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Research Article

Water Deficit Severity Increases Tuber Sprouting Attributes of Tacca Leontopetaloides (L.) in Tropical Semi-Arid Conditions

Loyapin Bondé[1, *], Abdoul Faouzi 1er Jumeau Ouédraogo[1], Pawend-taoré Christian Bougma[2], Abdou Dramane Tinto[1], Francois Wenemi Kagambéga[3], Oumarou Ouédraogo[1], Joseph Issaka Boussim[1]

[1]Department of Plant Biology and Physiology, Université Joseph KI-ZERBO, Ouagadougou, Burkina Faso

[2]Department of Forestry Engineering, Université Yembila Abdoulaye TOGUYENI, Fada N'Gourma, Burkina Faso

[3]Institute of Environmental and Agricultural Research (INERA), Centre National de la Recherche Scientifique et Technologique (CNRST), Ouagadougou, Burkina Faso

Abstract

Tacca leontopetaloides, is a semi-wild food plant slightly domesticated and underutilized in tropical semi-arid regions due to the lack of information on its planting techniques, notably tuber sprouting attributes. This study aimed to assess the effect of water deficit severity on tuber sprouting attributes of *T. leontopetaloides* for improving its domestication strategies in the context of increasing drought events. Experiment trials were conducted in controlled conditions using a randomized complete block design, including four treatments based on water stress conditions: 100% field capacity (control), 75% (mild stress), 50% (moderate stress), and 25% (severe stress). Results showed that tuber sprouting rate significantly increased with water stress severity (X^2 = 15.75; df = 3; p-value = 0.001276), with the lowest (37.5%) and highest (87.50%) rates recorded under control and severe stress conditions, respectively. In contrast, water deficit has no significant effect on tuber sprouting time, which ranged from 218 to 225 days after sowing, indicating a long dormancy. Tuber dormancy breaking started in April when ambient temperature increased. Our findings revealed that tuber sprouting of the species requires less water, indicating that its planting should occur in pre-rain season. This study provided significant insights to shape research on ecological drivers of *T. leontopetaloides* tuber dormancy.

Keywords

Domestication, Drought, Sprouting Rate, Tuber Dormancy

1. Introduction

Tacca leontopetaloides is a wild food plant (WFP) widely distributed in tropical and equatorial climate regions from western Africa through southern Asia to northern Australia [1, 2]. The tubers of the species are traditionally used as staple

*Correspondence: Loyapin Bondé (loyapinbonde@yahoo.fr)

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foodstuff and/or famine food in different tropical regions, contributing significantly to people subsistence in food crisis events [3, 4]. However, the species remains largely wild-harvested [5], making it under-utilized species, and reducing its contribution to food security.

The domestication of *T. leontopetaloides* arouses great scientific interest due to the quality of its starch for food and pharmaceutical purposes, as well as the decline of its wild populations caused by land use and climate changes [6, 7]. Although tubers are increasingly considered promising propagation materials in sub-humid Asian areas where limited cultivation has been initiated, their sprouting behavior remains poorly understood [8]. Literature indicated that the species reproduces both sexually and asexually through true seeds and seed-tubers, respectively [7], but the sexual reproduction is limited by a low seed germination capacity [9, 10].

Vegetative propagation through tubers offers a potential to climate change adaptation because they promote rapid seedling growth and enhance their resilience to drought events [11]. However, despite their importance as propagules, tuber sprouting attributes are poorly investigated. This knowledge gap limits the development of effective domestication and conservation strategies. Previous investigations were focused on how tuber size, media composition, and water deficit influence seedling growth traits, as well as on their tuber production [12, 13]. Information on a possible dormancy in tubers and factors affecting tuber sprouting are still missed, while they are essential to improve the species conservation and domestication strategies [14].

The tubers of the species are vegetative seeds enabling it to survive the dry season and regenerate when climatic conditions are favorable, suggesting that the species has a physiological dormancy. According to Xu et al. [15], dormancy is a well-recognized adaptive mechanism that allows seed survival under harsh environmental conditions and ensures germination occurring when conditions become suitable. In some tuberous plants, such as potatoes, tuber dormancy is regulated by biochemical reactions and physiological processes that prevent them from sprouting even under suitable environmental conditions [16]. Understanding these mechanisms has been essential for improving propagation techniques and crop productivity. Regarding *T. leontopetaloides*, no information is available about its tuber dormancy, and the environmental factors regulating sprouting, particularly under water-limited conditions typical of Sahelian ecosystems, limiting the species domestication process. Therefore, understanding Tacca tuber dormancy and its response to water deficit is crucial for improving the propagation strategies, the domestication efforts, and the valuation of this underutilized species. This study aimed to analyze tuber dormancy and sprouting ability under different water deficit conditions. In tropical semi-arid areas, where climate conditions are highly stressful, we assumed that water deficit is responsible for Tacca tuber dormancy.

2. Materials and Methods

2.1. Study Area

Experimental design was installed in the Department of Environment and Forest research station of the National Center for Scientific and Technological Research (CNRST) located at 12°22′49″N latitude and 1°30′23″E longitude. Tubers used for experiments were harvested in natural vegetation, especially in the classified forest of Gonsé (12°22′60″N, 1°18′0″W), located at around 20 km from the experimental station and characterized by similar environmental conditions. The study area is located in the Sudano-Sahelian climate zone of Burkina Faso, where the average annual rainfall and temperature at the study period were 816.5 mm and 29.77°C, respectively. With an aridity index (AI) of 0.28, the study area is under tropical semi-arid climate conditions [17]. Daily temperature variation during the sprouting experiment is illustrated in Figure 1.

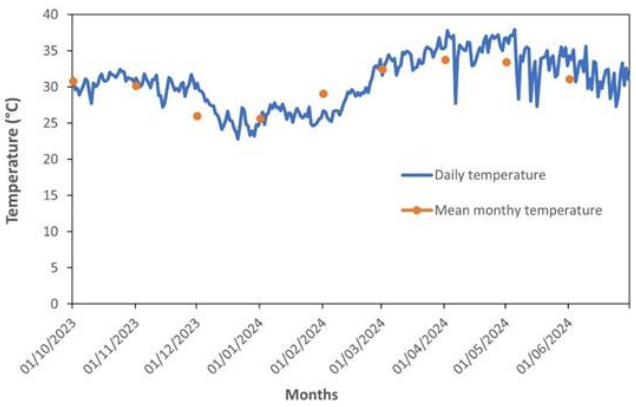


Figure 1. *Temperature variation during the experiments period.*

2.2. Experimental Design

Tubers were harvested during their maturity period, which is highlighted by the change in leave color from green to yellow [18]. Individual tubers were directly weighted on field using electronic balance (precision: 2, 000 g ± 1 g). Tuber weight ranged from 4.4 to 137.7 g. plant-1. To optimize the germination process, soil was collected directly from the same forest plots where the tubers were harvested, ensuring similar edaphic conditions. Then, before sowing, the collected soil was mixed with sand at a proportion of 25% and sterilized to eliminate unwanted seeds, and promote more uniform germination. sprouting trials were conducted using a randomized complete block design, with four (4) replications, and four (4) treatments based on water deficit conditions. Within each replication, six (6) pots were installed per treatment, resulting in a total of 96 growth pots (4 treatments × 6 pots × 4 replications = 96 pots). The diameter and height of the individual growth pot were 15 cm and 10 cm, respectively. Treatments included four levels of water deficit, which were defined based on the

gravimetric soil-water content (wg) as follows: control corresponding to the field water capacity (Fwc) (100% wg), mild stress (75% wg), moderate stress (50% wg), and severe stress (25% wg).

wg was determined at the laboratory using growth pots. A sample of germination soil was first weighed and dried in an oven at 65 ℃ until a constant dry weight was obtained. Then, the dry soil, weighing 3,100 g, was saturated with water in a growth pot, and left to drain for 48 hours (drying out). When no more drops were flowing from the bottom, the saturated soil weight was determined, and the gravimetric soil-water content was calculated using equation (1). Water required was consequently provided every three days to each treatment (0.40 L for control plots, 0.30 L for mild stress, 0.20 L for moderate stress, and 0.10 L for severe stress), from tuber sowing until the end of the experiments. Observations were concomitantly made during pots watering to register the occurrence of tuber sprouting. The experiments lasted over nine months, from October 2023 to June 2024.

$$wg = [(SSW- DSW) / DSW] \times 100 \quad (1)$$

where SSW= Saturated Soil Weight, and DSW = Dry Soil Weight.

2.3. Data Analysis and Statistical Tests

Four sprouting attributes, especially sprouting time (period from tuber sowing to their sprouting), mean sprouting time (period at which 50% of tubers have sprouted), sprouting rate, and sprouting duration (time from the first sprouting to the last) were calculated. Generalized Linear Model -GLM (family = binomial, link = logit) was performed to assess the effect of water deficit on tuber sprouting status, which was coded as follows: 0= unsprouted tuber, and 1= sprouted tuber. Tuber weights was used as co-variables in the model to adjust the effect of tuber size on their sprouting. GLMs, with Poisson error distribution (log link function) were performed to test the effect of water deficit on germination time, which is expressed in number of days, and therefore considered as counting data [19]. Chi-squared test at 5% significance level was performed to assess the effect of water deficit on tuber sprouting rate. All statistical analyses were performed using R software version 4.3.1.

3. Results and Discussion

3.1. Effect of Water Deficit on Tuber Sprouting Status and Rate

Water deficit has significant and positive effect on tuber sprouting status (Table 1), meaning that tuber sprouting increased with water deficit levels. The Chi-squared test showed that tuber sprouting rate was significantly influenced by water deficit levels (X^2 = 15.75, df = 3, p-value = 0.001276), with the highest rate (87.50%) recorded in plots under severe water deficit, and the lowest (37.50%) in control plots. In general, tuber sprouting rate increased with water deficit level (Figure 2). These results indicate that lightly or moderately watered growing media are mostly suitable for Tacca tuber sprouting, which is beneficial for the species planting in a context of recurring drought events due to climate change. When tubers are permanently in humid conditions, this probably leads to their rotting, which could explain the low germination rate observed in the control plots. Indeed, persistent high humidity stimulates the growth and activity of pathogens responsible for tuber rot [20]. Hrytseva and Skivka [21] found that the prevalence of *Pectobacterium atrosepticum*, the pathogen responsible for soft rot in potato tubers, was strongly and positively correlated with monthly sums of precipitation during the growing season. In addition, seed-tuber sprouting generally involves water loss [22], suggesting that light watering is sufficient during the sowing period.

Tuber weight was positively correlated with their sprouting status, suggesting that large tubers have a high germination capacity compared to small tubers. This is consistent with observations made on potato (*Solanum tuberosum* L.), in which larger seed tubers exhibited the highest germination rate [23, 24]. Larger tubers contain more buds, which increases their germination capacity [24].

Table 1. *GLM results indicating the effect of water deficit and tuber size on Tacca tuber sprouting status (WDG= Water deficit gradient; TW= Tuber weight).*

	Estimate	SE	z value	Pr (>|z|)
(Intercept)	-2.38592	0.80312	-2.971	0.002970**
WDG	0.94523	0.24745	3.820	0.000133***
TW	0.04006	0.01948	2.056	0.039770*

Significance of model coefficients: *: p < 0.05, **: p < 0.01, ***: p < 0.001; Model statistics (AIC= 107.18; Residual deviance = 101.18).

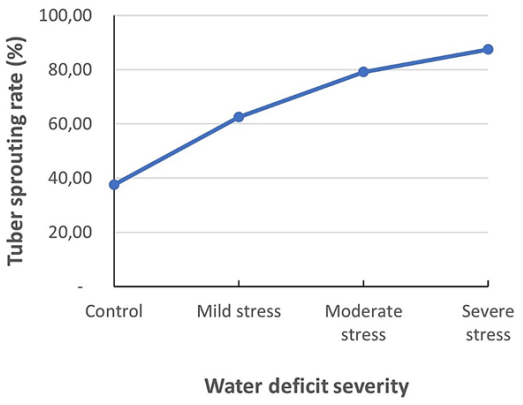


Figure 2. *Variability in tuber sprouting rate along water deficit gradient.*

3.2. Effect of Water Deficit on Tuber Sprouting Time

Results showed that both water deficit gradient and tuber size have no significant effect on Tacca tuber sprouting time ($p > 0.05$, respectively, Table 2). These results suggest that tubers of the species have a physiological dormancy. Indeed, tuber sprouting started approximately at the same time, regardless of the level of water deficit (Table 3). Tuber sprouting was observed on 225th day after sowing for control pots, 220th day both for mild and moderate water deficit, and on 218th day for pots under severe water deficit. Tuber dormancy varies greatly from short to long within species and between species depending on genetic traits, environmental factors, and harvest time [25, 26]). For instance, Kwambai et al. [27] found that the dormancy of tubers of *Solanum tuberosum* ranged from 44 to 173 days according to the cultivars of the species. Dormancy in T. leontopetaloides is quite similar with those observed in *Dioscorea alata*, which lasting from 163 to 217 days depending on harvesting time [28]. The authors found that longest dormancy was recorded in tubers harvested at early maturity stage. The long dormancy of *T. leontopetoides* tubers observed in this study can be attributed to the species' adaptation to dry climatic conditions, which is confirmed by the fact that water deficit had significant variation in tuber dormancy. This is consistent with observation made by Dogramaci et al. [26], who reported that potato species with longer dormancies tend to originate from semi-arid regions. In addition, tubers of *T. leontopetaloides* used for experiments were harvested at the end of September, which may be considered as earlier harvesting period and could probably explained the long dormancy observed. According to Spennemann [8], unprocessed tubers of the species can be stored for up to six months, after which they begin to sprout. Some tuber species, such as *Dioscorea rotundata* have longer dormancy (288 to 311 days) than T. leontopetaloides [29].

Tuber sprouting dates observed in this study occurred in April, which was the hottest dry period (Mean temperature = 35.46°C, Figure 1) and the pre-rain season, suggesting that environmental factors, especially high temperature probably plays a key role in breaking tuber dormancy. Temperature was found to be one of the most important factors affecting tuber sprouting behavior in many tuber species, such as *Solanum tuberosum*, *Momordica subangulata*, *Momordica dioica*, and *Momordica sahyadrica* [30, 31]. Deligios et al. [32] found that, tubers of Solanum tuberosum exposed at 38°C recorded the highest tuber sprouting activity compared to those under low temperatures, and was therefore considered as the most effective temperature range both for dormancy termination and for promoting tuber sprouting.

Table 2. *GLM results indicating the effect of water deficit and tuber size on Tacca tuber sprouting time ((WDG= Water deficit gradient; TW= Tuber weight).*

	Estimate	SE	z value	Pr (>|z|)
(Intercept)	5.1741184	0.0307861	168.066	<2e-16***
WDG	-0.0057608	0.0091396	-0.630	0.528ns
TW	-0.0003218	0.0004739	-0.679	0.497ns

Significance of model coefficients: ns: non-significant, *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$, Model statistics (AIC= 474.48, Residual deviance = 21.29).

Table 3. *Germination time attributes according to water deficit gradient (WDG: Water deficit severity, SD: Sprouting duration, MST: Mean sprouting time).*

WDS	SD (days)	MST (days)
Control	13 (from 225 to 238 day)	230
Mild stress	32 (from 220 to 252 day)	235
Moderate stress	32 (from 220 to 252 day)	235
Severe stress	30 (from 218 to 248 day)	229

4. Conclusion

This study revealed that water deficit is more relevant for Tacca tuber sprouting out than breaking their dormancy. Severe water deficit was found to be the most suitable for promoting tuber sprouting of *T. leontopetaloides*. Temperature increasing seems to be the main environmental factor stimulating the termination of tuber dormancy. Our findings suggest that Tacca planting should be made in pre-rain season in dry climate areas. This is a useful information to shape the species cultivating. Given the long dormancy of Tacca tubers (approximately 7 months), further research is needed to define the optimal conditions for tuber storage to secure their viability. Investigations are also required to assess the effect water deficit on the species growth and tuber production.

Abbreviations

AI	Aridity Index
Fwc	Field Capacity
SSW	Saturated Soil Weight
DSW	Dry Soil Weight
GLM	Generalized Linear Model

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Author Contributions

Loyapin Bondé: Conceptualization, Formal Analysis, Funding acquisition, Methodology, Project administration, Writing – original draft

Abdoul Faouzi 1er Jumeau Ouédraogo: Data curation, Writing – review & editing

Pawend-taoré Christian Bougma: Formal Analysis, Writing – review & editing

Abdou Dramane Tinto: Data curation, Writing – review & editing

Francois Wenemi Kagambéga: Writing – review & editing

Oumarou Ouédraogo: Writing – review & editing

Joseph Issaka Boussim: Writing – review & editing

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Data Availability Statement

The data is available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

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