Egypt. J. Bot. **Vol. 61,** No.2, pp. 541-551 (2021)

Egyptian Journal of Botany
http://ejbo.journals.ekb.eg/

Seed Germination, Seedling Growth and Photosynthetic Responses to Temperature in the Tropical Tree *Moringa oleifera* and Its Relative Desert, *Moringa peregrina*

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MORINGA oleifera and *Moringa peregrine* are cultivated in many areas in Almadinah Almunawwarah, western part of Saudi Arabia. The aim of the present study is to examine the responses of seed germination, seedling growth and photosynthetic performance for two *Moringa* species to different temperature treatments; 15/12°C, 25/22°C and 35/32°C; day/night. The obtained results indicated that seeds of both species could germinate at a wide range of temperatures with optimum temperature for highest percentage of germination, at 25°C. The results showed that most parameters of growth and the photosynthetic performances of the two species were highest at 25°C. However, the chlorophyll contents of *M. oleifera* and most values of chlorophyll fluorescence for both species were similar across the three temperature treatments. Additionally, the outcomes of this study showed that Moringa can be cultivated in many different regions with different temperatures.

Keywords: *Moringa oleifera*, *Moringa peregrina*, Photosynthetic responses, Seed germination, Seedling growth, Temperature.

Introduction

The Moringa genus contains 13 tree species and belongs to the Moringaceae family, most of them are found in the tropics (Olson & Carlquist, 2001). *Moringa oleifera* is the most important species and the most widely distributed in Asia, Africa, and America due to its economic importance (Ramachandran et al., 1980; Leone et al., 2015); it believed to be native to sub-Himalayan north-eastern India (Pandey et al., 2011). The second most important species is *Moringa peregrina*, which is distributed in the arid regions of the Arabian Peninsula (El-Lamey, 2015). *M. oleifera* is a medium-sized tree reached 3-15m high (Boulos, 1999); it is a fast-growing tree and is believed to be tolerant to drought and heat (Hegazy et al., 2008). *M. oleifera* is used for multiple purposes, including food, feed, fuel and cosmetics, which has resulted in its widespread use, especially in the recent decades (Leone et al., 2015; Boukandoul et al., 2018). In Africa and Asia, Moringa is used as human food and in medicines because of the high content of minerals and vitamins in the different parts of the tree (Abd El-Hack et al., 2018; Khor et al., 2018). For example, it was reported that *M. oleifera* leaves contain considerable amounts of proteins, minerals, and amino acids, which make the plant a valuable fodder crop (Amaglo et al., 2010; Leone et al., 2015). The oil content in *M. oleifera* seeds, reaches approximately 35-45%, with a high content of unsaturated fatty acids and 73% oleic acid (Ayerza, 2019). The high content of oleic oil in Moringa oil makes it a good source for high-quality biodiesel production (Da Silva et al., 2010; Boukandoul et al., 2018). Moringa seeds are a valuable source of oil, which is

Corresponding author email: Ashoaibi@taibahu.edu.sa
Received 16/2/ 2021; Accepted 24 /3/ 2021
DOI: 10.21608/ejbo.2021.63271.1631
Edited by: Prof. Dr.: Fawzy M. Salama, Faculty of Science, Assuit University, Assuit, Egypt.

promoted as a natural cosmetic emollient; it is pure, colourless, and tasteless and it is also used for medicinal purposes (Anjula et al., 2011; Abd El-Hack et al., 2018). Due to the multiple uses of the raw material from Moringa trees, their cultivation has spread worldwide to more than 80 countries (Pandey et al., 2011).

It has been reported that Moringa trees are well adapted to harsh environmental conditions, can grow in high temperatures and can highly considered drought and heat tolerant plant (Hegazy et al., 2008; El-Lamey, 2015; Wasonowati et al., 2019). The adaptation of plants to environmental stresses is usually associated with metabolic changes that resulted in the accumulation of a range of metabolites, such as sugars, phenols, and proline (Tesfay et al., 2011), that have a considerable impact on seed germination, seedling development and the productivity of plants (Tesfay et al., 2016). Tesfay et al. (2016) reported that temperature had a significant effect on the germination rate of *M. oleifera* seeds and radicle emergence was accelerated at 30/20°C, leading to germination within 48hrs. In general, plants developed adaptive strategies in response to biotic and abiotic stress, such as drought, salinity, and temperature. Although plant species differ considerably in the optimum temperature range for seed germination and growth performance, it has been reported that the optimal temperature for seed germination of *M. oleifera* is 30/20°C (Muhl, 2009; Muhl et al., 2011A). The growth and seed production of Moringa species might be affected by climatic conditions, particularly high temperatures, drought, and high levels of irradiance (Melesse et al., 2012; Hassanein & Al-Soqeer, 2017; Wasonowati et al., 2019). In a recent study on the performance of several *M. oleifera* cultivars, variations in vegetative and reproductive growth traits were observed under dry, hot climate conditions (Zheng et al., 2019).

Photosynthesis is considered one of the most sensitive physiological processes in plants. It has been found that temperature is among the uncontrollable climate variables that have the greatest effect on regulating the process of photosynthesis (Urban et al., 2017). Elevated temperatures can reduce the photochemistry of PSII (F_v/F_m), the assimilation of CO_2 and the evolution of O_2, resulting in a decrease in the light reactions of photosynthesis and the light saturation point of photosynthesis (A_{sat}) (Savitch et al., 2000; Youssef, 2007). Elevated temperatures limit photosynthetic activity by affecting the transportation of electrons in the thylakoid membrane, carboxylation ability and Rubisco kinetics (Posch et al., 2019). It has also been found that the ratio of the linear quantum yield to the mean variable of fluorescence (F_v/F_m) decreases at elevated temperatures (Maxwell & Johnson, 2000). Furthermore, the chlorophyll content was found to decrease when plants were exposed to elevated temperatures. Elevated temperatures inhibit chlorophyll biosynthesis and speed up its degradation (Ashraf & Harris, 2013).

In the Almadinah Almunawwarah region, in the western part of Saudi Arabia, *Moringa peregrina* and *Moringa oleifera* are cultivated in different areas with different temperature conditions. Temperature is one of the main factors that determine the distribution of plants in these areas. The mean temperatures of the Almadinah Almunawwarah region range between 15°C and 35°C annually (Presidency of Meteorology and Environment, Saudi Arabia). Since there is a shortage of information concerning the responses of *Moringa* species to temperature change in this region, this study is performed to investigate the responses of seed germination, seedling growth and photosynthesis performance of these two *Moringa* species to three temperature regimes:15/12°C, 25/22°C and 35/32°C; day/night.

Materials and Methods

Seed germination

The seeds of two *Moringa* species, *M. oleifera* and *M. peregrina*, were used to investigate the effects of temperature on germination. The seeds of *M. oleifera* were obtained from Al-Hilali Agricultural Company, while the seeds of *M. peregrina* were donated by the Jeeda Charity Community in the Al-Ula district, where the seeds are collected from their natural habitats. The experiments in this study were carried out in the Department of Biology, Faculty of Science, Taibah University, Almadinah Almunawarh, Saudi Arabia. For the germination test, seeds were sterilised by soaking in 0.1% mercuric chloride, washed in distilled water five times. The seeds were placed on two layers of Whatman No. 1 filter paper inside a Petri dish (9cm x 1.6cm) and watered with 10mL of distilled water. Each Petri dish contained 10 seeds, and four replicate Petri dishes were used for both *Moringa* species (*M.*

oleifera and *M. peregrina*). Three temperature treatments were used to test the temperature at germination (15°C, 25°C and 35°C), and the Petri dishes were placed inside incubators in darkness. The emergence of the radicle from the seeds was considered as an indicator of germination. The germination process was recorded every day for the whole incubation period during two weeks.

Plant growth parameters

Seeds of the two *Moringa* species, *M. oleifera* and *M. peregrina*, were grown in plastic pots (12cm x 20cm) containing 2kg of compost. The pots were placed inside an environmentally controlled chamber (JSR 314-240, JS Research Inc., Gumsang-Dong 40-1, city of Gongju, Korea) with a photoperiod of 14/10hrs. (light/dark) and 60% relative humidity. Fluorescent and halogen lamps were used for illumination, resulting in 400µmoL $m^{-2}s^{-1}$. For each *Moringa* species, four replicates were used for the three temperature treatments (15/12°C, 25/22°C and 35/32°C; day/night). In each pot, five seeds were planted, and after emergence, the seedlings were thinned, leaving two per pot. The plants were irrigated with full-strength Hoagland solution to full field capacity. At the end of the experiment, 40 days after planting, the following growth parameters were measured: height of the plant, number of leaves, and fresh weight of the roots and shoots. To determine the dry weight, root and shoot samples were oven-dried for 48hrs. at 80°C. Leaf area was measured according to the method described by Pandey & Singh (2011), using the weight of graph paper covered by the leaves. Then, the weight was converted to area using the following equation: leaf area (cm^2)= x/y, where x is the weight of the graph paper covered by the leaf and y is the weight (gm).

Photosynthesis measurements

The rates of photosynthesis were measured using a 6400XT LICOR infrared gas analyser (LI-6400, LI-COR Inc., Lincoln, Nebrasks, United States of America) on the youngest fully expanded leaves, following methods described by Al-Shoaibi (2008). For photosynthesis and dark respiration, the fourth fully expanded young leaves were used. The leaf temperature was maintained at 25°C during the measurement process by using a Peltier cooling system. The leaves were illuminated steadily, with photon flux densities from 0 to 1500µmoL $m^{-2}s^{-1}$. The net photosynthesis per leaf area and intercellular CO_2 concentration (c_i) were determined by applying the equations of Von Caemmerer & Farquhar (1981). A_{sat} was determined at a saturating photosynthetic photon flux density of 1500µmol $m^{-2}s^{-1}$ and at an ambient CO_2 concentration of 410µmol mol^{-1}.

The response of A to the intercellular CO_2 concentration (ci) was estimated using the same gas exchange system over a range of ca = 50-550µmol mol^{-1}, with a photosynthetic photon flux density of 1500µmol $m^{-2}s^{-1}$ at a leaf temperature of 25°C. The measurement of A was first performed at a CO_2 concentration equal to the ambient concentration in the environment where the plants were grown. To determine the initial slope of the A/ci response, ca was gradually decreased over six steps to 50µmol mol^{-1}. To check the original rate that might be regained, ca was then restored to the ambient concentration. To complete the curve, the ca was finally increased stepwise to 550µmol mol^{-1}. The assumed amount of active phosphoenol pyruvate carboxylase *in vivo*, which is called 'carboxylation efficiency', was calculated from the gradient of the initial slope of the response of A to ci, following the model of Collatz et al. (1992).

Chlorophyll content determination

The chlorophyll contents, which are expressed as the chlorophyll index, were determined by using a handheld chlorophyll content metre (Opti-Sciences Inc., CCM-200, United States). The chlorophyll contents were measured in the fourth expanded leaves, with four readings for each *Moringa* species and each temperature treatment. The average of the four measurements was used as the final chlorophyll content index.

Chlorophyll fluorescence measurements

The fluorescence of chlorophyll was measured by using a handheld fluorimeter (PEA, Hansatech, King's Lynn, Norfolk, U.K.). The measurements were performed on the youngest fully expanded leaves of the two *Moringa* species. Prior to the chlorophyll measurement, the leaves were dark-adapted for 20min. For both *Moringa* species, the variable ratio of maximum fluorescence (Fv/Fm) was measured four times for each temperature treatment, as described by Al-Shoaibi (2008).

Statistical analysis

The data obtained for the different measurements were statistically analysed using

one-way and two-way analysis of variance (ANOVA) and general linear model to test the main effects and the interactions of the investigated factors (i.e., temperature and species). The significance between the different levels of the investigated factors was tested, and a multiple comparison using Tukey's test was carried out. Version 15 of Minitab (Brandon Court, Unit E1-E2, Progress Way, Coventry CV3 2TE, U.K.) was used for all analyses. For each temperature treatment, four replicates were used, and standard deviations and standard errors were determined using Microsoft Excel 2016.

Results

Seed germination

The effects of the three temperature treatments on the final germination percentages of the two *Moringa* species are illustrated in Fig. 1. At all the temperatures, seed germination started on the fourth day and was completed within the 14-day period of the germination trial. The effect of temperature on the germination performance was highly significant (P<0.001). At 15°C, *M. oleifera* had a significantly higher percentage of germination compared to *M. peregrina* (P<0.05). Moreover, both species showed higher percentages of germination at 25°C. The germination percentage approached 100% and 90% for *M. oleifera* and *M. peregrina*, respectively, while the lowest germination percentage (60%) was achieved at 15°C for *M. peregrina*.

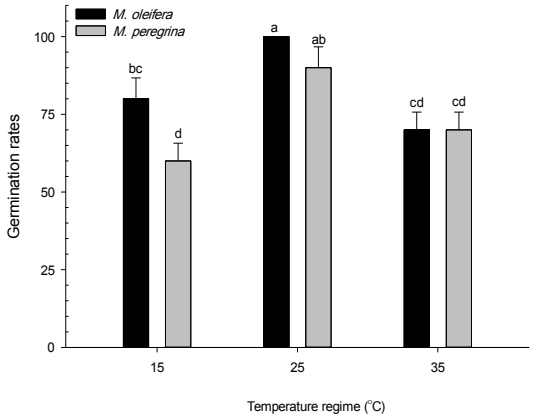

Fig. 1. The effect of temperature treatments (15ºC, 25ºC and 35ºC) on seed germination (as %) of the two *Moringa* species; *M. oleifera* and *M. peregrina* [n= 4, mean± S.E., means that do not share the same letter are significantly different at P ≤0.05]

Plant growth parameters

Several growth parameters were measured to determine how different temperature treatments influenced the growth parameters of the two *Moringa* species; the results are summarized in Table 1. Temperature significantly affected most growth parameters of the two *Moringa* species (P<0.001). The results showed that, most growth parameters of the two *Moringa* species grown at 25°C and 35°C were significantly increased when compared to their relative plants grown at 15°C (P<0.01). The leaf number and leaf area of *M. oleifera* grown at 35°C were 631% and 547.5% higher, respectively, than those of the same species grown at 15°C; these increases were the highest observed for these indices. Similarly, the plant height and root length of *M. peregrina* grown at 35°C approached 143.2% and 198.7% higher, respectively, than those of the same species grown at 15°C, representing the maximum percentage increases for these indices. Moreover, the considerable percentage increases for most of the fresh and dry weights of both shoots and roots of *M. oleifera* were observed for plants grown at 35°C compared to those of the same species grown at 15°C (P<0.001; Table 1).

Photosynthesis measurements

The results presented in Fig. 2 show the response of the uptake of photosynthetic CO_2 (A) to photon flux (Q) for the two *Moringa* species grown in the three temperature treatments. The temperature treatments significantly affected the photosynthetic performance of the two *Moringa* species (P<0.001). Both *Moringa* species, the highest photosynthesis performance was observed at 25°C (Fig. 2). The rates of light saturation (A_{sat}) for both *Moringa* species grown at 25°C were considerably higher than those of the same species grown at 35°C (P<0.01; Fig. 3A), with percentage increases for *M. oleifera* and *M. peregrina* of 63% and 29%, respectively. Moreover, the quantum yield (φ) of *M. peregrina* grown at 25°C was significantly greater than the quantum yield of the same species grown at 35°C (P<0.01; Fig. 3B), with a 46% increase. However, both *Moringa* species showed significantly lower A_{sat} and φ at 15°C than at 25°C or 35°C (P<0.01; Fig. 3A & B). Measurements of the A/c_i curve for both *Moringa* species in the three temperature treatments are illustrated in Fig. 3. In general, the plateaus of the A/c_i curve (A_{max}) and carboxylation efficiency for both *Moringa* species were considerably higher at 25°C than

at 35°C (P<0.01; Fig. 3C & D). For *M. oleifera*, the highest percentage increases in A_{max} and carboxylation efficiency were observed for plants grown at 25ºC; these were 87% and 168% higher, respectively, than those of the same species grown at 35ºC (P<0.01; Fig. 3). On the other hand, both *Moringa* species showed significantly lower A_{max} and carboxylation efficiency values when grown at 15°C than at 25 or 35°C (P<0.01; Fig. 3C & D).

TABLE 1. Effects of temperature on the growth parameters of *M. oleifera* and *M. peregrina*

Trait	Species	15°C	25°C	35°C
Plant height (cm)	*M. oleifera*	$18^{bc} \pm 1.25$	$24.4^{b} \pm 2.3$	$43^{a} \pm 4.16$
	M. peregrina	$8.4^{d} \pm 0.56$	$16.67^{c} \pm 1.85$	$20.43^{bc} \pm 1.45$
Leaf number	*M. oleifera*	$40^{d} \pm 0.58$	$223.3^{b} \pm 9.21$	$292.4^{a} \pm 13.62$
	M. peregrina	$15^{e} \pm 1.73$	$41^{d} \pm 7.57$	$72.3^{c} \pm 6.84$
Leaf area (cm^2)	*M. oleifera*	$80^{cd} \pm 1.15$	$446.7^{b} \pm 18.41$	$518^{a} \pm 43.55$
	M. peregrina	$22.5^{d} \pm 2.59$	$62^{cd} \pm 11.75$	$108.5^{c} \pm 10.26$
Shoot fresh weight (g)	*M. oleifera*	$2.16^{c} \pm 0.37$	$10.23^{b} \pm 1.57$	$20.1^{a} \pm 1.07$
	M. peregrina	$2.8^{c} \pm 1.55$	$4.1^{c} \pm 0.28$	$5.1^{c} \pm 1.29$
Shoot dry weight (g)	*M. oleifera*	$0.5^{cd} \pm 0.11$	$1.4^{b} \pm 0.2$	$3.43^{a} \pm 0.24$
	M. peregrina	$0.23^{d} \pm 0.03$	$0.38^{cd} \pm 0.05$	$0.84^{c} \pm 0.21$
Root length (cm)	*M. oleifera*	$6.5^{bc} \pm 1.25$	$11.83^{ab} \pm 1.48$	$12.16^{a} \pm 1.58$
	M. peregrina	$5.3^{c} \pm 0.34$	$8.5b^{c} \pm 1.04$	$15.83^{a} \pm 3.65$
Root fresh weight (g)	*M. oleifera*	$0.56^{e} \pm 0.18$	$7.33^{c} \pm 0.55$	$11.1^{a} \pm 0.44$
	M. peregrina	$0.4^{e} \pm 0.11$	$3.93^{d} \pm 0.46$	$9.76^{b} \pm 0.52$
Root dry weight (g)	*M. oleifera*	$0.06^{e} \pm 0.02$	$0.8^{c} \pm 0.17$	$1.56^{a} \pm 0.03$
	M. peregrina	$0.12^{e} \pm 0.09$	$0.4^{d} \pm 0.05$	$1.17^{b} \pm 0.03$

- n = 4, mean±S.E.
- Means that do not share a letter are significantly different at P ≤0.05

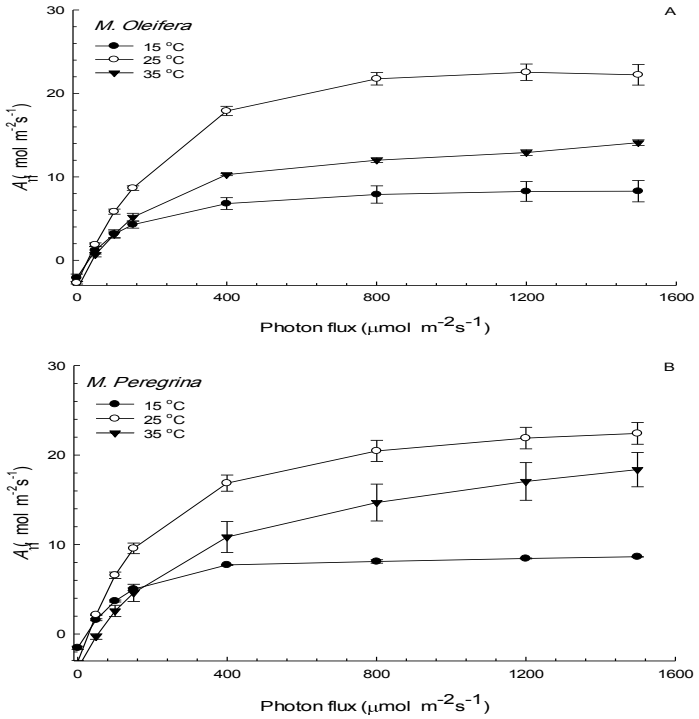

Fig. 2. The photosynthetic CO_2 absorption response (A) per unit area of the leaf to photon flux (Q) for two *Moringa* species; *M. oleifera* and *M. peregrina* [n= 4, mean±S.E., CO_2 absorption measurements were all made at 25°C and C_a of 410μmol mol^{-1}]

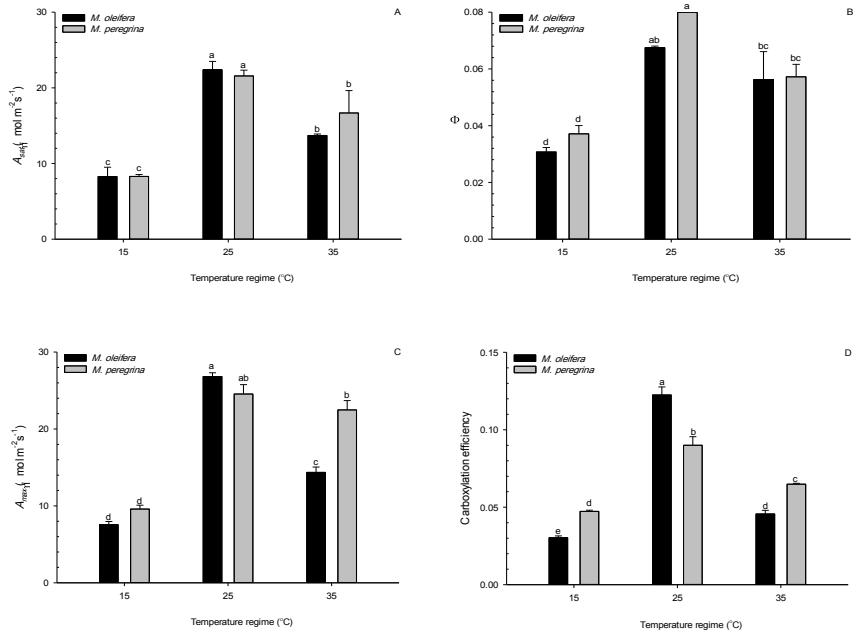

Fig. 3. The effect of temperature treatments (15ºC, 25ºC and 35ºC) on physiological parameters of the two *Moringa* species; *M. oleifera* and *M. peregrina* [n = 4, mean±S.E., (A)Asat, (B) Quantum yield, (C) Amax and (D) Carboxylation efficiency. Means that do not share the same letter are significantly different at P ≤0.05]

Chlorophyll content determination

Figure 4B illustrated the effect of the three temperature treatments on the chlorophyll content of *M. oleifera* and *M. peregrina*. The chlorophyll contents of *M. peregrina* were significantly increased by increasing the temperature from 15°C to 35°C (P<0.01). The chlorophyll contents of *M. peregrina* grown at 25°C and 35°C increased by 29% and 117%, respectively, compared to those of the same species grown at 15°C (P<0.01). However, the three temperature treatments did not induce significant variation in the chlorophyll content of *M. oleifera*.

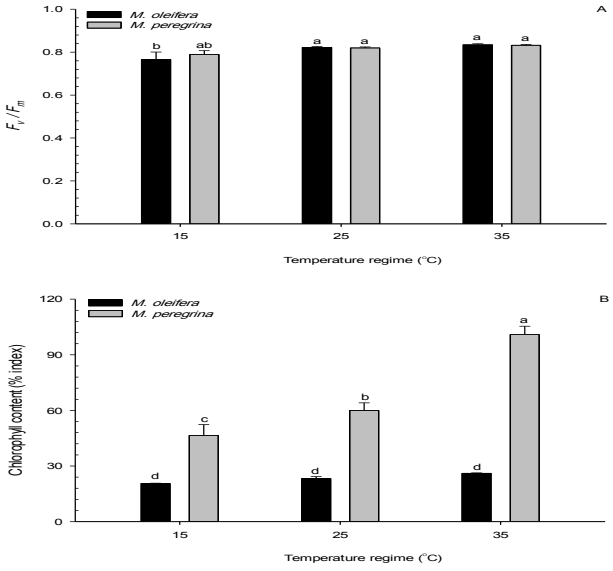

Fig. 4. The effect of temperature treatments (15ºC, 25ºC and 35ºC) on physiological parameters of the two *Moringa* species; *M. oleifera* and *M. peregrina* [n= 4, mean±S.E., (A) F_v/F_m and (B) Chlorophyll content. Means that do not share the same letter are significantly different at P ≤0.05]

Chlorophyll fluorescence measurements

The maximum quantum efficiency of the photochemistry of PSII (*Fv/Fm*) of the two *Moringa* species grown in the three temperature treatments is shown in Fig. 4A. For both *Moringa* species, the *Fv/Fm* values of the plants grown at 35°C were similar to those plants grown at 25°C. However, the chlorophyll fluorescence parameter of *M. oleifera* plants grown at 15°C was significantly decreased compared to their analogues parameters of the two *Moringa* species grown at 25°C and 35°C ($P<0.05$).

Discussion

The present study examined the responses of seed germination, seedling growth and photosynthesis of two *Moringa* species to temperature. Temperature is one of the most significant factors influencing seed germination and seedling development (Zhao et al., 2014; Wang et al., 2020). The results showed that seeds of both *Moringa* species germinated over a wide range of temperatures, from 15°C to 35°C (Fig. 1). The germination of the two *Moringa* species in all the temperature treatments began on day 4 of the experimental period. The germination suppression reported in the first days of this study is consistent with some previous studies which showed germination delays for few days (Redondo et al., 2004; Yan et al., 2011A; Causin et al., 2020). This indicated the need for optimal environmental conditions to ensure a high percentage of germination and thus growth efficiency (Redondo et al., 2004). Furthermore, the results obtained showed that the optimum temperature for seed germination of both *Moringa* species was 25°C. Similar findings have been reported for *M. oleifera* (Muhl et al., 2011A; Zhang et al., 2017).

Temperature is one of the main influential and uncontrollable climate factors that regulate plant development and growth (Munir, 2004). For both *Moringa* species used in this study, all the growth parameters were higher at 35°C than 15°C (Table 1). The optimum temperature for seedling growth of both *Moringa* species was 35°C. It was previously reported that the optimum temperatures for seedling growth in *Moringa* ranged from 20°C to 35°C (Alatar, 2011; Muhl et al., 2011A). *M. oleifera* grown at 35°C showed better growth performance, especially leaf number and leaf area, than *M. peregrina*. The considerably greater leaf area of *M. oleifera* increased the total number of stomata per plant, resulting in increased growth of vegetation and accumulation of dry matter (Muhl et al., 2011B). Furthermore, the highest percentage increase was observed for the fresh and dry weights of the shoots and roots of *M. oleifera* grown at 35ºC compared with those of the same species grown at 15ºC (Table 1). Genetic variations between the two studied species and their distinct origins can explain the differences observed (Mridha, 2015; Muhammad et al., 2016). Furthermore, the ability of the two *Moringa* species to develop over a large range of temperatures, from 15°C to 35°C, may support their distribution and use as important crops for medicine and nutrition (Hassanein & Al-Soqeer, 2017).

Temperature also significantly affected the gas exchange parameters of both *Moringa* species in this study. The photosynthetic measurements showed that the optimum temperature for gas exchange of both *Moringa* species was 25°C (Fig. 3). Additionally, both *Moringa* species showed nearly similar photosynthetic performances at 25°C and 35°C. However, a temperature of 15°C caused a substantial decrease in the A_{sat}, φ, A_{max} and carboxylation efficiencies of both *Moringa* species compared with those of plants grown in the other temperature treatments. The inhibition of photosynthesis in *Moringa* plants grown at 15°C may be due in part to a reduction in stomatal conductance or a decrease in photosynthetic pigments. All these factors affect photosystem II (PSII) activities, clearly contributing to the deactivation of enzymes that play a key role in the photosynthetic process (Ashraf & Harris, 2013; Li et al., 2015). A decrease in the photosynthetic performance of Moringa was previously observed at low temperatures in controlled environments and fields (Mabapa et al., 2018). There are many physiological mechanisms that allow these two *Moringa* species to cope effectively with harsh environmental conditions, such as temperature stress (Mabapa et al., 2018). Furthermore, Chaves (1991) found that the primary processes adversely affected by drought and higher temperatures are gas exchange operations, primarily those related to photosynthetic rates. The results of this study showed that the photosynthetic parameters of the two Moringa species were significantly lower at 35°C than at 25°C. Similar findings were reported by Mabapa et al. (2018), who found that higher temperatures in summer months had

a negative impact on the photosynthetic rate of *M. oleifera*. This reduction in the photosynthetic process of the two *Moringa* species could be the result of stomatal limitations and reductions in the chlorophyll and carotenoid contents (Sharma et al., 2019; Morales et al., 2020). Other reasons for the reduction in the photosynthetic process could be limitations in the electron transport of the thylakoid membrane or decreases in the activity of Rubisco (Sharma et al., 2019; Morales et al., 2020).

The findings of this research showed that the chlorophyll content in the leaves of *M. peregrina* increased as the temperature increased (Fig. 4B). The highest increase in chlorophyll content was recorded for *M. peregrina* grown at 35°C. The leaves of plants grown in the highest temperature treatment area visible sign of this increase. The reason for this increase could be the rise in the number of chloroplasts within leaves developed at high temperatures. However, the chlorophyll contents in the leaves of *M. oleifera* were similar across the three temperature treatments. The chlorophyll contents of *M. peregrina* leaves were significantly higher than the chlorophyll contents of *M. oleifera* leaves in all the temperature treatments. Similar findings were reported by Hassanein & Al-Soqeer (2017), who found that *M. peregrina* accumulated greater chlorophyll contents than *M. oleifera* when grown under field conditions.

Chlorophyll fluorescence measurement has been used to determine the integrity of photosystem II when exposed to stress (Shabala & Shabala, 2002). In this study, chlorophyll fluorescence (*Fv/Fm*) was not affected by the temperature treatments in either *Moringa* species, except the15°C treatment, in which a slight decrease was recoded for *M. oleifera* (Fig. 4A). These high *Fv/Fm* values offered clear evidence that both *Moringa* species were resistant to photo inhibition when grown under different temperature treatments. Similar results have been reported previously for *Pennisetum purpureum* grown in two temperature treatments (AL-Shoaibi, 2008). Thus, the current research shows that chlorophyll fluorescence cannot be considered one of the variables for regulating the rate of net CO_2 assimilation in *Moringa* species grown at different temperatures. On the other hand, the slight decrease in the *Fv/Fm* values of *M. oleifera* grown at 15°C could result from oxidative damage to photosynthetic organelles, particularly under temperature stress (Aro et al., 1993; Yan et al., 2011B).

Conclusion

The present study showed that both *M. peregrina* and *M. oleifera* have similar responses to different temperature treatments. The optimum temperature for both species, leading to the highest percentage of germination and best photosynthetic performance, is 25°C. The results also showed that 35°C was the optimal temperature for most parameters of growth of the two *Moringa* species. However, the chlorophyll contents of *M. oleifera* and most values of *Fv/Fm* for both species were similar across the three temperature treatments. Additionally, the outcomes of this study showed that Moringa can be cultivated in many different regions with different temperatures.

Ethical approval: Not applicable.

Research funding: The author state no funding involved

Data availability: Data that are supplementary to the manuscript will be available by request.

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إنبات البذور ونمو الشتلات واستجابات البناء الضوئي لدرجة الحرارة في الشجرة الاستوائية *Moringa oleifera* والشجرة الصحراوية *Moringa peregrina*

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تزرع المورينجا أوليفيرا والمورينجا بريجرينا في العديد من المناطق في المدينة المنورة، الجزء الغربي من المملكة العربية السعودية. تهدف هذه الدراسة إلى فحص استجابات إنبات البذور ونمو الشتلات والبناء الضوئي لنوعين من المورينجا لمعالجات درجات الحرارة المختلفة. أشارت النتائج إلى أن بذور كلا النوعين يمكن أن تنبت في نطاق واسع من درجات الحرارة مع درجة الحرارة المثلى لأعلى نسبة إنبات عند 25 درجة مئوية. كان أداء البناء الضوئي للنوعين أعلى عند 25 درجة مئوية. ومع ذلك، كانت محتويات الكلوروفيل في المورينجا اوليفيرا ومعظم قيم *Fv/Fm* لكلا النوعين متشابهة عبر معاملات درجات الحرارة الثلاثة. بالإضافة إلى ذلك، أظهرت نتائج هذه الدراسة أنه يمكن زراعة المورينجا في مناطق عديدة بدرجات حرارة مختلفة.