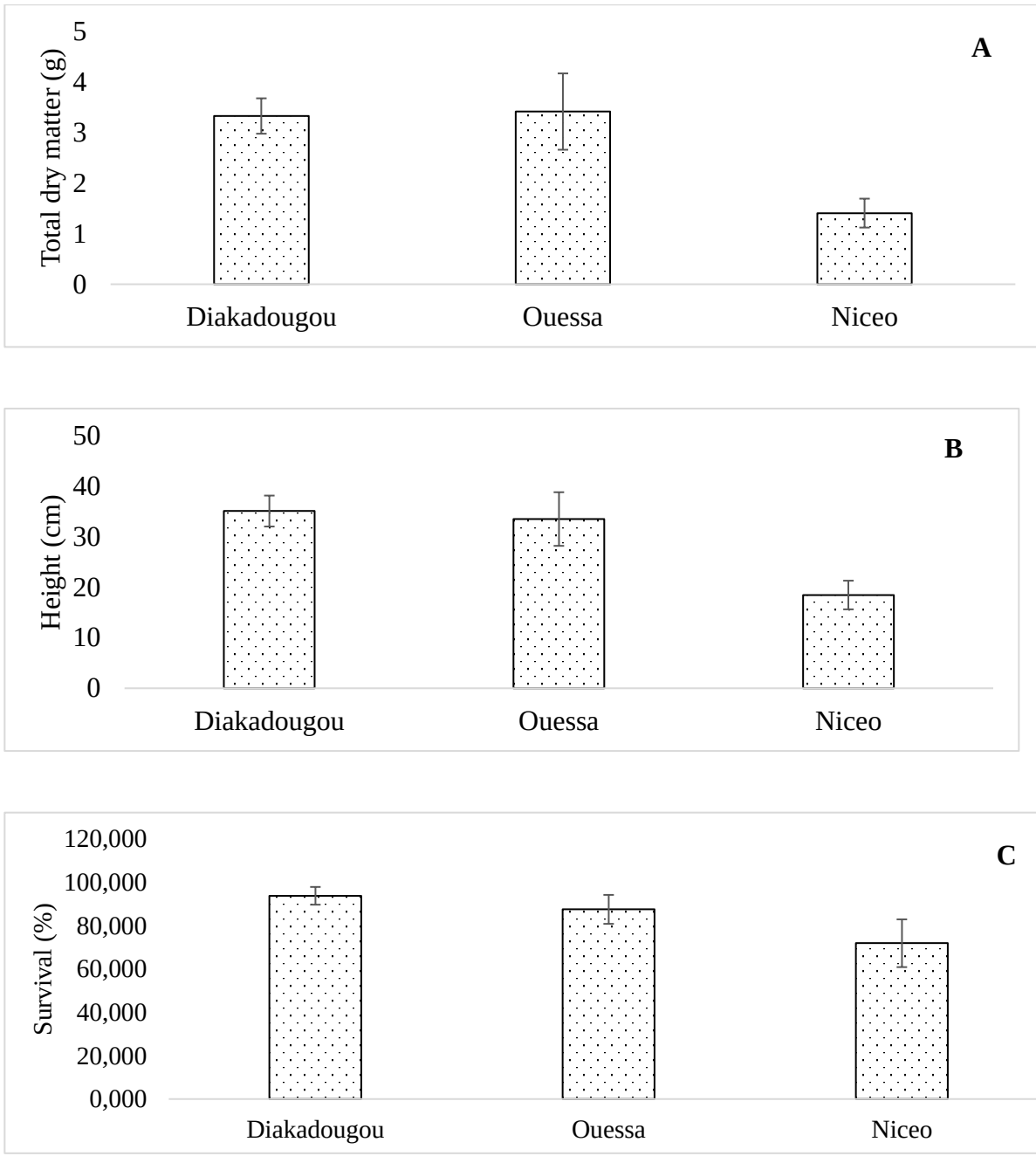
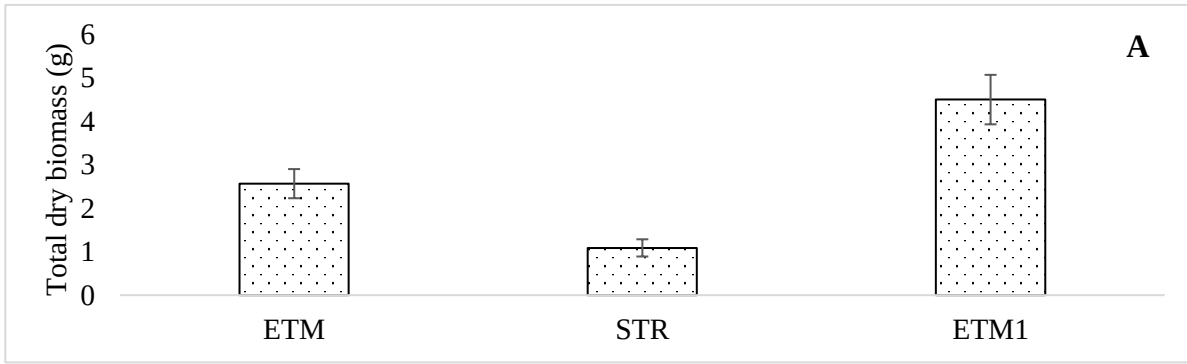
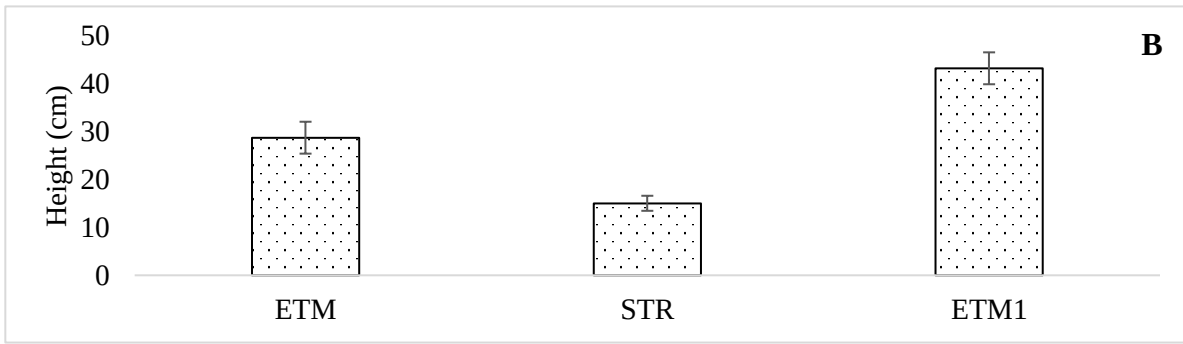


Figure 1: Variation of the : (A) total dry biomass, (B)height and (C) survival percentage according to the cashew origins.





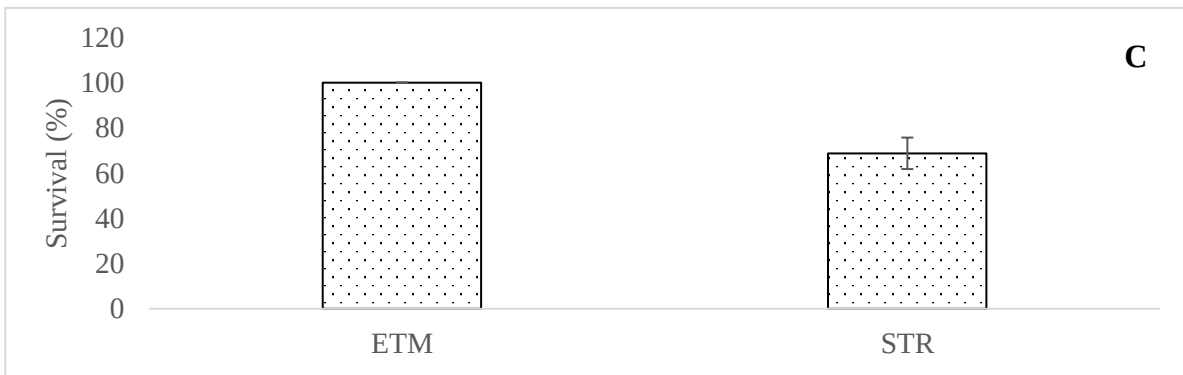


Figure 2: Variation of the : (A) total dry biomass, (B) height and (C) survival percentage according to the water regimes

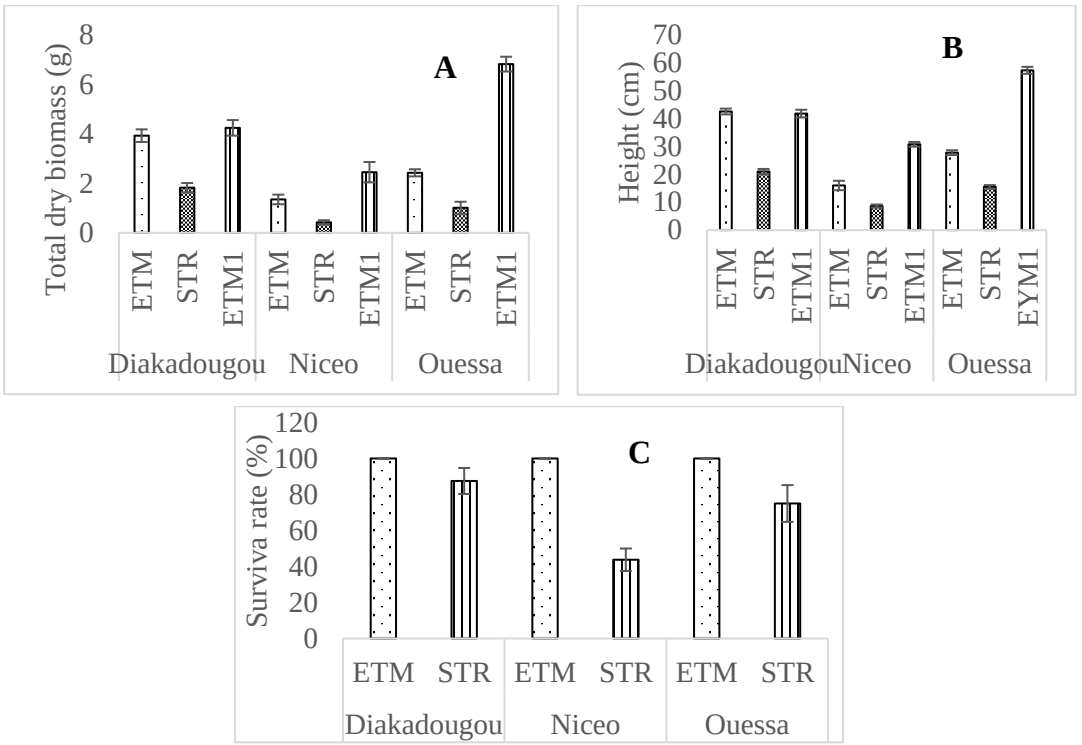


Figure 3: Variation of the : (A) total dry biomass, (B) height and (C) survival percentage for the cashew origins according to the water regimes.

DISCUSSION

The total dry biomass, height and the survival percentage varied significantly between the origins with the best performance observed for cashew of Diakadougou origin. Also, the three origins studied were collected in the South West Region of Burkina Faso and they were therefore under the influence of the same conditions of precipitation, temperature and soil. However, the cashew of Diakadougou origin had the higher size, weight and KOR compared to the other two origins. These results could be explained by the influence of genetic factors. Several authors reported the influence of genetic factors on fruit tree performances including cashew (Ginwal et al., 2005; Diallo, 2010; Hounsou-Dindin et al., 2021). The high performance of the total dry biomass, height and survival percentage observed for cashew of Diakadougou origin previously observed during a field experiment and also observed at the present study suggests that these traits could be used as descriptors of cashew varieties or ecotypes that would be identified (Hounsou-Dindin et al., 2021). The water regime significantly affected the total dry biomass, height and survival percentage. These parameters were significantly reduced in STR compared to ETM and ETM1 for all the cashew origins. These results show that cashew is sensitive to drought and corroborate several authors (Mbow et al., 2009; Bambara et al., 2013; Bello et al., 2017; Djighaly et al., 2021; Grüter et al., 2022). However, these results contradict other authors who reported that cashew is drought tolerant (Bezerra et al, 2008; Pitono et al., 2015; Capelari et al., 2021). The total dry biomass and height were significantly increased in ETM1 compared to ETM and for the maximum of the cashew origins. These results show that irrigation could help improve cashew performance under drought and corroborate several authors (Oliveira et al., 2006; Carr et al., 2014; Bello et al., 2017). The cashew origins showed different responses related to the total dry biomass, height and

survival percentage according to the water regime applied and this is in agreement with others research studies (Adji et al., 2020; Djighaly et al., 2021; Hounsou-Dindin et al., 2021). The cashew of Diakadougou origin presented the highest total dry biomass, height and survival percentage in STR. It also showed a total dry biomass and height similar in ETM and ETM1. The cashew of Diakadougou origin would therefore be the most drought tolerant and the least water demanding in case of irrigation based on the measured parameters. Indeed, the biomass measurement was reported to be one of the best factors to assess plant tolerance to water stress (Esmaeilpour et al., 2015; Füzy et al., 2019). The cashew of Diakadougou origin drought tolerance could be explained by a deep root system allowing the plant to better access water in the soil (Kou et al., 2022) and a better regulation of its relative water content through a reduction in stomatal conductance to avoid water loss by transpiration (Parida et al., 2008; Siddiqui et al., 2015; Khoyerdi et al., 2016). In ETM1 the total dry biomass and height were significantly higher for the cashew of Ouessa origin suggesting a greater sensitivity of this origin to drought and higher demand in water in case of irrigation and this corroborates Olivera et al. (2006) who reported different positive response of irrigation on cashew nuts yield according to the genotypes used.

Conclusion

This research investigated the effects of different water regimes and origins on cashew total dry biomass, height and survival percentage. These parameters were influenced by the genetic factors due to the differences observed according to the origin. The water regime had a significant effect on the total dry biomass, height and survival percentage with a reduction observed in STR and an increase observed in ETM1 suggesting cashew sensitivity to drought and irrigation as a tool to maintain and/or improve cashew performance under drought. The origins had different responses of total dry biomass, height and survival percentage depending on the water regime. The cashew of Diakadougou origin seemed to be more drought tolerant and the cashew of Ouessa origin more drought sensitive and more water demanding in case of irrigation. The results of this research are a contribution for adaptation of cashew based agroforestry systems to drought under climate change. However, the results of this research suggest further research to study the effect of drought and irrigation on physiological parameters of the 3 cashew origins studied.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

YNC is the first author of this article because he developed the research protocol, collected and analysed the data and initiated this manuscript. GZ supervised the work.

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