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Desertification Combating and Ecological Restoration of Selected *Acacia* Species from Sub-Sahara, Savanna Regions

Mulik Abbaker Ibrahim Yousif[1, 2], Yan Rong Wang[1, *]

[1]State Key Laboratory of Grassland Agroecosystems, College of Pastoral, Agricultural Sciences, and Technology, Lanzhou University, Lanzhou, P. R. China

[2]Department of Forestry Sciences, Zalingei University, Zalingei, Sudan

Email address:
yrwang@lzu.edu.cn (Yan Rong Wang)
*Corresponding author

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Abstract: The *Acacia* species are widely distributed in the Sub-Sahara, Savanna regions and are of significant importance in terms of ecological remediation, afforestation programming, and economic value. Seed dormancy is common in *Acacia* species, and it creates difficulties in seed testing and planting. The initial aim of the current study was to assess the influence of a different temperature and different levels of water potential for germination based on the hydrothermal time models that had been successfully prophesying germination demand in several threat categories. Seeds of four *Acacia* species were treated at different temperature (15°C, 20°C, 25°C, 30°C and 35°C) and different levels of osmotic stress (0, -.4, -0.8, and -1.2 MPa). The results revealed that the degree of dormancy variation among the species, they were 81% for *A. nilotica*, 74% for *A. seyal*, 15% for *A. mellifera*, and 5% for *A. senegal*. Whereas, the optimal temperatures responded is 25°C for A. *seyal*, and *A. senegal*, *A. nilotica*, and 20°C for *A. mellifera*. Therefore, there are negative correlations appeared within germination percentages and water potential, *A. seyal*, and *A. senegal* was displayed a drought-tolerant significantly lower levels of water stress. In contrast, *A. nilotica* and *A. mellifera* indicated less drought-tolerant of promoting water stress.

Keywords: *Acacia*, Temperature, Water Stress, Hydrothermal Time, Germination, Drought, Restoration

1. Introduction

Acacia species are rising normally in Savanna areas, there are most serious sources noted to be useful for livelihoods, gum, food, fuel, firewood, timber, forage, fiber, tannins, domestic utensils, handicrafts, nitrogen-fixing, soil stabilization, medicine, ornamentals, shade, shelter, and Agroforestry system. Besides, have a significant trait in degraded land in arid, semi-arid and desert districts. *Acacia seyal, A. nilotica, A. mellifera,* and *A. senegal* are the most promising fodder trees and their flowers, bark, fruits, gum, roots, and stems used for medicinal purposes [1, 2]. Whereas, these species adapt to very erratic climate conditions in dunes arid, semi-arid, desert, and saline land, further protective environmental conditions [3]. Along with, thus, it can live in

high temperatures and drought sand [4-7]. So, desertification combating and drought is one of the most severe environmental stresses affecting trees and crop growth and development and ultimately reducing yield potential [8]. Besides, drought acceptance is a multifaceted trait that involves several morphological adaptive and metabolic ways. Thus, deciphering the genetic basis of drought tolerance mechanisms in plants remains a challenging task [9]. Indeed, the temperature is an essential trigger for seed germination, of *Acacia* species require light within 20-30 and 25, 35°C [10-13].

Further, many studies evaluated the effect of water potential and temperature in seed germination ability modeled by hydrothermal time models [14-16]. This model has been multiple purposes to process seed germination

progress also provide measuring of yield coefficients and the physiological time those frequently used to show potential rank temperature, screen germplasms and water probable responses of species [14, 17-19]. The borders defined as three models to get the measure of germination response of water stress and temperature. Furthermore, the benefit of knowing about the ecological relationships within plant species. Seed germination response to water potential and temperature of several species, ecosystems have been resolved independently [20-24]. However, soaking osmotic solutions such as polyethylene glycol (PEG), glycol, in seeds able broke seed dormancy and promoting seedling growth [25]. Appropriate periods of priming depending on osmotic chosen, of water stress, osmotic solution, temperature during priming, and plant species [26]. The priming method was presented for breaking seed dormancy and enhancing seedling growth also priming allows the metabolic procedure to be necessary for germination before actuality germination to get the start [27]. The positive effects of priming have been indicated for various species, for instance, chickpea [28, 29]. Shorter germination time, emergence overall seedbed environmental and broad temperature range of germination, leading to homogeneity, the best crop establishment and improved harvest yield and quality, particularly under stress and the abnormal situation in the field are the typical responses to seed priming [1, 30]. Moreover, the influence of temperature and water potential on seed germination could be modeled by hydrothermal time models [14-16, 31]. There are little data about the effect of osmotic stress and temperature on *Acacia* seed germination [5, 32-34]. This makes vital candidate species for food and forage trees in drylands [35]. *Acacia* species have evolved many strategies to adapt to dune sand and drought surface environment, including rapid growth after germination, long hypocotyl, and pronounced drought and heat tolerance [35, 7]. Therefore, most Acacia species have durable seed coats impervious to water. One of the characteristics of the seeds of some desert species is a thick testa that does not allow water to enter [36]. Although, this species represents a new tree alternative for the future providing as food and forage production [2, 37, 38].

The present work evaluates the influence of different levels of salt stress and also temperature for germination according to the hydrothermal time model's response of selected *Acacia* seeds, and identify the more tolerant in under drought stress.

2. Materials and Methods

2.1. Seed Collection

Seeds of *Acacia seyal, A. nilotica, A. senegal,* and *A. mellifera* were collected from Darfur, Western Sudan. The seed collection from December 2015 to February 2016, the mean yearly temperature is 20-30°C, with an average annual rainfall of 200-1200 mm. The seeds were selected by sorting out the healthy, uninfected seeds of almost uniform size. These seeds were stored in plastic boxes at 5°C and were used

for evaluating different treatments.

2.2. Impact of Water Potential

The influence of water potential on germination was tested by incubating seeds at 20°C lights for 21 days. Samples of four replicates of 50 seeds were used for each treatment. Seeds were examined by diverse stages of (PEG 6000) solution that preciously created three levels of osmotic potential (0, -0.4, -0.8, and -1.2 MPa) [39].

2.3. Influence of Temperature

Temperature responses were examined in scarifying seeds incubated at several temperatures (15°C, 20°C, 25°C, 30°C and 35°C).

2.4. Influence of Hydrothermal Time

Thermal time model of the cumulative germination values [probit (g)], suboptimal temperature range and supra-optimal temperatures were regressed and pooled against a function of time (t_g) also temperature (T) Eq. 1 [40].

Probit $(g) = [\log (T - T_b) t_g - \log (^{\theta}T_{(50)}]/ ^{\sigma}_{\theta T}$ probit (g) is the probit transformation of cumulative germination percentage g, which linearizes the sigmoidal time subjected in a long-timescale [41]. T_b base temperature under which seed did not germinate, T germination temperature, $^{\theta}T_{(50)}$ median thermal time to germinate, t_g actual time to germination of fraction g and $^{\sigma}_{\theta T}$ standard deviation of log $^{\theta}T$ demand between individual seeds or the population of the slope of the probit of a regression line. Those cumulative germination values [probit (g)], whole times as well as, supra-optimal temperatures were regressed and pooled against a function of time (t_g).

However, temperature (T) as in Eq. 2 [42-44]. probit $(g) = [T + ^{\theta}_{T} / t_g) - T_{c (50)}] / ^{\sigma}_{Tc}$.

When $^{\theta}T$ is the thermal time constant of whole individual seeds, $^{\sigma}T_c$ the standard deviation within individual seeds in the population of the slope of the probit regression line and $T_{c (50)}$ the median temperature of germination. The value of $T_{c (50)}$ able to get from the regression of the time when $g = 50\%$ and probit $(g) = 0$. $^{\theta}T$ was evaluated by the iterative method. The $^{\theta}T$ produced the least residual was considered to be the best estimate of $^{\theta}T$ [31]. For hydro time model [45, 46]. possible to define as:

$$^{\theta}H = [\Psi - \Psi_b (g)] t_g$$

When $^{\theta}H$ is the hydro time constant of fixed seed population, $\Psi_b (g)$ the threshold water potential of a specific germination fraction g, Ψ the reality water potential of germination testing, and t_g the real-time to germination of fraction g. The normal distribution of $\Psi_b (g)$ values between seeds on the population are propertied by the median [$\Psi_{b (50)}$] and standard deviation ($^{\sigma}\Psi_b$), the formula able to derived using continuous probit analyses to describe ahead [46, 40]. probit $(g) = [\Psi - (^{\theta}_H/t_g) - \Psi_{b (50)}] / ^{\sigma}\Psi_b$

Kindness-of-fit among the observed and predicted data was estimated using the coefficient of the determination (R^2).

2.5. Seed Germination Test

The seed germination was exposed before and after the final experiment incubated at 20°C. Four replicates of 50 seeds were used for each treatment in the experiment and placed on top of 2 layers of filter paper in 90 mm Petri dishes. A seed was considered to have germinated when the radical extension was at least 0.5cm. Seeds were evaluated according to the international rules for seed testing association [47]. The experiments were laid out in a completely randomized design.

2.6. Statistical Analysis

Differences of water potential and temperature is affected in germination rate ($1/T_{50}$) and germination percentage of seed species were analyzed using SPSS 20.0 software by using one-way ANOVA ($P < 0.05$). Duncan's multiple range test was followed to compare means of the germination rate ($1/T_{50}$) and germination percentage within treatments on each species when significant differences.
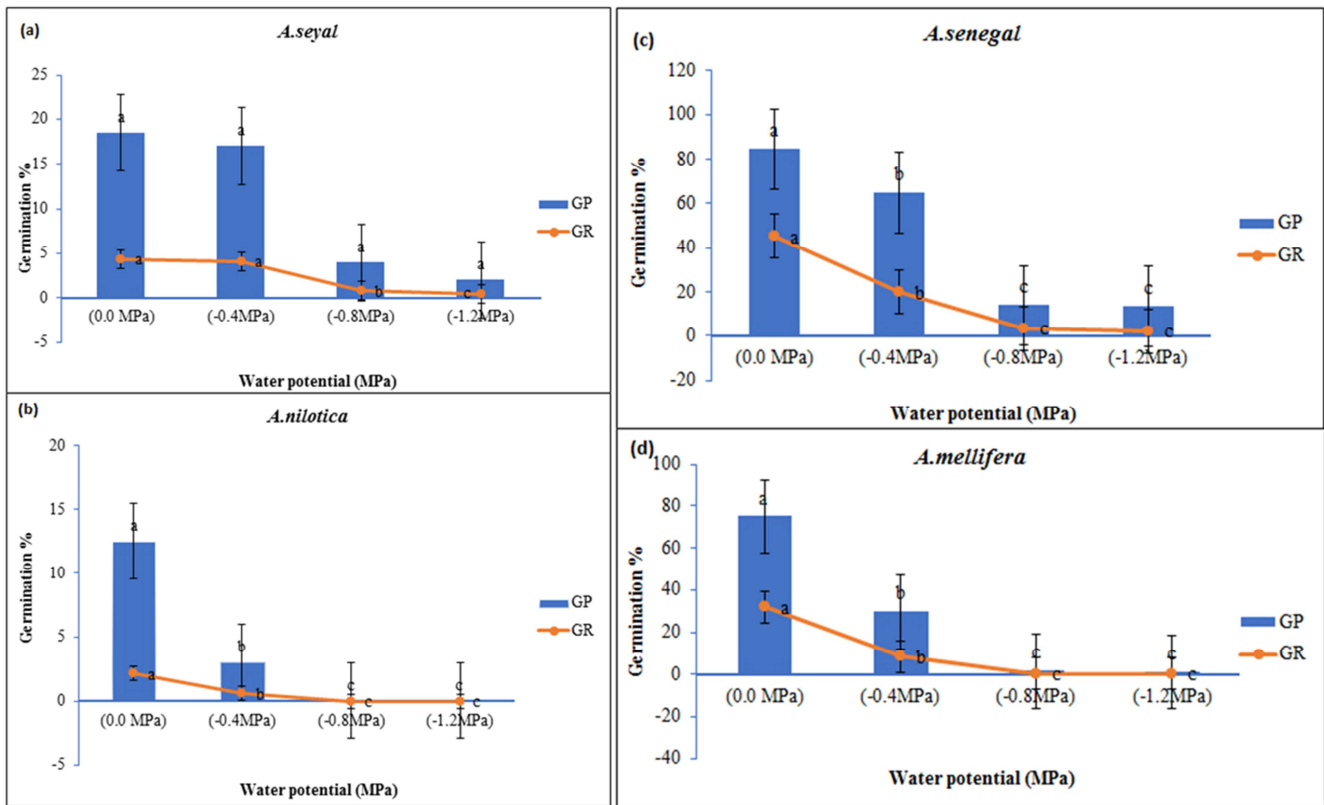

Figure 1. a, b, c, d. Seed germination percentage and rate of Acacia species at water potential.

3. Results

3.1. Effect of Water Potential Performance

A significant influence of water stress on germination percentage and germination rate ($P < 0.05$). Germination percentage of *A. nilotica* and *A. mellifera* was failed to germinate at (− 0.8 and −1.2 MPa). Consequently, significantly diminished by (− 0.4 MPa). Germination percentages of *A. seyal* and *A. senegal* were significantly declined by (−1.2 MPa). Germination rates generally reduced as water stress decreased, which is always associated failed of seed emergence. The fitted with hydro time models displayed the germination dynamics of whole *A.* species perfect for responding high-water stress (> − 0.4 MPa). Though, there is a failure to display germination dynamics in low water stress (< -1.2 MPa) in those species (Figure 1a, b, c, d).

3.2. Impact of Temperature Performance

The temperature has a significant influence on percentage and germination rate ($1/T50$) for each species ($P < 0.05$). Germination percentage of *A. mellifera* and *A. senegal* permeable seed dormancy lead to in high germination at 20°C, 75%, 84.5%, and 25°C, 80%, 88.5%, respectively. Moreover, significantly decreased by 30°C 15.5%, 11% and 35°C, 13%, 8%. Germination percentages of *A. seyal* and *A. nilotica*, impermeable seed coat dormancy, were shown germination at 20°C, 18.5%, 12.5%, and 25°C, 20.5%, 14.5%, respectively. Further, significantly diminished by 30°C and 35°C. Germination rates generally enhanced as temperature increased and then decreased as temperature increased. Germination rate regularly improving linearly with increased temperature up to a maximum point, after that, diminished to a ceiling temperature (Figure 2a, b, c, d).
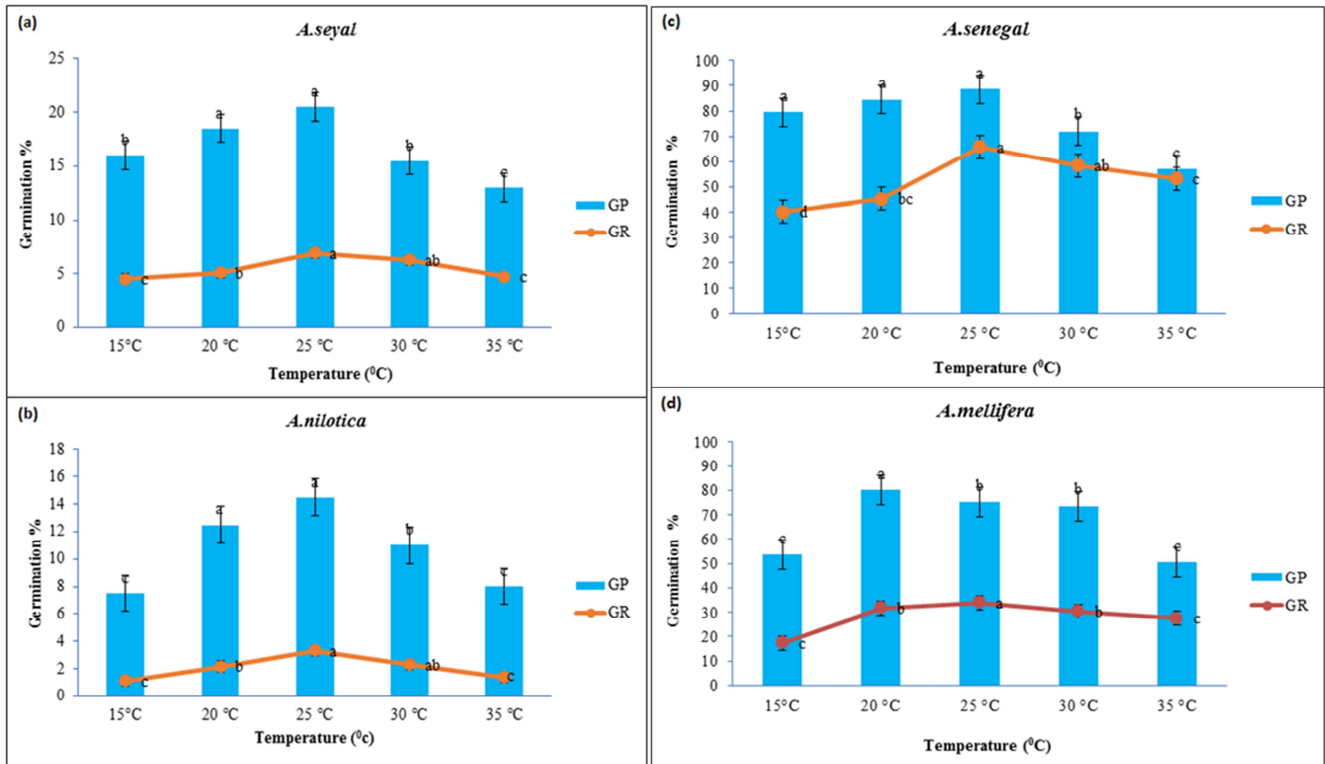
Figure 2. a, b, c, d. Seed germination percentage and rate of Acacia species at different temperature ranges.

3.3. Influence of Hydrothermal Time Models

The hydrothermal time models have indicated excellent germination time when exposed *Acacia* seeds in various water stress and temperatures. The subtleties of seed germination of *Acacia* species in temperature were outstandingly depicted the thermal time model in supra-optimal and suboptimal temperatures. Nevertheless, there was no difference within those species at ^{0}T (*50*) and Tc (50) in supra-optimal and suboptimal temperatures (Figures 3, 4; Tables 1, 2, 3).

Table 1. Seed germination parameters of Acacia species, based on thermal-time model analysis at suboptimal temperature.

Species	$^\theta$T $_{(50)}$ (°C)	$^\sigma{_{\theta T}}$	T_b (°C)	R^2
Seyal	50	0.1	10	0
Nilotica	50	0.1	10	0
Senegal	50	0.1	10	0
A. mellifera	1.22	39.3	0.58	0.46

Notes: T_b = constant base temperature in suboptimal temperature range, $\theta_{T (50)}$ = thermal time on 50% of germinate seeds, $^\sigma{_{\theta T}}$ = standard deviation for $^\theta$T $_{(50)}$.

Table 2. Seed germination parameters of Acacia species based on thermal-time model analysis at supra-optimal temperature.

Species	$T_{c (50)}$ (°C)	$^\sigma T_c$	^{0}T (°Cd)	R^2
A. seyal	-331.7	- 411.1	1140.6	0.679
A. nilotica	- 2.40	-2.63	1.84	0.581
A. senegal	82.8	-57.4	184.1	0.510
A. mellifera	2.13	-2.67	1.47	0.639

Notes: $T_{c (50)}$ = ceiling temperature on 50% of germinate seeds, $^\sigma T_c$ = standard deviation for $T_{c (50)}$ at supra-optimal temperature $^\theta$T = constant thermal time.

Table 3. Seed germination parameters of Acacia species, water potential based on hydro-time model analysis.

Species	$^\theta$H (MPa. d)	$\Psi_{b (50)}$ (MPa)	$^\sigma{_{\Psi b}}$	R^2
A. seyal	6.10	0.50	0.98	0.88
A. nilotica	7.08	0.77	0.84	0.91
A. senegal	3.08	- 0.66	0.44	0.90
A. mellifera	1.75	- 0.26	0.38	0.90

Notes: $\Psi_{b(50)}$ = base water potential on 50% of germinate seeds, $^\theta$H = constant hydro time, $^\sigma{_{\Psi b}}$ = standard deviation of $\Psi_{b(50)}$.
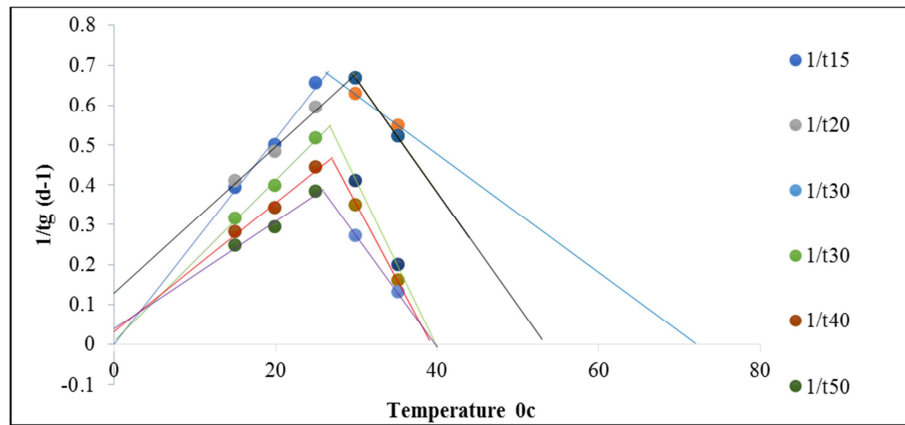
Figure 3. *Linear regression for germination rate (1/t$_g$) of each temperature and subpopulation at supra-optimal and suboptimal temperature ranges of A. senegal.*
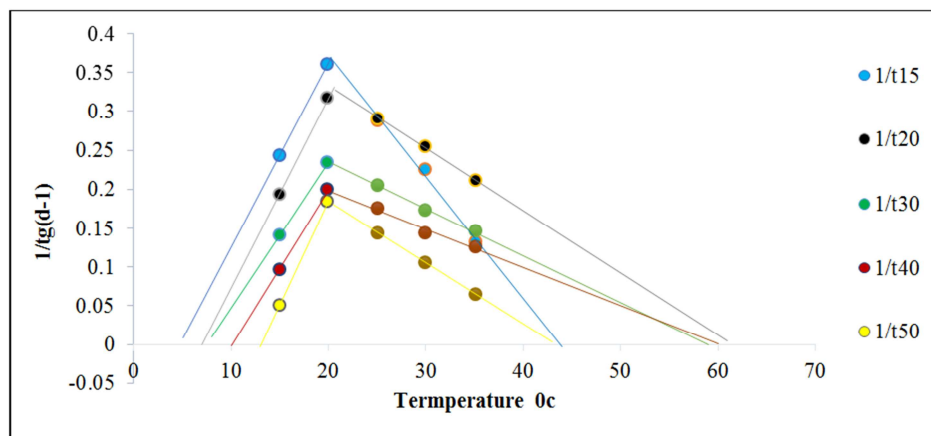

Figure 4. *Linear regression for germination rate (1/t$_g$) of each temperature and subpopulation at supra-optimal and suboptimal temperature ranges of A. mellifera.*

4. Discussion

This study presented that the water stress for *A. nilotica and A. mellifera*, exhibited higher sensitivity and less tolerance to encourage water stress than other species. Supplementary *A. senegal and A. seyal* could germinate at lower water stress (-1.2 MPa). Germination responses to water stress and temperature of *Acacia* seeds can relate to the plant ecology and naturally seedling survived after germination is in need of soil water availability. The current research justified with previous researches of another species [48-52]. The capability of the seeds to germinate in low soil water, water stress can enhance ecological advantages of the species that permit to display in areas anywhere less resistant drought species should not. Seeds that they germinate below low water availability after a rainfall incident. [53] recommended that considering plant populations and seed characteristics, do not follow a regular pattern. This means that some species, the impact of drought created with (PEG 6000) on germination is not significant, and germination was not influenced by drought stress. [54] description that the negative potentials between (-0. 4 and -0. 8 MPa) are the better condition for studying the germination

surface of different genotypes of plants under drought stress. The temperature responses of the plants to view the environments in which they are adaptable. Even more, differences within the species have substantial ecological significance [55, 23]. Species from tropical sections ordinarily require high-level temperature for germination in temperate species [56]. The optimal temperature for germination of four *Banksia* species has been positively correlated together with the mean annual temperature in the area of seed originates [57, 58].

For the existing study, the seed germination of *Acacia* species completely more tolerant of low temperatures. The hydrothermal time models have been indicated that the hydro time and thermal time models may describe very well the germination time course of scarified *Acacia* seeds in various water potentials and temperatures. Furthermore, the recent research justified with previous researches of another species [58, 17, 55, 24]. A benefit of these two models to seeds incubated across a range of water potentials and temperatures is that the similarity and variation in germination able to ascribe to define underlying factors, for example, $^{\sigma}T$, T_b, and $^{\theta}T_{(50)}$ [15].

Additionally, the summary derived from the parameters of these two models is compatible with the raw data also, more

comfortable to compare and understand between these species [15, 24]. The content of these, $\Psi_{b\,(50)}$ and Tb designate a similar trend within species by their response to water potential and temperature. Even more, hydrothermal time, that standard deviation as early as providing very important information that the biological and ecological significance, such as seeds those had high $\Psi_{b\,(50)}$ and low $^{\theta}H$ can have a rapid germination rate by nothing water potential, but to be strong support inhibited of germinating in lower water stress species [17, 24].

5. Conclusion

Differences have been found between four species in their reaction to these treatments. The most resistant to drought conditions are *A. seyal and A. senegal*, which may specify the potential for a further selection of drought-tolerant of lines for future climate scenarios. It seems that the potential osmotic levels were most cynical. The hydrothermal time models performed incredibly to demonstrate the germination time course of scarified seeds of these *Acacia* species in response to water stress and temperature, the models possible to be useful materials in comparative researchers for germination of seeds of the plants that they produce seeds efficacious by physical dormancy.

These outcomes raised the most critical trait of water stress, and temperature response efficiency in the seed of *Acacia* species will be resulting in the future to promote sustainable agriculture, livelihoods, ecological restoration, afforestation program and degradation lands in arid, semi-arid and desert regions.

Our study is very instructive research, we recommended for follow-up in future work, also, it would be much better to carry additional studies using molecular data, which could be contributing to the open a new field of research to identify genotypic differences and dormancy behavior which are genetically controlled.

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Conflicts of Interest

All the authors do not have any possible conflicts of interest.

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