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Temperature and Light Effects on Germination Behaviour of African Eggplant (*Solanum aethiopicum* L.) Seeds

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ABSTRACT

Background: A preliminary study of the African eggplant seeds obtained from farmers sources recorded a wide variation in percentage germination under ambient conditions (25±2°C). The germination percentage ranged from 0% to 25%, while fresh seeds ranged between 53% and 87%. As temperature and light are important factors of seed germination, the current study investigated the effect of temperature on the germination pattern and the influence of light interaction with temperature on seed germination of African eggplant (*Solanum aethiopicum* L.) under controlled conditions.

Methods: Seeds of two cultivars of African eggplant were subjected to constant and alternating temperatures and under three light exposure regimes. Seed quality was accessed by per cent germination, mean germination time, time to reach 50% germination, germination index and mean daily germination.

Result: The highest percentage germination under constant temperatures was recorded at 25°C (76%) and 20°C (74%). The maximum temperature and light conditions required for maximum seed germination quality (76-95%) at the shortest time (4-5 days) was 30/20°C under alternating 8/16 hours light and dark.

Key words: African eggplant, Light, Seed germination, *Solanum aethiopicum,* Temperature.

INTRODUCTION

The African eggplant (*Solanum aethiopicum* L.) is one of the most commonly consumed fruit vegetable in Ghana and other West African countries. In both quantity and value, the crop is third after tomato and onion and before okra (Osei *et al*., 2010). Unfortunately, the long neglect of this crop by formal crop improvement programmes except in breeding has resulted in absence or lack of formal seed system for the production and supply of quality seeds. Farmers therefore, rely largely on saved and recycled seeds for planting with observed erratic germination behaviour and poor seedling establishment.

A preliminary study of the African eggplant seeds obtained from farmers and breeder sources recorded a wide variation in percentage germination under ambient conditions (25±2°C). The germination percentage (normal seedlings) ranged from 0% to 25% while fresh seeds ranged between 53% and 87% (Botey, 2019, unpublished data). This observation could be attributed to several factors that influences germination. Previously, there have been reports on seed dormancy in cultivated varieties of eggplant (*Solanum melongena*) and *Solanum torvum,* which are close relatives of *Solanum aethiopicum* (Yogeesha *et al*., 2006; Cutti and Kulckyzynski, 2016). This type of dormancy could be either due to seed immaturity at harvest or external stimuli such as temperature and light.

Among the various germination factors, temperature is the most prominent environmental factor regulating growth and development of plants (Ghaderi *et al*., 2008). The temperature at which the maximum germination and emergence occurs tends to differ among crops and within species. Some germinate well under constant temperatures while others do well under alternating temperatures. Kamgar (2009) reported that germination of *Solanum nigrum* seeds was maximum at constant temperatures of 26°C and 30°C under 16/8 hours photoperiod. It was however, concluded that alternating temperatures of 20/12°C and 30/12°C gives a greater seed germination. Similar reports by Finch-Savage and Leubner-Metzger (2006) for five Solanum species concluded that optimum germination occurs between 28-33°C. In *Solanum torvum* seeds, maximum germination (86-95%) occurred when seeds were incubated at alternating temperatures of 20/30°C under 16 hours of light and 8 hours of dark respectively (Cutti and Kulckyzynski, 2016).

At low temperatures (5-10°C) seed germination was inhibited for *Solanum lycopersicum and Solanum nigrum* but responded to germination when temperatures increased to 15°C and above (Abdel *et al*., 2016; Dong *et al*. 2019). Torres-Gonzalez (2019) also recorded low germination at lower temperatures in studying *Solanum betaceum* and S. *quitoense*. *Solanum lycopersicum* seeds however,

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exhibited thermo dormancy, with no seed germination at 40°C, similar to an observation for *S. nigrum* at 35°C and 40°C (Dong *et al*., 2019). Wilcox and Pfeiffer (1990), had earlier also demonstrated the effect of temperature on time to germinate (days). They reported that eggplant (*Solanum melongena*) took between 8 days when germination temperatures decreased from 24°C to 12.3°C. Low temperatures of 10°C and 15°C delayed by 160 and 33.3 times to achieve 50% seed germination in several common bean genotypes (Lamichaney *et al.,* 2021).

The requirement of light for the germination of seeds of certain plant species prevents germination in places and times not favourable for seedling establishment (Fenner and Thompson, 2005). The light requirement of such seed acts as a mechanism that determines where and when germination takes place and it is important for survival of the plant species concerned, as it prevents stored seed reserves from being depleted. Some seeds germinate equally well in light and darkness, whilst others germinate better under only light or darkness (Teuton *et al*., 2004). Ochuodho and Modi (2005) reported that both light influenced seed germination of *Cleome gynandra* and temperature and this differed between the seed lots of same species. Seeds subjected to $\geq$ 12 h day^{1} at 20°C continuously significantly ($p<0.001$) reduced germination compared to those exposed to $\leq$ 8 h day^{1}. Thus, it the requirement of these two important factors for germination of especially neglected crops becomes imperative.

For a rapid and uniform germination to occur, the seed must be placed in an optimum environmental condition such as temperature, moisture and in some cases light (Fenner and Thompson, 2005). There is currently less information on the temperature and light requirement for the African eggplant seeds and how they interact to influence their seed germination pattern under controlled conditions. This study investigated the effect of temperature on the germination pattern and the influence of light in interaction with temperature on seed germination of African eggplant (*Solanum aethiopicum* L.) under controlled conditions.

MATERIALS AND METHODS

The experiment was conducted at the Seed Physiology Laboratory, Department of Seed Crop and Horticultural Sciences, University of Eldoret, Kenya from March to September 2019.

Plant material

Seeds of two cultivars of African eggplant grown in Ghana namely cv. *Oforiwaa* and cv. *Kpando* were obtained from CSIR-Crops Research Institute, Ghana. These are seeds that have been improved and currently been proposed for released into the seed system. The seeds were produced in 2018/2019 cropping season and about 4 weeks old in cold storage when they were collected for the experiment.

Seed weight and seed moisture content determination

The thousand seed weight (TSW) was determined from a sample of eight replicates of 100 seeds using an analytical balance and mean weight expressed in grams and multiplied by 10 to obtain thousand seed weight. The seed moisture content was determined using the low constant temperature oven method at 105± 3°C for 24 hours with two replicates of 2g of seeds (Brasil, 2009). Seed moisture content was expressed as a percentage of fresh weight basis (fwb).

Seed germination and temperature

Four replicates of 25 seeds were placed in petri dishes on two layers of Prat Dumas (90 mm) filter papers, moistened with 5 ml distilled water. Additional water was added to filter paper as and when necessary to keep the filter paper moist. The seeds were incubated in growth chamber (WTB binder BD 400) at constant and alternating temperatures of 15, 20, 25, 30, 35, 20/30, 30/25 and 35/20°C at 8/16 hours of light/ dark. Seeds were observed daily for germination for a period of 14 days and considered germinated when the radicle had protruded at least 2 mm from the testa.

Seed germination and light

To investigate the effects of light exposure periods on germination, seeds were incubated at temperatures of 15, 20, 25, 30/20 and 35/20°C under three different light exposure periods: 24 hours dark (L1) and 24 hours full light (L2) and 8/16 hours of light/dark alternating (L3), for a period of 14 days. The light source was 6 tubes (100cm) of TL-D 36W (Philips EcoBright®).

Determination of seed germination pattern

Germination capacity (G %) was determined as the proportion of germinated seeds in relation to the total number of seeds sown in the petri dishes. Other seed quantitative traits such as mean germination time (MGT), time to 50% germination (T_{50}), germination index (GI) and mean daily germination (MGD) were calculated using the advanced germination measurement Tool developed by Khalid (2018). The relationship dynamics among these seed quantitative traits were measured by Pearson correlation using Statistical Tool for Agricultural Research (STAR).

Data analysis

The experimental design was a completely randomized design. Variables expressed in percentages were arcsine transformed before subjected to statistical analysis. Data was checked for normality using Shapiro-Wilk test of normality, followed by analysis of variance (ANOVA).Mean separation was carried out using Tukey with a significance level of 5% (α=0.05). The Statistical Tool for Agricultural Research (STAR) was used for analysing the data.

RESULTS AND DISCUSSION

Effect of constant temperatures on seed germination (G %) of *Solanum aethiopicum* cultivars

The total germination of *cv. Oforiwa* was significantly ($p<0.001$) higher than that of *cv. Kpando* regardless of constant and alternating temperature conditions during germination (Fig 1). However, under constant temperatures

(Fig 1A), germination was maximum (74%) at 20°C and 25°C (76%) while lower temperatures of 15°C and higher temperatures of 30°C and 35°C gave the least percent seed germination ≤15% for *cv. Oforiwa*. No germination was recorded at lower (15°C) constant and higher (35°C) temperatures for *cv. Kpando* (Fig 1C).

The results is consistent with other solanum species. Kamgar (2009) observed maximum seed germination for S. *nigrum* at constant temperatures of 26 and 30°C. Similarly, Finch-Savage and Leubner-Metzger (2006) recorded optimum germination for five solanum species at 28-33 constant temperatures. The maximum germination (74%) recorded for cv. *Oforiw*a (Fig 1A) at 20°C is consistent with that of *Solanum ptychchanthum* (Zhou *et al.,* 2005) and S. *betaceum* (Mavi and Uzunoğlu, 2020). At lower temperatures, no germination occurred in both cultivars. This is consistent with other reports for *Solanum lycopersicum and Solanum nigrum,* where seeds failed to germinate at low temperatures (5-10°C) (Abdel *et al.,* 2016; Dong *et al*. 2019). This observation confirms that the African eggplant (*Solanum aethiopicum* L.) as related to the commonly cultivated relative (*Solanum melongena* L.) is a warm tropical crop and requires relatively warmer environment for germination, characterized by slow germination rates (Chen and Li, 1996).

At constant higher temperatures, seeds exhibited thermo inhibition, especially in *cv. Kpando*. This could be attributed to the inhibitory effects of protein denaturing at higher temperatures (Maguire, 1973) or embryo immaturity as reported for eggplant (Yogeesha *et al.,* 2006). Saeidnejad *et al*., (2012) also asserted that such observed differences could be due to genetic variability among the seeds. The inability of seeds to germinate at higher than optimal temperatures is attributed to a condition called thermo inhibition (Hills and van Staden, 2003). The current study corroborates with studies of other solanaceous crops. Abebe (1993) observed that seeds of *Solanum lycopersicum* seeds did not germinate at high temperatures of 35°C but germinated when temperatures reduced to 25°C or 30°C. Abdel *et al.,* (2016) later concluded that the optimal temperature for tomato is 25°C for maximum germination. Similarly, *Solanum nigrum* failed to germinate at higher temperatures of 35 and 40°C (Dong *et al*., 2019).

Effects of alternating temperatures on seed germination (G %) of *Solanum aethiopicum* cultivars

The current study further showed that seed germination increased significantly ($p<0.01$), when subjected to alternating temperatures (Fig 1B and D) for both cultivars. The highest seed germination were 95 % and 76 % for *cv. Oforiwa* and *cv*. *Kpando* respectively at alternating temperatures of 30/20°C. This suggests that African eggplant germinates well under alternating temperatures of 30/20°C, which simulates the tropical temperatures. This result concurs with reports of Chen and Li (1996) and Ullio (2003)

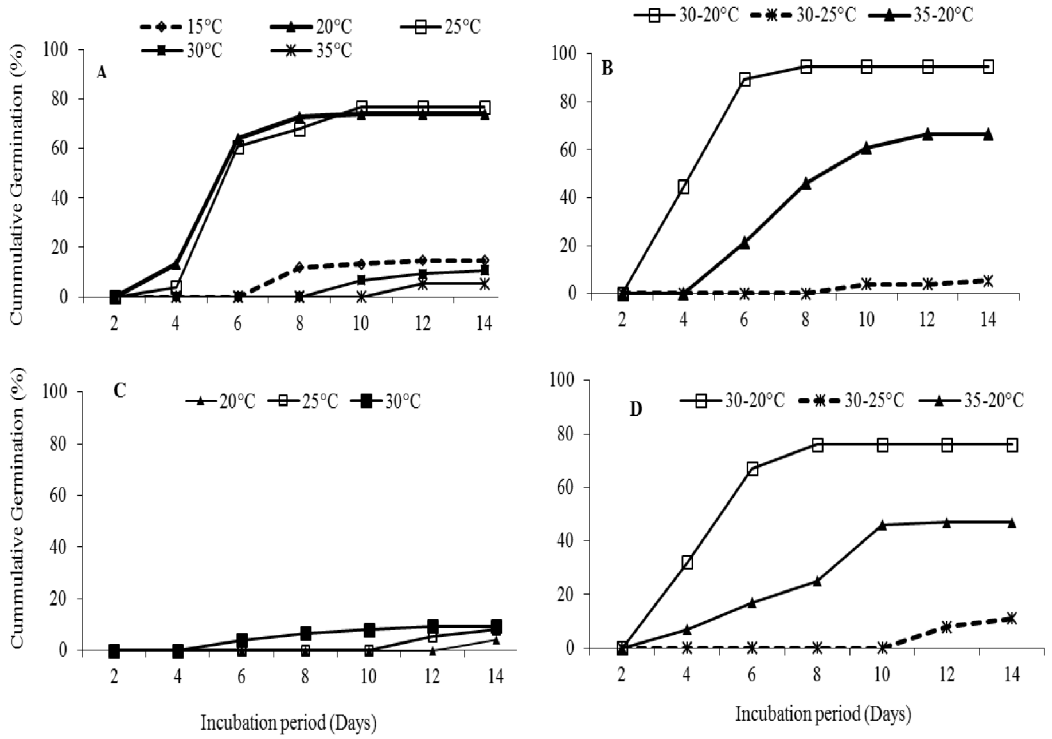

Fig 1: Germination of cv. *Oforiwa* seeds under various constant (A) and alternating temperatures (B) and cv. *Kpando* seeds under constant (C) and alternating temperatures (D) germinated under 8 hours/16 hours light and dark photoperiods.
Note: $LSD_{0.05}$ = 4.97 (A), 6.1 (B), 1.87 (C), 10.2 (D).

that seed germination in *Solanum melongena* ranges from 20-32°C with the highest germination at 27-30°C. Similarly, Cutti and Kulckyzynski (2016) reported maximum germination (86-95%) for S. *torvum* at 20/30 under 16/8 hours light and dark periods. Torres-Gonzalez (2019) and Dong *et al.,* (2019) concluded that alternating temperatures of 25/15°C and 30/20°C, gives maximum germination for *Solanum betaceum* and *Solanum nigrum* respectively. In a non-dormant seed, temperature alternations may accelerate germination by regulating the balance of growth inhibitors and promoter hormones (Copeland and McDonald, 2001; Ferreira and Borghetti, 2004). This suggests that alternating temperature is effective in increasing the germination percentages of most seeds than constant temperatures (Govindaraj *et al*., 2017).

Effect of light exposure and its interaction with temperature on seed germination

The seed germination of *cv. Oforiwa* was essentially indifferent to light although there was some minor negative effect when germinated at 20°C under full darkness (Fig 2A). This concurs with the report that many cultivated species are indifferent to light to germinate (Miranda *et al*., 2017). This result is consistent with the germination behaviour of *S. nigrum,* where light had no effect on seed germination at certain constant and alternating temperatures (Dong *et al.* 2019). Seed germination of *cv. Kpando* however, was significantly ($p < 0.01$) affected when placed under full darkness (Fig 2A) or limited light (Fig 2C) at constant temperatures (20°C and 25°C). Germination improved at alternating temperatures (30/20°C or 35/20°C) and full light (Fig 2B) or limited light (Fig 2C).

This germination behaviour of *cv. Kpando* could be a temperature or light imposed dormancy (Baskin and Baskin, 1998). It further suggests that seed germination in African eggplant requires an interaction of light and temperature. At alternating temperatures (15/5°C and 20/10°C), germination was greater in darkness (75.5 and 93%) than in light/dark for *Solanum nigrum* (Dong *et al*., (2019). Similarly, Ochuodho and Modi (2005) observed that *Cleome gynandra* seeds lots failed to germinate or were lower <10% under 20°C with 24h light but improved significantly under alternating temperatures of 30/20°C. Zhou *et al*., (2005) also observed that seed germination of S. *physalifolium* was not sensitive to photoperiod and germinated well under 14 hour photoperiod or continuous darkness at 30 °C. This suggests

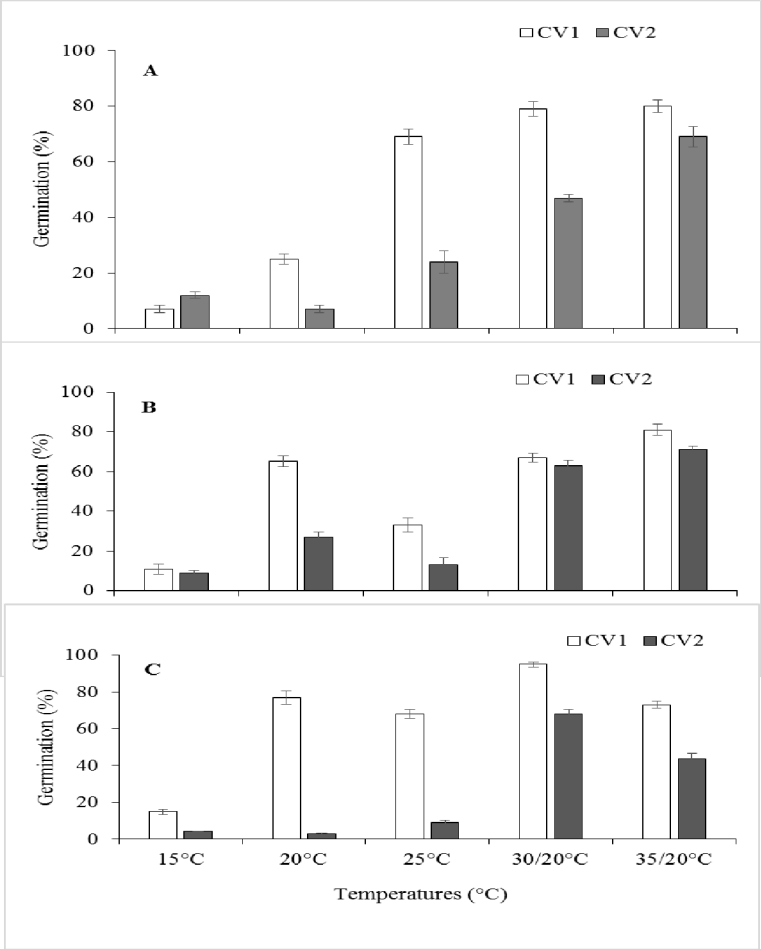

Fig 2: Effect of temperature and its interaction with light exposure on seed germination ± SEM of two cultivars of African eggplant. (CV1: cv. *Oforiwa*, CV2: cv. *Kpando*, SEM: Standard error of means).

that light effects on seed germination depends on the surrounding temperatures. Thus, seed germination in most solanum species will occur at favourable temperature regimes irrespective of the presence or absence of intermittent exposure to light as observed in the present study.

Effect of temperature and light on mean germination time (MGT) and time to reach 50% germination (T_{50})

The results of this study indicated a highly significant (α=1%) relationship between temperature and light on mean germination time (MGT) and time to reach 50% germination (T_{50}) (Table 1). The data showed that, under constant lower temperatures (15°C) at full light or alternating light/dark periods, seeds of both cultivars took more days to reach 50% germination (T_{50}) and complete germination (MGT) Table 1. Seeds took 8.3 to 8.5 days to complete germination (MGT) under 15°C but gradually reduced to (5-7 days) when temperature increased to 20°C or 25°C.

This result concurs with earlier observations by Wilcox and Pfeiffer (1990) that *Solanum melongena* seeds and pepper seeds took between 18 to 44 days to complete germination when temperature decreased from 16.7 to 14.5°C respectively. At higher temperatures of 21.1 to 24°C however, germination completed in 7-8 days (MGT). Simon *et al.,* (1976) has earlier reported similar trends for cucumber seeds where the time required for 50% of seeds to germinate increased to 14 weeks at about 14°C or below. The rate of seed germination (the reciprocal of MGT) is reported to usually increase as the temperature increase (Al-Ahmadi and Kafi, 2007) attributed to the reactivation processes occurring within the imbibing seeds (Hills and van Staden, 2003). Thus, the temperature effect observed in this study suggests that at lower temperatures, the rate of metabolic activities was retarded or enzymatic activities were inhibited (Kamaha and Magure, 1992; Thygerson *et al.,* 2002). This low temperature condition slows down the diffusion process, which causes a disruption of imbibition and escape of solutes from seeds, which are critical in the protrusion of the radicle, hence delaying germination.

Correlation dynamics among seed quantitative parameters of the African eggplant

Seed germination percentage represents the number of seeds germinated within a specified period under favourable conditions such as suitable temperature, adequate moisture and in some seeds light as observed for African eggplant in this study. In this study, all the quantitative parameters measured significantly ($p < 0.01$) related to seed germination percentage (Table 2). While mean germination time (MGT), correlated significantly with percent seed germination, giving an indication of the time taken for a seed lot to germinate, it was not strong (-0.481**) as this measure fails to account

Table 1: Effect of temperature and light on time to germinate (MGT) and time to 50% germination (T_{50}).

Cultivar	Temp.	MGT (days)			T_{50} (days)		
		L1	L2	L3	L1	L2	L3
cv. Oforiwa	15°C	5.3c	8.3a	8.5a	4.8c	8.2a	7.6a
	20°C	7.4bc	6.3bc	5.6b	6.7bc	5.2bc	5.1b
	25°C	9.7a	7.7ab	6.0b	9.5a	7.0ab	5.1b
	30/20°C	8.3ab	4.9c	4.5b	7.6ab	3.7c	3.9b
	35/20°C	5.9c	5.6bc	8.2a	4.9c	5.0bc	7.7a
cv. Kpando	15°C	9.2b	8.3ab	*	8.5b	7.7b	*
	20°C	12.0a	10.2a	*	11.5a	10.5a	*
	25°C	11.0ab	9.3a	6.9ab	10.8a	9.0ab	6.3a
	30/20°C	10.6ab	6.0c	4.9b	9.8ab	5.5c	4.1b
	35/20°C	7.0c	6.3bc	7.9a	6.1c	5.5c	7.0a

Temp.: Temperature; L1: 24 hours Full Dark; L2: 24 hours Full Light; L3: Alternating 8/16 hours of light/dark periods; *: No germination occurred. Means with the same letters are not significantly different.

Table2: Correlation dynamics among seed quantitative measurements of African eggplant.

	G (%)	MGT	MGR	MDG	CVG	GI	T_{50}
G (%)	1		.				
MGT	-0.481**	1					
MGR	0.453**	-0.966**	1				
MDG	0.979**	-0.481**	0.453**	1			
CVG	0.453**	-0.966**	0.985**	0.453**	1		
GI	0.934**	-0.675**	0.675**	0.934**	0.675**	1	
T_{50}	-0.491**	0.987**	-0.954**	-0.491**	-0.954**	-0.665**	1

G (%): Germination percentage; MGT: Mean germination time (days); MGR: Mean germination rate (day^{-1}); MDG: Mean daily germination (seed/day); CVG: Coefficient of velocity of germination (%); GI: Germination Index (seed/day); T_{50}: Time to 50% germination (days); **: Correlation is significant at the 0.01 level; *: Correlation is significant at the 0.05 level.

for the time spread and uniformity of germination (Kader, 2005). Germination index (GI) and mean daily germination (MDG) however, strongly correlated to seed germination 0.934** and 0.979** respectively (Table 2). Mean daily germination indicates the percentage of filled-seed germinating at the end of the test period divided by the number of days of the test (Diavanshir and Pourbeik, 1976). GI in the other hand from this study appears to be the most comprehensive measured parameter as it combines both the germination percentage and its speed in terms of spread and duration (Kader, 2005). These parameters are significant in giving an indication of the seed vigour and stress resistance of the African eggplant seeds studied (Kader and Jutzi, 2001).

CONCLUSION

Temperature affected germination of seeds of African eggplant. Seeds fail to germinate or <10% under low temperatures (15°C) or higher constant temperatures (30°C and 35°C). The highest percentage germination under constant temperatures was recorded at 25°C (76%) and 20°C (74%). The interactive effect of temperature and light exposure during incubation period also improved germination particularly under alternating temperatures and constant full light exposure. Lower temperatures also delayed the time to complete germination (MGT) and time to acquire 50% germination (T_{50}). Maximum seed germination (76%-95%) for the African eggplant was observed when seeds were subjected to alternating temperatures of 30/20°C under alternating 16/8 h light/dark periods. This condition also reduced the time to complete germination and reach 50% germination to 4-6 days.

REFERENCES

Abdel, C.G., Asaad, S.S. and Mohammad, D.S. (2016). Minimum, optimum and maximum temperatures required for germination of onion, radish, tomato and pepper. International Journal of Farming and Allied Sciences. 5(1): 26-45.

Abebe, Y. (1993). Improving tomato *(Lycopersicon escidentum* Mill.) seed germination under high temperature by seed priming, scarification, heatshock and light. MS Thesis, Hort. Sci. Dept. Univ. of Florida, Gainesville.

Al-Ahmadi, M.J. and Kafi, M. (2007). Cardinal temperatures for germination of *Kochia scoparia* (L). J. Arid Environ. 68(2): 308-314.

Baskin, C.C. and Baskin, J.M. (1998). Seeds: Ecology, biogeography and evolution of dormancy and germination. Elsevier, p: 666.

Brasil (2009). Ministério da Agricultura, Pecuária e Abastecimento - Secretaria de Defesa Agropecuária. Regras para análise de sementes. [Rules for seed testing, eggplant]. Brasília: Mapa/ACS. p. 82.

Chen, N.C. and Li, H.M. (1996). Cultivation and breeding of eggplant. In: Training Workshop on Vegetable Cultivation and Seed Production; AVRDC World Vegetable Center: Shanhua, Taiwan.

Copeland, L.O. and McDonald, M.B. (2001). Principles of Seed Science and Technology. 4th. edn. Norwell, Kluwer Academic Publisher.

Cutti, L. and Kulckzynski, M.S. (2016). Treatment of *Solanum torvum* seeds improves germination in a batch-dependent manner. Pesquisa Agropecuária Tropical. 46(4): 464-469.

Dong, H., Ma, Y., Wu, H., Jiang, W. and Ma, X. (2019). Germination of *solanum nigrum* (black nightshade) in response to different abiotic factors. Planta Daninha**.** 38:1-12.

Diavanshir, K. and Pourbeik, H. (1976). Germination value a new formula. Silvae Genetica. 25: 79-83.

Ferreira, A.G. and Borghetti, F. (2004). Germination: From basic to applied. ATMED. p: 324.

Fenner, M. and Thompson, K., (2005). The Ecology of Seeds. Cambridge University Press, Cambridge.

Finch-Savage, W.E. and Leubner-Metzger G. (2006). Seed dormancy and the control of germination. New Phytologist. 171: 501-523.

Ghaderi, F.A., Soltani, A. and Sadeghipour, H.R., (2008). Cardinal temperatures of germination in medical pumpkin (*Curcubita pepo* convar. pepo var. styriaca), borage (*Borago officinalis* L.) and black cumin (*Nigella sativa* L.). Asian Journal of Plant Sciences. 7(6): 574–578.

Govindaraj, M., Masilamani, P. Alex Albert, V. and Bhaskaran M. (2017). Effect of physical seed treatment on yield and quality of crops: A review. Agricultural Reviews. 38(1): 1-14.

Hills, P.N. and van Staden, J. (2003). Thermoinhibition of seed germination. South African Journal of Botany. 69(4): 455-461.

Kader, M. and Jutzi, S. (2001). Drought, heat and combined stresses and the associated germination of two sorghum varieties osmotically primed with NaCl. Phytogen. 3: 22-24.

Kader, M.A. (2005). A Comparison of seed germination calculation formulae and the associated interpretation of resulting data. Journal and Proceedings of the Royal Society of New South Wales. 138: 65-75.

Khalid, F. (2018). Advanced Germination Measurement Tool, AGRON Info-Tech. Available at:https://agronexcel.blogspot.com/2018/06/this-tutorial-is-about-advanced-seed.html.

Kamaha, C. and Magure, Y.D. (1992). Effect of temperature on germination of 6 winter wheat cultivars. Seed Sci. Technol. 20(1): 181-185.

Kamgari N. (2009). Temperature requirement for germination of *Solanum nigrum* seeds. Thesis: Department of Crop Production and Ecology, Swedish University of Agricultural Sciences, Uppsala, p. 16-18.

Lamichaney, A., Basavaraja, T., Katiyar, P.K. and Singh, N.P. (2021). Seed germination response of commonbean (*Phaseolus vulgaris* L.) genotypes to optimal and sub-optimal temperatures. Legume Research-An International Journal. 44(4): 419-424.

Maguire, J.D. (1973). Physiological Disorders in Germinating Seeds Induced by the Environment. In: Seed Ecology. [Heydecker W. (ed.)], London, Butterworths. p. 289-310.

Mavi, K. and Uzunoğlu, F. (2020). Effects of pre-sowing treatments with allelopathic plant extracts on tree tomato (*Solanum betaceum* Cav.) seedling emergence and performance. Agronomía Colombiana. 38(2): 190-196.

Miranda, R.M.D., Dias, D.C.F.D.S, Picoli, E.A.D., Silva, P.P.D., Nascimento, W.M. (2017). Physiological quality, anatomy and histochemistry during the development of carrot seeds (*Daucus carota* L.). Ciênc Agrotec. 41: 169-180.

Ochuodho, J. O. and Modi, A. T. (2005). Temperature and light requirements for the germination of *Cleome gynandra* seeds. South African Journal of Plant and Soil. 22(1): 49-54.

Osei, M.K., B. Banful, C.K. Osei and M.O. Oluoch (2010). Characterization of African eggplant for morphological characteristics. Journal of Agricultural Science and Technology. 4(3): 33-37.

Ullio, L. Eggplant growing. Agfacts (2003**).** H8.1.29. 1-4. Available at: https://www.dpi.nsw.gov.au/_data/assets/pdf_file/0004/126292/Eggplant-Growing-Agfact-H8.1.29.pdf (accessed on 1 December 2019).

Saeidnejad, A.H., Kafi, M. and Pessarakli, M., (2012). Evaluation of cardinal temperatures and germination responses of four ecotypes of *Bunium persicum* under different thermal conditions. International Journal of Agriculture and Crop Science. 4(17): 1266–1271.

Simon, E.W., Minchin, A., McMenamin, M. and Smith, J.M. (1976). The low temperature limit for seed germination. New Phytologist. 77: 301-311.

Teuton, T.C., Brecke, B.J., Unruh, J.B., MacDonald, G.E., Miller, G.L. and Ducar, J.T. (2004). Factors affecting seed germination of tropical signal grass (*Urochloa subquadripara*). Weed Science. 52: 376-381.

Thygerson, T., Harris, J.M., Smith, B.N., *et al*. (2002). Metabolic response to temperature for six populations of winter fat (*Eurotia lanata*). Thermochimica Acta. 394 (1-2): 211-217.

Torres-González, A.M. (2019). Seed dormancy and germination in tree tomato (*Solanum betaceum* Cav.) and lulo (*Solanum quitoense* Lam.). Revista Colombiana De Ciencias Hortícolas. 13(3): 336-347.

Wilcox, G.E. and Pfeiffer, C.L. (1990). Temperature effect on seed germination, seedling root development and growth of several vegetables. Journal of Plant Nutrition. 13(11): 1393-1403.

Yogeesha, H.S., Upreti K.K., Padmini, K., Bhanuprakash, K. and Murti, G.S.R. (2006). Mechanism of seed dormancy in eggplant (*Solanum melongena* L.). Seed Sci. Technol. 34: 319-325.

Zhou, J., Deckard, E.L. and Ahrens, W.H. (2005). Factors affecting germination of hairy nightshade seeds. Weed Science. 53: 41-45.