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Effect of Low and High Temperature Regimes on Seed Dormancy and Germination of *Ricimus Communis* (Castor Oil plant) using Thermal Time Method

Hemen Terseer Joseph*

Department of Biological Sciences, faculty of science, Nigeria Police Academy Wudil kano.

***Corresponding Authors:** **Hemen Terseer Joseph,** *Department of Biological Sciences, faculty of science, Nigeria Police Academy Wudil kano.*

Abstract: *The Ricinus communis, commonly known as the castor oil plant, is widely cultivated for its oil-rich seeds. Understanding the effects of temperature on seed dormancy and germination is crucial for optimizing agricultural practices. Seed dormancy and germination are significantly influenced by environmental factors, particularly temperature, which regulates metabolic processes essential for seed development. This study aimed at investigating the impact of extreme low and high temperature regimes on the seed dormancy and germination of Ricinus communis using the thermal time method. The experiment was conducted under controlled temperature conditions. Seeds of Ricinus communis were subjected to two temperature regimes: low (wet) and high (heat). Seed emergence was monitored at regulated times (5, 10, and 15 days). Data on seed emergence rates (%SDE), plant height, number of leaves, and plant width were collected. The thermal time model was employed to analyze germination parameters, including actual temperature (T), maximum temperature (Tc), base temperature (Tb), optimal temperature (To), initial germination time (tg), and thermal time (Tt).The study found that temperature regimes significantly influenced seed emergence and early plant development. Under wet conditions, seed emergence rates were 18.18%, 13.64%, 9.09%, and 12.12% at 5, 10, and 15 days, respectively. In contrast, high temperature regimes resulted in lower seed emergence rates, with the highest at 15.15%. Plant height, number of leaves, and plant width varied significantly between treatments. Wet conditions promoted greater plant height and leaf number compared to high temperature conditions. The results indicate that extreme temperatures adversely affect seed emergence and early growth of Ricinus communis. The thermal time method effectively elucidates the temperature ranges that may influence seed dormancy and germination. For optimal agricultural practices, maintaining temperatures within a moderate range is recommended to enhance seed emergence and plant development. Further research should explore long-term effects of temperature variations and their impact on overall plant yield.*

keywords: *castor- oil, dormancy, germination, seed, temperature*

1. INTRODUCTION

The seed is an important stage in the higher plant life cycle with respect to its survival as a species. It is the dispersal unit of the plant, which is able to survive the period between seed maturation and the establishment of the next generation as a seedling after it has germinated. For this survival, the seed, mainly in a dry state, is well equipped to sustain extended periods of unfavorable conditions (Finch-Savage and Leubner-Metzger, 2021). To optimize germination over time, the seed enters a dormant state. Dormancy prevents pre-harvest germination as well. Numerous studies have been performed to better understand how germination is controlled by various environmental factors and applied chemicals. However, still very little is known about the process by which the embryo emerges from the seed to complete germination and how embryo emergence is blocked in dormant seeds (Bewley, 2022).

Castor oil plant is an economically important crop known for its oil-rich seeds, which are used in various industrial and pharmaceutical applications. Seed dormancy and germination are key stages in the life cycle of castor oil plants, and their successful completion is essential for crop establishment and yield potential (Singh and Singh, 2021). However, temperature fluctuations, especially extreme temperatures, can disrupt these processes and affect seedling emergence and crop performance (Gummerson, 2022). The thermal time model, based on the concept of accumulated heat units required for seed dormancy release and germination, provides a quantitative framework for studying temperature effects on seed development and germination. By tracking the accumulation of heat units over time, researchers can predict seed dormancy release and germination rates under different temperature regimes.

Extreme temperature regimes, including both low and high temperatures, can disrupt seed dormancy release and germination processes in the castor oil plant, leading to reduced crop establishment and yield potential (Bewley and Black, 2020). However, the specific effects of temperature stress on seed dormancy and germination of castor oil seeds remain poorly understood. This study aims to address this knowledge gap by investigating the impact of extreme low and high temperature regimes on seed dormancy release and germination of castor oil seeds using a thermal time model.

2. MATERIALS AND METHODS

2.1. Procurement and Viability test of the Seeds

The processed and packaged seeds of *Ricinus communis* were purchased from an open market in Makurdi, Benue State. It was authenticated by a Botanist in the Department of Biological Sciences, Benue State University, Makurdi. The viability for the seeds was tested in accordance with the methods of Germ (1975) and Copeland (1976).

2.2. Experimental Design and Procedure

The study consists of two temperature regimes treatment experiment (that is, low and high) arranged as 2x4x3 factorial treatment structure in a completely randomized design (CRD). Each of the 12 experimental units were replicated twice giving a total of 24 experimental units. The temperature regimes treatment factor was categorized into two (A and B), the seeds treated with hot water and the seeds treated with cold water respectively. Temperature regulated intervals factor of 55^0C, 50^0C, 45^0C and 40^0C and the time regulated factor in the duration of 5, 10 and 15 seconds were used.

2.3. Experimentation

Ten seed from group A were treated with hot water at various temperature intervals of 55^0C, 50^0C, 45^0C and 40^0C and each of the duration of 5, 10 and 15 seconds. The same numbers of seeds were also used for group B and were treated with chilled (cold) water obtained from a refrigerator at the temperature intervals of 12^0C, 9^0C, 6^0C and 3^0C for the same duration in seconds. Folded wire gauze with a handle was used in removing the seeds from the hot and cold water into separate containers with distilled water for 5 minutes and thereafter spread on a white paper to be sun dried for 4 hours before planting experiment. The seeds planting experiment were performed in 24 polythene pots packed with composited sandy-loam soil with an ambient temperature of 24^0C. Ten (10) seed per pot were planted at a depth of 1.5cm for all the replicates. The potted seeds and seedlings were lightly watered twice a day (morning and evening) to ensure adequate water supply for germination. Seeds were considered to have germinated when the tips of the radical has grown free above the soil and the rate of germination (in terms of number of leaves) for each plant category were also recorded and calculated at the interval of three days after germination. The number of leaves was calculated using the formula prescribed by Abubakar and Maimuna (2013).

NL = Tnl / Tnsem

Where, **NL** = Number of leaves

Tnl = Total number of leaves on a particular plant

Tnsem = Total number of seeds emerged

2.4. Data analysis

Statistical values (data) from this study were analyzed using Statistical Package for the Social Sciences (IBM SPSS) Version 23.00. Descriptive statistics was used to represent quantitative data as percentages and means values were compared by one-way Analysis of Variance (ANOVA).

3. RESULTS

This study evaluated the effect of extreme low and high temperature regimes on the growth parameters of *Ricinus communis.*

Table1a. *Effect of temperature Regimes on seed Emergence of Ricinus Communis*

Temperature Regimes		Seed emergence at Regulated time(s) (5)	(10)	(15)	Total	%SDE
Wet (Low)	3	6	6	0	12	18.18
	6	5	4	0	9	13.64
	9	2	4	0	6	9.09
	12	0	5	3	8	12.12
High	40	0	4	1	5	7.58
	45	5	5	0	10	15.15
	50	3	4	0	7	10.61
	55	0	5	4	9	13.64
Total		**25**	**26**	**15**	**66**	

Note: % SDE = percentage seed emergence

Table1b. *Determination of thermal – time model for low and high temperature regimes for germination of seeds a sub and supra optimal temperature.*

Temperature regime (°C)	Measurement parameters T(°Cd)	Tc	Tb(°C)	To(°C)	tg	Tt(°Cd)	%SDE	
Wet (Low)	3	-	12	3		**10**	**<2**	**18.18**
Heat (High)	40	55	-	45		**10**	**>56**	**15.15**

Note**:**

T= Actual temperature at which the seeds can germinate.

Tc = Max temperature at which seeds can germinate.

Tb = Lowest temperature at which germination occur.

tg = initial Time required for the seeds to germinate.

Tt (g_1) = Thermal – time in degree – base temperature at which germination cannot occur

Tt (g_2) = Thermal – time in degree – the high temperature at which germination cannot occur

SDE = Seed Emergence Rate.

To = Optimal Temperature (Sub & Supra).

3.2a Main Effect of Low and High Temperature on the height of *Ricinus communis.*

The main effect of extreme low and high temperature on the height of *Ricinus communis* is presented in Table 2a The comparative main effect of the treatments (Wet and heat) on the height of *Ricinus communis* showed a significantly higher ($P<0.05$) height in plants under wet treatment compared to the heat treatment at 5, 10, 15 respectively .The main effect of the temperature at 10s showed higher height at 3^0C, although no significant difference($P>0.05$) was observed compared to plants at 6, 9 and 4^0C respectively . The least plant height was observed at 55^0C with no significant difference ($P>0.05$) observed compared to the plants at 50^0 C . Similarly, at 10 and 15s, the highest height was observed at 3^0C, while the least height was observed at 55^0C.

Table2a: *Main Effect of low and high temperature regimes on the height of Ricinus Communis*

Treatment		Plant Height (cm) 5s	10s	15s
	Wet (Low)	5.24 ± 1.22^a	5.15 ± 1.81^a	3.64 ± 1.05^a
	Heat (High)	3.44 ± 1.59^b	2.73 ± 0.68^b	2.69 ± 0.90^b
	FLSD (0.05)	**1.500**	**1.898**	**0.110**
	Temperature			
	$3^0{}_C$	5.91 ± 0.72^a	6.87 ± 0.73^d	4.74 ± 0.78^g
Wet (Low)	$6^0{}_C$	5.66 ± 0.49^a	3.34 ± 0.60^{ce}	3.04 ± 0.89^h
	$9^0{}_C$	5.97 ± 0.65^a	3.63 ± 0.84^{cef}	3.53 ± 1.02^h
	$12^0{}_C$	3.41 ± 0.50	6.76 ± 0.49^d	3.24 ± 0.68^h
	$40^0{}_C$	5.34 ± 0.51^a	3.64 ± 0.40^e	3.66 ± 027^g

Heat (High)	45^0C	4.49 ± 0.47	2.40 ± 0.70^f	3.29 ± 0.43^h
	50^0C	2.04 ± 0.54^b	2.50 ± 0.00^f	2.04 ± 0.54^i
	55^0C	1.90 ± 0.35^b	2.36 ± 0.38^f	1.79 ± 0.39^i
	FLSD (0.05)	**0.899**	**1.000**	**0.799**

Key Note: Values are mean ± standard deviation in triplicates. Mean values with similar superscript within the column are not significant.

2.2b Interaction Effect between Treatments and Temperature on the Height of *Ricinus Communis*.

The interaction effect between treatments and temperature on the height of *Ricinus communis* is presented in Table 2b. The result showed that the height of the plants in the Wet treatment was higher at 3^0c compared to 12^0c (P<0.05). No significant difference (P>0.05) was observed compared to 6 and 9^0C at 15^0C. After 10s of observation, no significant difference (P>0.05) was observed between 3^0C and 12^0C; and also between 6^0C and 9^0C. At 15s, the height was significantly higher (P<0.05) at 3^0C compared to the other temperature levels. In the heat treatment, the plant height was observed to be higher (P<0.05) at 40^0C compared to the other temperatures at 5 and 10s . No significant difference (P>0.05) was however observed compared to 45^0c after 15s

Table2b. *Interaction effect between treatments and temperature on the height of Ricinus Communis*

Treatment	**Temperature**	**Plant Height (cm)** 5s	10s	15s
	3°c	5.91 ± 0.72^a	6.87 ± 0.73^c	4.74 0.78
Wet (Low)	6°c	5.66 ± 0.49^a	3.34 ± 0.60^d	3.04 ± 0.89^f
	9°c	5.97 ± 0.65^a	3.63 ± 0.84^d	3.53 ± 1.02^f
	12°c	3.41 ± 0.50	6.76 ± 0.49^c	3.24 ± 0.68^f
	40°c	5.34 ± 0.51	3.64 ± 0.40	3.66 ± 0.27^g
Heat (High)	45°c	4.49 ± 0.47	2.40 ± 0.70^e	3.29 ± 0.43^g
	50°c	2.04 ± 0.54^b	2.50 ± 0.00^e	2.04 ±0.54^i
	55°c	1.90 ± 0.35^b	2.36 ± 0.38^e	1.79 ± 0.39^i
FLSD (0.05)		**2.800**	**1.500**	**2.111**

Key Note: Values are mean ± standard deviation in triplicates. Mean values with similar superscript within the column are not significant.

3.3a Main Effect of Treatment and Temperature on the Number of Leaves of *Ricinus communis*

Table 3a shows the main effect of treatment and temperature on the number of leaves of *Ricinus communis*. The main effect of the treatment showed that plants in the Wet treatment had significantly (P<0.05) more number of leaves than the heat treatment throughout the period of observation. The main effect of temperature on the number of leaves showed more leaves at 9^0C after 5s of observation; although no significant difference (P>0.05) was observed compared to 3^0C, 6^0C and 40^0C respectively. After 10s of observation, the leaves observed at 3^0C were significantly (P<0.05) more than the ones observed at all other temperatures. After 15s, the leaves were more at 3^0C, but no significant difference (P>0.05) was observed compared to 40^0C.

Table3a. *Main Effect of treatment and temperature on the number of leaves of Ricinus Communis*

Treatment		**Number of Leaves** 5s 10s15s		
	Wet (Low)	16.07 ± 2.55^a	9.07 ± 6.16^a	6.39 ± 5.03^a
	Heat (High)	**7.75** ± 3.87^b	3.93 ± 4.22^b	3.75 ± 4.48^b
	FLSD (0.05)	**7.550**	**3.011**	**2.990**
	Temperature			
	3^0C	14.57 ± 2.44^a	16.14 ± 2.27	12.57 ± 1.62^f
Wet (Low)	6^0C	15.43 ± 2.76^a	9.00 ± 2.08^c	8.57 ± 2.07^h
	9^0C	16.71 ± 2.63^a	0.00 ± 0.00^e	6.43 ± 3.21^h
	12^0C	17.57 ± 1.62^a	11.14 ± 1.46	0.00 ± 0.00^g
	40^0C	11.71 ± 3.09^a	10.00 ± 2.24^c	9.29 ± 3.15^f
Heat (High)	45^0C	5.14 ± 4.14^b	2.29 2.69^d	0.00 ± 0.00^g

	50^0C	7.14 ± 2.54[b]	3.43 ± 1.90[d]	5.71 ± 2.69
	55^0C	7.00 ± 2.65[b]	0.00 ± 0.00[e]	0.00 ± 0.00[g]
	FLSD (0.05)	**5.515**	**2.000**	**4.111**

Key Note:Values are mean ± standard deviation in triplicates. Mean values with similar superscript within the column are not significant.

3.3b Interaction Effect between Treatments and Temperature on the Leaves of *Ricinus communis*

Table 3b shows the interaction effect between the treatments and temperature on the leaves of *Ricinus communis*. In the Wet treatment, the leaves were more at 12^0C after 5s, of observation with however no significant difference (P>0.05) observed between the respective temperatures. After 15s, a significantly higher (P<0.05) number of leaves was observed at 3^0C . In the heat treatment, more leaves were observed at 40^0C compared to the other treatments throughout the period of observation (P<0.05).

Table3b. *Interaction effect between treatments and temperature on the leaves of Ricinus Communis*

Treatment	Temperature	Number of Leaves 5s	10s	15s
	3°c	14.57 ± 2.44[a]	16.14± 2.27	12.57 ± 1.62
Wet (Low)	6°c	15.43 ±2.76[a]	9.00 ± 2.08	8.57 ± 2.07
	9°c	16.71 ± 2.63[a]	0.00 ± 0.00	6.43 ± 3.21
	12°c	17.57 ± 1.62[a]	11.14 ± 1.46	0.00 ± 0.00
	40°c	11.71 ± 3.09	10.00 ± 2.24	9.29 ± 3.15
Heat (High)	45°c	5.14 ± 4.14[b]	2.29 ± 2.69	0.00 ± 0.00
	50°c	7.14± 2.54[b]	3.43 ± 1.90	5.71 ± 2.69
	55°c	7.00 ± 2.65[b]	0.00 ± 0.00	0.00 ± 0.00
FLSD (0.05)		**4.600**	**1.000**	**1.990**

Key Note: Values are mean ± standard deviation in triplicates. Mean values with similar superscript within the column are not significant.

3.4a. Main Effect of Treatment and Temperature on the Plant Width

Table 4a shows the main effect of treatment and temperature on the width of *Ricinus communis.* The main effect of the treatment showed no significant difference (P>0.05) between the Wet and heat treatments after 5s and 10s respectively. After 15s, the width was higher (P<0.05) in the heat treatment compared to the Wet treatment. The main effect of the temperature showed no significant difference (P>0.05) in plant width between the respective temperatures throughout the period of treatment.

Table4a. *Main Effect of treatment and temperature on the plant width*

Treatment		Plant Width 5s 10s15s		
	Wet (Low)	2.0 ± 0.32	2.02 ± 0.32	1.69 ± 0.30
	Heat (High)	2.16 0.33	1.95 ± 0.34	2.01 ± 0.35
	FLSD (0.05)	**NS**	**NS**	**0.115**
	Temperature			
	3^0C	2.21 ± 0.27	2.21 ± 0.26	1.63 ± 0.26
Wet (Low)	6^0C	1.86 ± 0.24	1.26 ± 0.24	1.63 ± 0.26
	9^0C	1.79 ± 0.27	1.79 ± 0.27	1.79 ± 0.42
	12^0C	2.21 ± 0.27	2.21 ± 0.27	1.73 ± 0.29
	40^0C	2.29 ± 0.27	2.09 ± 0.32	1.91 ± 0.11
Heat (High)	45^0C	2.10 ± 0.37	2.04 ± 0.36	2.01 ± 0.46
	50^0C	2.07 ± 0.41	1.89 ± 0.31	2.06 ± 0.33
	55^0C	2.19 ± 0.30	1.79 ± 0.36	2.07 ± 0.45
	FLSD (0.05)	**NS**	**NS**	**NS**

Key Note: Values are mean ± standard deviation in triplicates. Mean values with similar superscript within the column are not significant.

3.4b Interaction Effect between Treatments and Temperature on *Ricinus communis*

The interaction effect between the treatments and temperature on *Ricinus communis* width is presented in Table 4b. The highest width after 5s and 10s of treatment was observed at 40^0c in the heat treatment.

No significant difference (P>0.05) was however observed compared to the other temperatures. After 15s on the other hand, the width was higher at 55^0C with no significant difference observed (P>0.05). In the Wet treatment, the width after 5s and 10s of treatment was higher at 3^0C and 12^0C respectively with no significant difference (P>0.05) observed between the treatments. No significant difference (P>0.05) between the temperatures was observed after 15s of treatment.

Table4b. *Interaction effect between treatments and temperature on Ricinus Communis width*

Treatment	Temperature	Plant Width 5s	10s	15s
	3°c	2.21 ± 0.27^a	2.21 ± 0.27^c	1.63 ± 0.26
Wet (Low)	6°c	1.86 ± 0.24^b	1.86 ± 0.24^e	1.63 ± 0.26
	9°c	1.79 ± 0.27^b	1.79 ± 0.27^e	1.79 ± 0.42
	12°c	2.21 ± 0.27^a	2.21 ± 0.27^c	1.73 ± 0.29
	40°c	2.29 ± 0.27^c	2.09 ± 0.32^f	1.91 ± 0.11
Heat (High)	45°c	2.10 ± 0.37^c	2.04 ± 0.36^f	2.01 ± 0.46
	50°c	2.07 ± 0.41^c	1.89 ± 0.31^f	2.05 ± 34
	55°c	2.19 ± 0.30^c	1.79 ± 0.36^f	2.07 ± 0.45
FLSD (0.05)		**0.225**	**0.225**	**NS**

Key Note: Values are mean ± standard deviation in triplicates. Mean values with similar superscript within the column are not significant.

4. DISCUSSION

The study on the effects of extreme low and high temperature regimes on seed dormancy and germination of *Ricinus communis* (castor oil plant) using the thermal time method yielded significant insights into the impact of temperature on seed emergence, plant height, leaf number, and plant width. The data obtained during this study shows a clear differentiation in seed emergence rates under varying temperature regimes. Wet (low) temperature regimes yielded a higher percentage of seed emergence compared to high temperature regimes. Within the wet regime, the emergence was highest at lower time points, indicating a prompt germination response, which gradually decreased over time. Conversely, in high-temperature conditions, seed emergence was notably lower, with significant emergence only at the beginning, followed by a marked decline. This suggests that *Ricinus communis* seeds are more sensitive to higher temperatures, which adversely affect their germination capability

The result indicates the parameters for the thermal-time model. The lowest temperature (Tb) at which germination occurred was 12°C for wet conditions, with an optimal temperature (To) of 10°C. In contrast, the high-temperature regime showed an optimal temperature (To) of 45°C but indicated that temperatures beyond 55°C inhibited germination. This model underscores the temperature sensitivity of *Ricinus communis,* where supra-optimal temperatures significantly reduce germination rates.

The effect of temperature on plant height showed that, Plants in the wet (low) temperature regime consistently exhibited greater heights at all-time points compared to those in high-temperature conditions. This suggests that low-temperature regimes support better overall growth in terms of height. Furthermore, interaction effects reinforce that lower temperatures are more conducive to plant height growth than higher temperatures, where growth is significantly stunted.

As shown in this study the number of leaves was significantly higher in plants exposed to wet (low) temperature regimes compared to high-temperature regimes. The maximum number of leaves was observed at lower temperatures with a notable decline as temperatures increased. This trend aligns with the plant height data, indicating that extreme temperatures (both low and high) negatively impact foliage development.

Plant width, detailed results showed less variation compared to height and number of leaves, though wet (low) temperatures still resulted in slightly larger widths than high temperatures. Interaction effects suggest that moderate temperatures are optimal for width development, similar to height and leaf number trends.

5. CONCLUSION

The study demonstrates that *Ricinus communis* exhibits significant sensitivity to temperature variations, affecting seed dormancy, germination, and early growth performance. Lower temperature regimes (wet conditions) generally favor better seed emergence, greater plant height, more leaves, and consistent plant width compared to high-temperature regimes. The thermal-time model further elucidates that temperatures exceeding the optimal range (10°C for low and 45°C for high regimes) negatively impact germination and subsequent plant growth.

6. RECOMMENDATIONS

Based on the findings, the following recommendations can be made:

i. Cultivation of *Ricinus communis* should be optimized around the identified optimal temperature ranges (10°C for low and 45°C for high regimes) to ensure maximum germination and growth performance. Avoiding temperatures beyond these ranges is crucial to prevent adverse effects on plant development.

ii. For regions with extreme temperature variations, employing controlled environment agriculture (CEA) techniques can help maintain optimal growth conditions. This includes using greenhouses with temperature regulation systems to stabilize the growth environment.

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