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Research Article

Early Age Sex Identification in Date Palm (*Phoenix dactylifera*)

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ABSTRACT

The date palm is a widely cultivated important fruit crop in the world's dry and semi-arid regions. Date palm plants are easily multiplied from seeds, suckers or through plant cell and tissue culture. Both seed grown and tissue cultured plants require 4-5 years of vegetative growth to attain physiological maturity and reach the first flowering stage. However, identifying the sex of the plants during the vegetative phase remains highly challenging. Sucker propagation, with known sex, is a slow method and increases the risk of disease transmission. Therefore, early sex determination in the date palm is essential for breeding programs and long-term production. Here, we present a study of morphological, physiological and biochemical traits of female and male suckers from selected genotypes (Medjool, Amber and Ajwa) at an early vegetative growth stage. The results indicated significant differences between male and female plants, although variation in morphological and physiological traits was inconsistent, making it difficult establish reliable criteria for the sex differentiation based on these parameters alone. Notably, the stomatal conductance showed clearly differences between male and female plants of the selected genotypes. Similarly, biochemical traits also indicated significant and consistent differences between the sexes. Secondly, evaluation of highly responsive traits, stomatal conductance, and concentrations of nitrogen (N), phosphorus (P) and potassium (K) were assessed on randomly selected seedlings. The results indicated that male seedlings had higher stomatal conductance compared to female seedlings of the selected genotypes, whereas female seedlings consistently showed higher concentration of NPK. The study suggests that stomatal conductance and concentration of NPK are practical indicators for early-stage sex determination in date palm. Developing and refining sex determination methodologies will provide enabling tools for date palm breeders in designing and planting orchards for enhanced economic productivity in the future.

Keywords: Ajwa, Amber, Medjool, Morphological, Physiological, Stomatal conductance.

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INTRODUCTION

The date palm (*Phoenix dactylifera* L.) is one of the most valuable, nutritional, and economically significant fruit crops in the world. Date palm offers a socioeconomic benefit in the provision of fiber, food, and shelter. It is a monocotyledonous, dioecious plant species that must mate with female plants to produce seeds (Wilson and Harder, 2003; Xia et al., 2013; Schlessman et al., 2014). Based on their flowers, male and female plants could be identified clearly. However, identifying the sex implies a challenging job during vegetative growth stage of the plant. Individuals fertilized from pollen of different plants create healthier and more prolific progeny compared to the self-pollinated and fertilized plants (Khosla and Kumari, 2015). Male and female morpho-physiological differences in a variety of dioecious plants have been studied (Allen and Antos, 1988; Laporte and Delph, 1996; Espirito-Santo et al., 2003). Date palm morphological characteristics, including plant form, shape and structure, were used to identify genetic variation, however these markers are unclear because of the influence of the environment and development stage (Haider et al., 2015; Naqvi et al., 2015; Raza et al., 2020). The demands for the reproduction of female plants are higher compared to the male plants. Sexual specialization may develop while male and female functions are divided into separate morphs. This is especially common when different phosphorus and nitrogen demands exist between male and female plants (Case and Ashman, 2005). Normally one male plant is considered enough to pollinate 50 female plants, and both males and females have different resource requirements.

Different studies for physiological differences between the sexes have shown variance in plant height, leaf length, and other significant plant traits like phenology and growth characteristics, of date palm trees, showing a strong correlation in fruit's maturity with morphological and genetic variations (Hamza et al., 2011). Fruit consistency varies greatly among cultivars and is associated with genotype. There are differences in appearance, physiology, heredity and environmental adaptability between female and male in several dioecious plant species (Melnikova et al., 2017). Significantly larger leaves with sexual dimorphism appear to support females, especially in the generation of sporophytes, by extending hydration (Moore et al., 2016). When compared to males, females frequently have larger, denser leaves, which is consistent with stronger photochemical production in females.

Gender differences in energy integration are anticipated regardless of how considerably two sex plants differ in size or reproductive output (Dawson and Geber, 1999). The gaseous exchange capacities of male and female angiosperms are very diverse, with females usually possessing a stronger capacity for photosynthetic absorption compared to males. It is necessary to understand how resources affect demography and community organization in different dioecious species that are geographically isolated from their surroundings. It is also important to understand how physical consequences vary by genotype and sex (Dawson et al., 2004). When their life experiences differ, gender often has material variances (Geber et al., 1999).

Both male and females (angiosperms and gymnosperms) require different resources, for phosphorus and nitrogen uptake (Case and Ashman, 2005) that could aid in sex selection, resource demands, or reproduction (Barrett and Hough, 2013), in vegetative and generative anatomy (Ackerly and Jasienski, 1990; Delph et al., 1996; Harris and Pannell, 2008; Teitel et al., 2016) and physiology (Cornelissen and Stiling, 2005; Eppley et al., 2009; Petry et al., 2013; Varga et al., 2013; Li et al., 2015). Male mosses do not need to stay hydrated as long as females (Stark et al., 2007; Stark and Brinda, 2015). It has been indicated that male and female plants having different concentrations of nutrients particularly macronutrients (Nitrogen, Phosphorus and Potassium). In addition, the female and male plants also differ in acquisition and utilization of N, P, and K. It has been observed in many species (Barrett and Hough, 2013) that female plants are involved in reproduction and fruit formation, have higher nutrient concentration as compared to male plants (Dawson and Ehleringer, 1993; Li et al., 2007). Therefore, NPK concentrations could serve as potential markers for sex identification at early stages in date palms. Sex-specific morphological, physiological, and biochemical signatures in date palm offer a viable framework for early sex identification. This study systematically characterized these parameters across diverse genotypes, providing critical insights for targeted breeding and economically optimized orchard establishment.

MATERIALS AND METHODS

Plant Material

Fifty-four one-year-old male and female date palm suckers from cv. Ajwa, Amber and Medjool were randomly selected and equally divided into three replications. They were grown using Completely Randomized Design (CRD). Stomatal conductance and NPK uptake of these cultivars were evaluated and compared by random selecting of unknown seedlings of the respective genotypes.

Sampling and Analytical Procedures

Morphological Traits

The plant height, leaf length and leaf width of these selected suckers (plants) from the male and female date palm cultivars was measured in (cm) by using measuring tape. Similarly, three date palm suckers (plants) from females and males of each genotype were selected to measure their leaf area (cm^2).

Physiological Traits

Photosynthesis rate (μmol CO_2 m^{-2} s^{-1}), transpiration rate (mmol H_2O m^{-2} s^{-1}), water use efficiency (mmol CO_2 mol^{-1}

H_2O) and stomatal conductance (mmol H_2O m^{-2} s^{-1}) of the tagged leaves of both male and female suckers of each genotype was observed by using a CIRAS 3 (80018-3 Portable Photosynthesis System). It was operated at ambient leaf temperature (30 ˚C), photosynthetic photon-flux density at 767 µmol m^2 s^{-1}, 97 kPa atmospheric pressure, 90 mL min^{-1} air flow, and 325 µmol mol^{-1} CO_2 concentrations. The measurement of rate of photosynthesis was recorded from 10:30 am to 13:30 pm, three observations were noted at random, and the average was calculated from each genotype (Merrium *et al*., 2022).

Biochemical Traits (NPK)

Two leaf samples were used from suckers of female and male of three selected genotypes (Ajwa, Medjool and Amber) for nitrogen (N), phosphorus (P) and potassium (K) contents. The selected samples were dried for 48 hours at 65 ˚C. After drying the samples were then ground and carefully mixed to ensure uniformity. To digest samples, 0.1 g of ground samples were placed in 25 mL conical flasks containing 2-mL H_2SO_4 and kept at room temperature overnight. Following that, the flask was filled with 1 mL of hydrogen peroxide (35%) and heated for 20 minutes at 350 °C . After cooling, add 1 mL H_2O_2 then placed on the hot plate for further 20 minutes. This process was repeated until the mixture of the flask became colorless. After being diluted with DI water, the colourless liquid was filtered into a 50 mL volumetric flask, filled to the mark, and stored for N, P and K analysis. The concentration of N was determined using Kjeldahl ammonium distillation method. In this method, a digestion tube was filled with 5 mL of the digested sample solution and 10 mL of NaOH (40%) was added and the tube was attached to the Kjeldahl ammonium distillation equipment to begin the distillation process. The receiver (100 mL conical flask) absorbed the distillate (ammonium), which contains mixed indicator and boric acid (2%). When receiver volume had reached 50 mL, distillation was terminated and removed it from Kjeldahl apparatus left for some time to cool. The contents were back-titrated with 0.01 N H_2SO_4 until it turned into a bright pink color. 'N' was then calculated using Eq. 1 (Wolf, 1982).

$$\mathrm{N}\ (\%) = \frac{(\mathrm{V} - \mathrm{B1}) \times \mathrm{N}\ \times \mathrm{V2}\ \times 14.01\ \times 100}{\mathrm{Wt}\ \times \mathrm{V3}\ \times 1000} \qquad (1)$$

A spectrophotometer operating at a wavelength of 410 nm was used to calculate the concentration of 'P' in the digested samples. In this method, 10 mL Barton's reagent was added to a 5 mL samples aliquot and diluted to 50 mL. After 30 minutes, the absorbance was measured on a spectrophotometer. The actual concentration of 'P' was measured using the standard curve prepared by using the working standard of concentration 0, 0.5, 1.0, 1.5, 2.0, and 2.5 ppm developed from 50 ppm stock solution of KH_2PO_4 salt. The Barton reagent was made according to Ashraf et al. (1992). The reaction mixture was left for 30 minutes to develop color and then the samples were run on a spectrophotometer at 410 nm, absorbance was recorded and 'P' was estimated using Eq. 2 (Wolf, 1982).

$$\mathrm{P}\ (\%) = \mathrm{ppm\ P\ (from\ calibrataion\ curve)} \times \frac{\mathrm{V1}\ \times 100\ \times 1}{\mathrm{Wt}\ \times \mathrm{V2}\ \times 1000} \qquad (2)$$

A calibration curve created from known 'K' values between 0 and 100 ppm and fed to the Flame photometer was used to quantify the content of 'K' in the digested samples aliquot (Jenway PFP-7, England). The concentrations of 'K' in these solutions were 2, 4, 6, 8, 10, and 12 ppm using 1000 ppm stock solution developed from KCl salt, and K was determined using Eq. 3 (Wolf, 1982).

$$\mathrm{K}\ (\%) = \mathrm{mg\ l} - {}^{1}\mathrm{K\ (from\ calibration\ curve)} \qquad (3)$$

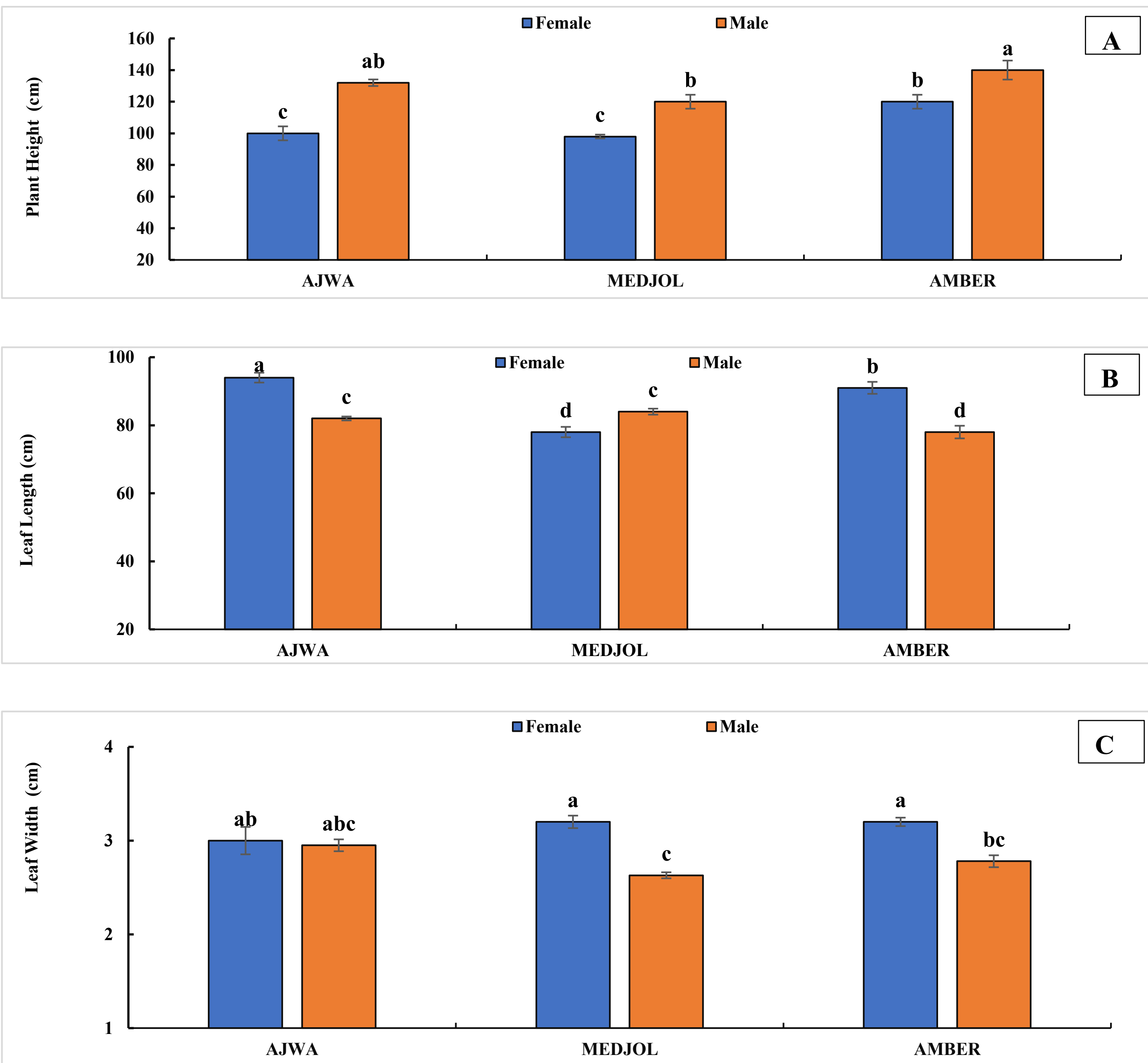
Statistical Analysis

The recorded data including morphophysiological and biochemical traits of date palm genotypes were subjected to analysis of variance (ANOVA) following Steel et al. (1997) to assess variability among the selected genotypes. Differences among the selected genotypes for morphophysiological and biochemical traits were further evaluated using LSD test at $p<0.05$ (Meier, 2006).

RESULTS and DISCUSSION

Morphological Traits

The findings showed that there was significantly difference in plant height, leaf length and leaf width of date palms among sex. Similarly, the leaf length of date palm also differed significantly showing significant sex × genotype interaction except plant height and leaf width of date palm (Table 1). Among cultivars of date palm, Amber showed the maximum plant height (140 cm) in comparison to Ajwa (132 cm) and Medjool (120 cm). In contrary, Ajwa showed the maximum leaf length (94 cm) in comparison to Amber (91 cm) and Medjool (78 cm). Similar to plant height, Amber and Medjool showed maximum leaf width (3.2 cm) in comparison to Ajwa (3 cm). Male date palms showed higher plant height (140 cm) as compared to female date palms (120 cm). In contrast, female date palms showed higher leaf length (94 cm) as compared to male date palms (84 cm). Moreover, male date palm suckers of Amber showed the maximum plant height (140 cm) in comparison to male and female date palm suckers of Amber and Medjool (Fig. 1A). Additionally, compared to male and female date palm suckers of Amber and Medjool, female date palm suckers of Ajwa showed larger leaf length (94.0 cm) (Fig. 1B). Male date palm suckers of Ajwa showed the higher leaf width (2.95 cm) in comparison to male date palm suckers of Amber and Medjool (Fig. 1C). Similarly, larger leaf area (cm^2) was observed high among the female plants of Ajwa, Medjool and Amber (282, 250, 291 cm^2 , respectively) as compared to their male plants (242, 221, 217 cm^2, respectively). Morphological traits are highly environmental dependent, and these are not reliable marker for sex determination in date palm due to this we are going to physiological parameters.



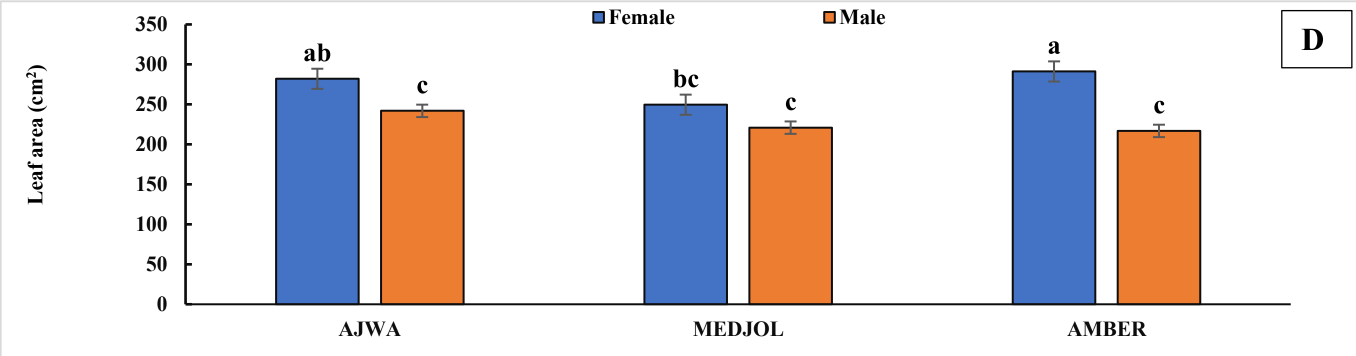


Figure 1. Mean comparison for morphological traits (Plant height, Leaf length, Leaf width and leaf area) of selected date palm genotypes (male and female). Error bar represents +SE of three experimental replicates.

Male and female plants may develop differently because male plants are created sexually by seeds, whereas female plants may or may not produce sexually. Male and female plants differ significantly in terms of plant height, leaf width, and leaf length, but not in consistency. The performance of male genotypes in terms of leaf length and leaf width was also noted to be inferior to that of female genotypes. Previously it was found that the sexually reproduced progeny had lower fit compared to apomictic progeny Bayer et al. (1990). The quickly developing reproductive processes of female plants, which require more nutrients and carbohydrates for a longer period compared to male plants, may be the cause of the differences in leaf morphology. It was observed that female plants have larger leaf size compared to male plants (Rhoades and Cates, 1976). Plant sex may sometimes be determined by comparing the height and leaf shape of male and female plants (Singh et al., 1999). Our findings, therefore, showed that the physical characteristics of the male and female plants were different. Significant differences were found between the male and female in terms of plant height. However, this variance is not consistent across male and females, demonstrating that this physical characteristic is not the standard for differentiating the sex of plants. Similar to this study, Sinha et al. (2012) studied morphological traits to distinguish between female and male plants. They observed a considerable difference in genotype-to-genotype variance in leaf length and plant height. Additionally, they noticed a considerable difference in the stem color, shape, height and rate of growth of female and male plants. However, they do not differ amongst individuals of the same genotype sex, demonstrating that these physical characteristics are not the primary factors for differentiating female and male plants. Ageez and Madboley (2011) verified the same findings, which demonstrated that morphological factors such as leaf length, leaf width and plant height are not permanent parameters for sex identification in date palm. Obtained findings also suggested that morphological traits are not considered as suitable criteria to identify early sex in date palm.

Physiological Traits

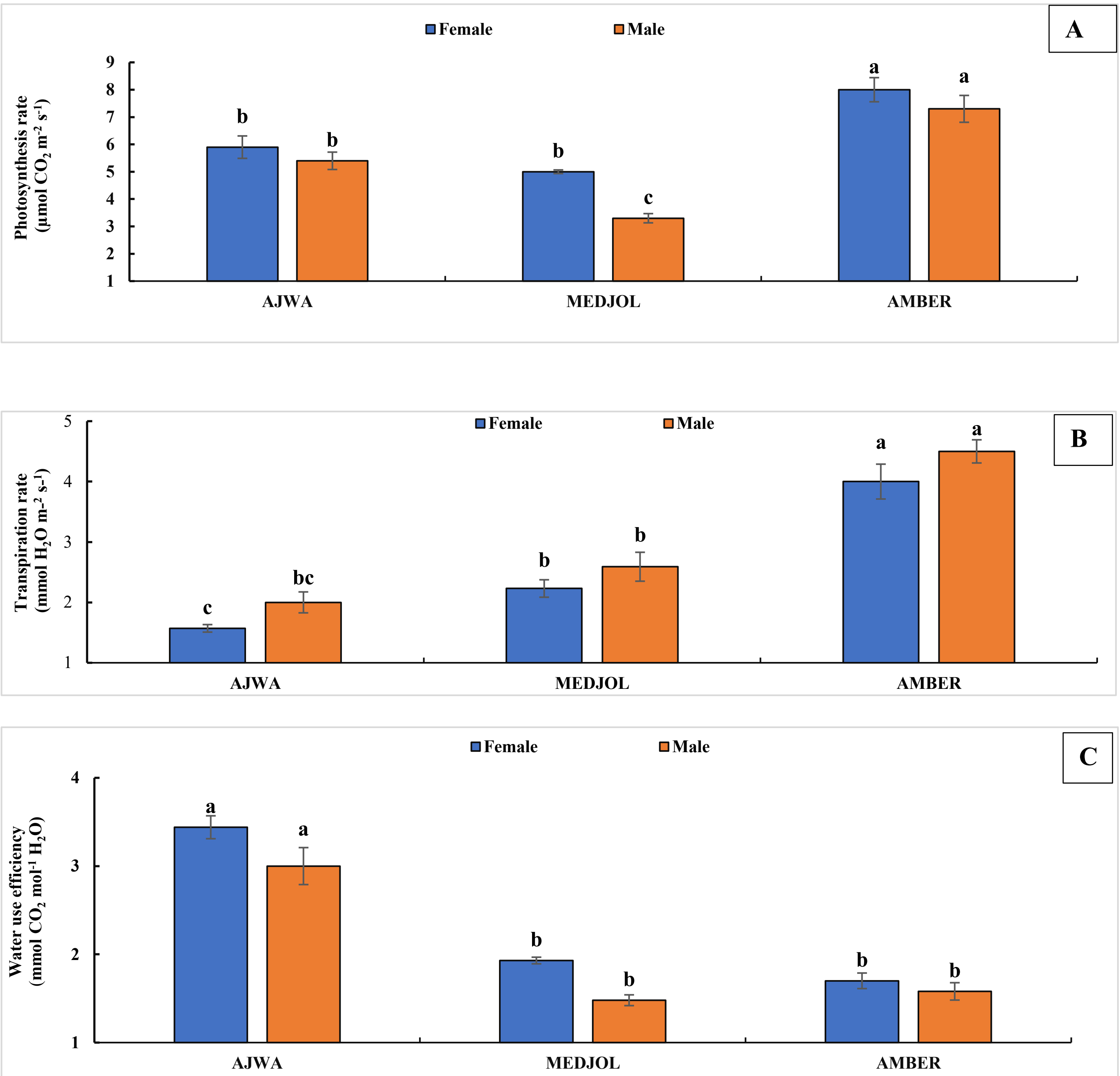
Photosynthesis rate, transpiration and stomatal conductance differed significantly among the sex of date palm. Similarly, interaction (sex × genotype) also differed significantly for the stomatal conductance (Table 1). Among cultivars of date palm, Female suckers of Amber showed the maximum photosynthesis rate 11%, 16% respectively, more in comparison to Ajwa and Medjool (Fig. 2A).

Similarly, male suckers of Amber showed the maximum transpiration rate of date palm 27%, 21 % respectively, more in comparison to Ajwa and Medjool (Fig. 2B). However, Female suckers of Ajwa showed the highest water use efficiency of date palm 21%, 24% respectively more in comparison to Medjool and Amber (Fig. 2C). In addition, male suckers of Amber showed the maximum stomatal conductance of date palm 18%, 33% respectively, more in comparison to male suckers of Medjool and Ajwa. Moreover, male date palm sucker of three selected genotypes showed maximum stomatal conductance as compared to female suckers (Fig. 2D). It is clearly noted that male and female date palm cultivars showed significant differences for stomatal conductance. Thus, stomatal conductance of date palm could serve as the best marker for the identification of sex at early stages of date palm and hence further studied and compared with the unknown date palm cultivars.

Table 1. Level of significance for morphophysiological parameters of date palm.

Source	DF	PH	LL	LW	LA	A	Gs	E	WUE
Sex	1	2738*	156.05*	0.57*	10551.2*	4.01*	1152.0*	0.83*	0.51 ^{NS}
Genotype	2	686*	28.38*	0.12^{NS}	1172.6^{NS}	18.5*	17275.0 *	9.83 *	4.82 *
Sex ×Genotype	2	62 ^{NS}	83.38*	0.11^{NS}	951 ^{NS}	0.60 ^{NS}	171.0 *	0.01 ^{NS}	0.05 ^{NS}
Error	12	66	6.05	0.037	336.6	0.26	154.7	0.12	0.147

* = significant at p≤0.05 and NS = non-significant if p>0.05, DF = degree of freedom, LL = leaf length, LW = leaf width, PH =plant height, A = photosynthetic rate, Gs = stomatal conductance, E = transpiration rate and WUE = water use efficiency of date palm genotypes of both sex (male and female).



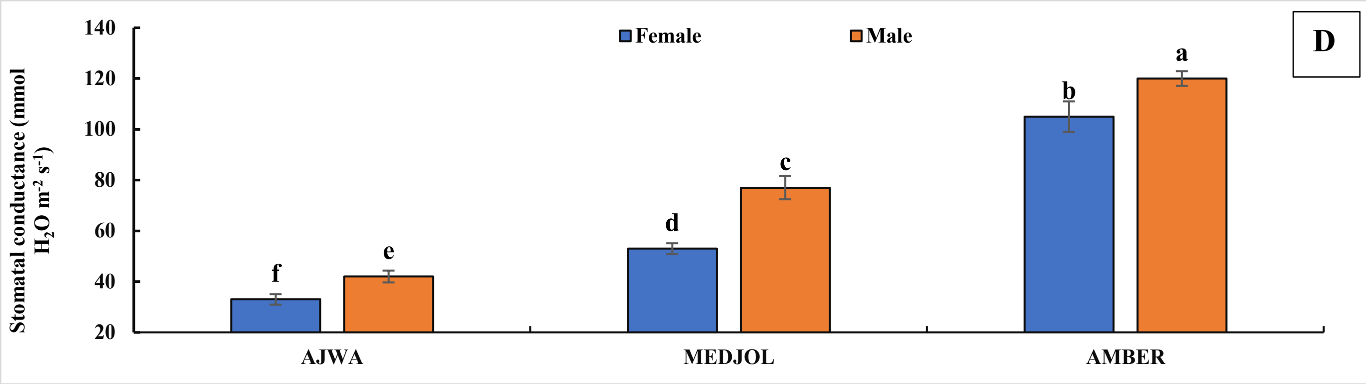
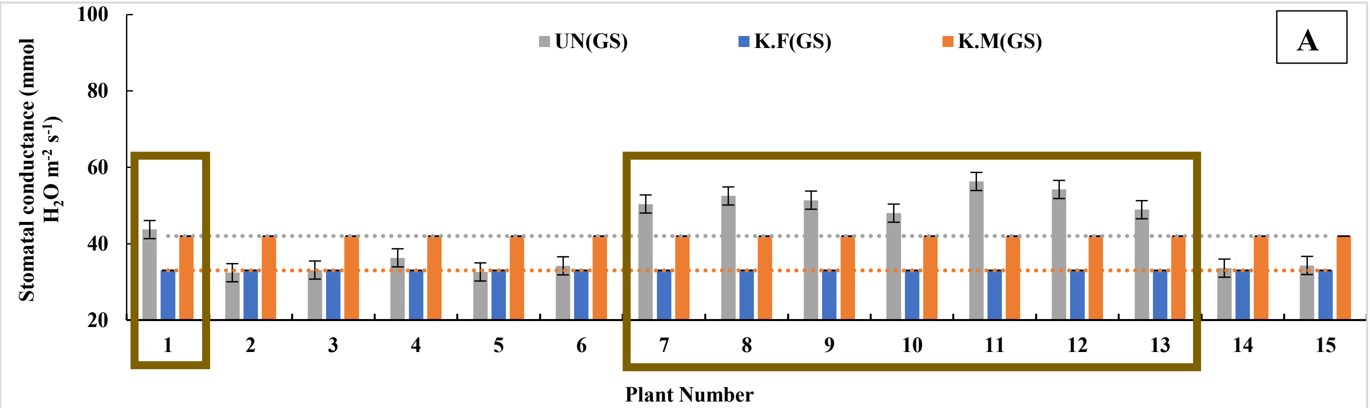
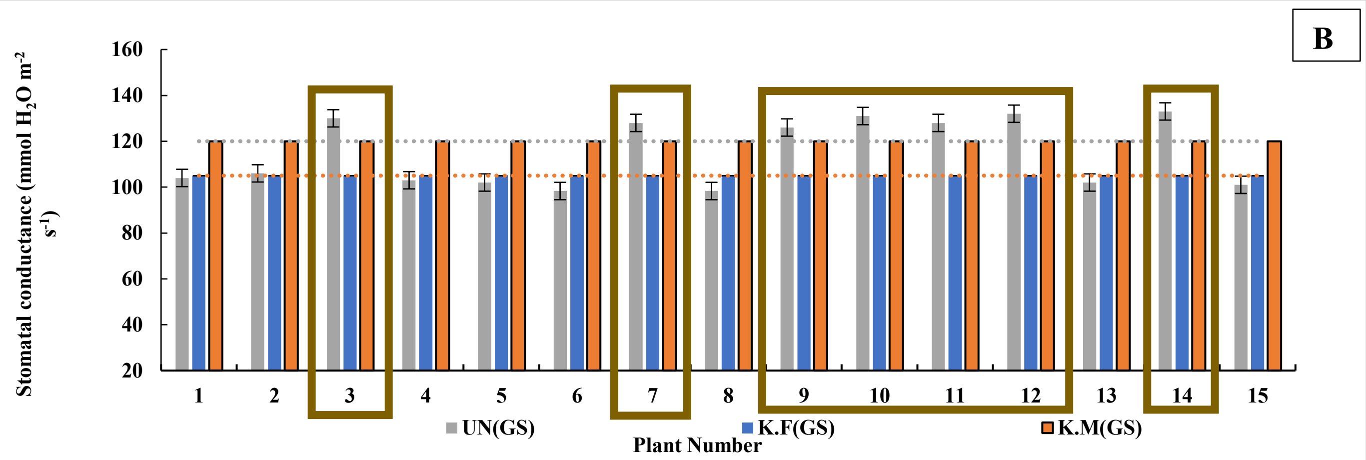


Figure 2. Mean comparison for physiological traits (Photosynthetic rate, transpiration rate, water use efficiency and stomatal conductance) of selected genotypes of date palm (male and female). Error bar represents +SE of three experimental replicates.

Sex Identification Based on Stomatal Conductance from Unknown Seedlings of Date Palm

Stomatal conductance showed a statistically significant difference among known male and female date palm. The male date palm plants showed higher stomatal conductance compared to the female plants. Among fifteen unknown plants of one-year date palm seedlings of Ajwa, male plants no. 1, 7, 8, 9, 10, 11, 12, and 13 had higher stomatal conductance compared to reference female stomatal conductance and were equivalent to or greater compared to reference male stomatal conductance (Fig. 3A). Similarly, among the fifteen plants of Amber, the seedlings plants 3, 7, 9, 10, 11, 12, and 14 had higher stomatal conductance than the reference female date palm and were thus identified as male plant (Fig. 3B). Among 15 seedlings of Medjool, when compared to the reference female plants, the male plants No. 3, 4, 8, 9, 10, 11, 12, 13, 14 and 15 had higher stomatal conductance (Fig. 3C).





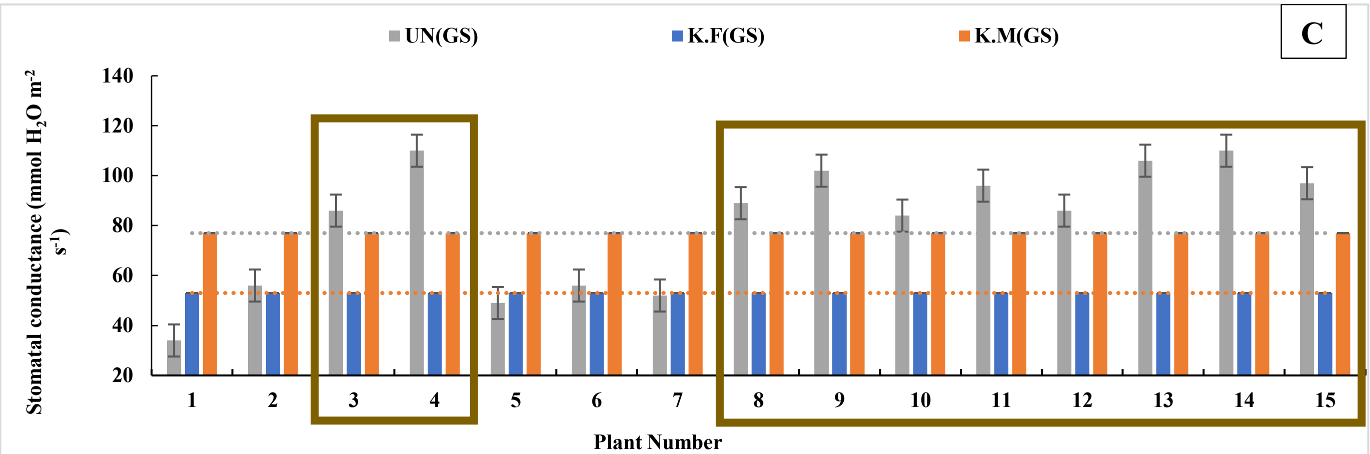


Figure 3. Mean comparison of known stomatal conductance with stomatal conductance of unknown date palm seedling.

The male and female genotypes of date palms differed considerably in terms of physiological characteristics, such as stomatal conductance, transpiration rate, photosynthetic rate, and water usage efficiency. Comparing the qualities of male and female plants, the females showed superiority over male plants. The most important characteristic used to differentiate the sex in date palm plants is stomatal conductance. Our findings also showed that male plants had greater stomatal conductance compared to female plants with high drought-induced evapotranspiration, which is the primary factor in the decline of the male population. While in certain species, both male and female plants had equal stomatal conductance (Meidner, 1987). Additionally, according to some researchers, stomatal conductance is the key characteristic for distinguishing the sex in plants. The stomatal conductance and stomatal index showed a positive correlation (Gaur et al., 2017). There are physiological variations between the sexes, because male and female plants have different needs to reproduce (Barrett and Hough, 2013). According to obtained results, female plants require more resources compared to male plants, that is, in line with the study conducted by Delph and Herlihy (2012) and Chen et al. (2014), who suggested that female plants need more water and other resources for growth as compared to male plants. Therefore, the most essential characteristic for differentiating between male and female plants may be the differences in the functional features and application of the resource pattern (Li et al., 2007). According to Stark et al. (2007) and Stark and Brinda (2015), female gametophyte needs to be more hydrous compared to male gametophyte during fertilization to promote sporophyte growth, that is, physiologically reliant on the maternal gametophyte for development. Male and female plants had significantly different physical and physiological traits. The growth of female plants was also more efficient compared to male plants. This difference was genotype-dependent, demonstrating that morphological traits are not the determinant of sex in date palms. Moreover, our results also showed that more significant differences in stomatal conductance were recorded among male and female plants as well as among genotypes hence this physiological trait may be considered a suitable criterion for sex determination at early growth stages of date palm. It was proposed that morphological and physiological traits are not permanent features owing to environmental dependency. Moreover, our results also showed that more significant differences in stomatal conductance were recorded among male and female plants as well as among genotypes hence this physiological trait may be considered a suitable criterion for sex determination at early growth stages of date palm.

Biochemical Traits (NPK)

The results showed that the NPK concentration differed significantly among the sex for selected genotypes (Table 2). The genotypes performed differently in males and females for the studied traits. The maximum N (2.37 %) were observed in Amber and Medjool female plants as compared to Ajwa female (2.34%) but lower nitrogen concentration was observed in Ajwa males (1.72 %) (Figure 4A), and the maximum phosphorus (0.36%) concentrations were observed in Medjool and Amber females as compared to Ajwa female (0.31 %), whereas minimum concentration of phosphorus was observed in Ajwa males (0.22 %) (Figure 4B). Higher concentration of potassium was recorded in Amber females (3.56 %) as compared to Ajwa and Medjool female plants. The lowest potassium (2.23%) was recorded in Medjool and Amber males as compared to Ajwa males, (Figure 4C). The current findings demonstrated that males and females responded differently to the studied biochemical traits (NPK). Our results suggested that these biochemical characteristics might be used to distinguish between male and female date palm plants.

Table 2. Level of significance for biochemical characteristics

Source	DF	N	P	K
Genotype	2	0.011^{NS}	0.005^{NS}	0.11*
Sex	1	1.5*	0.05*	5.6*
Sex x Genotype	2	0.004^{NS}	0.001^{NS}	0.13*
Error	12	0.03	0.001	0.012

* = significant at p≤0.05 and NS = non-significant, if p>0.05, DF = degree of freedom; N = Nitrogen, P = Phosphorus and K = Potassium

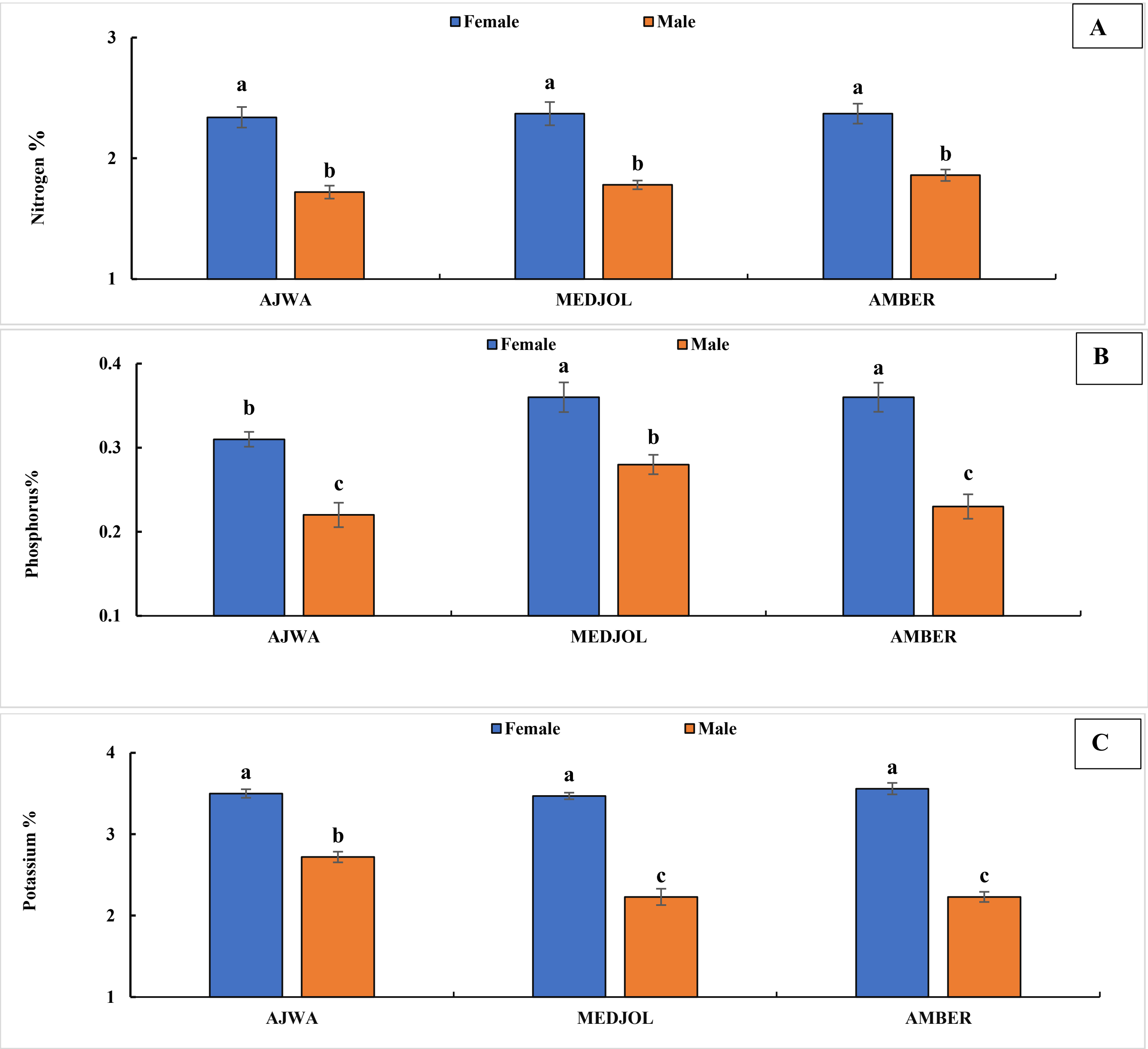


Figure 4. Mean comparison of biochemical parameters (NPK) for male and female plants of date palm.

Sex Identification Based on NPK from Unknown Seedling of Date Palm

Biochemical characteristics based on nitrogen, phosphorus, and potassium concentrations could be applied to differentiate the sex of date palm plants. The present study aimed at identifying the sex in date palm based on nutrients concentration. Results obtained from known male and female date palm suckers showed that the females had a higher concentration of NPK compared to the males that was further used to identify male and female date palm plants from unknown seedlings.

The results demonstrated that the 8 plants out of 15 for date palm variety Ajwa had lower concentrations of (NPK) contents with compared to the reference value of known female plants and had equal or more than reference male plants indicating that these seedlings are male (Figure. 5 A, B and C). In the case of Amber, 7 plants out of 15 showed lower concentrations of (NPK) contents as compared to the reference value for NPK of known females, and these plants were screened as male because they had higher or equal concentrations of (NPK) contents compared to the reference value for males (Figure. 6 A, B and C). Similarly, the seedlings of date palm variety Medjool, 10 plants out of 15 showed lower concentrations of (NPK) as compared to known female plants that was higher or equivalent to those of known males, therefore these plants are screened as male plants (Figure. 7 A, B and C). In the current study, the female genotypes showed higher concentrations of NPK compared to the male genotypes, indicating that the females required a higher concentration of NPK to meet their needs throughout the reproductive process.

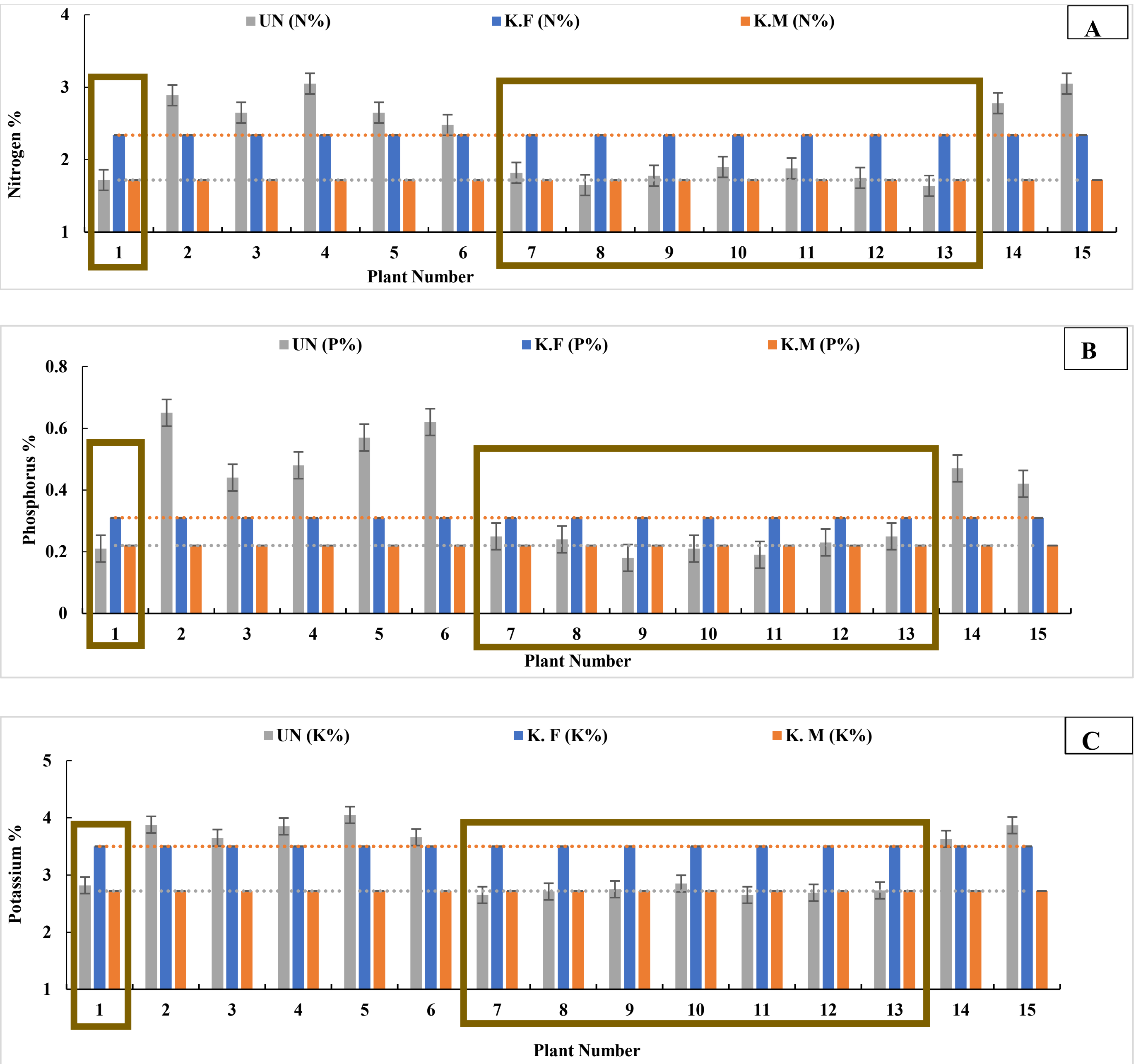


Figure 5. Mean comparison for biochemical parameters (NPK) of Ajwa with unknown seedling of Ajwa.

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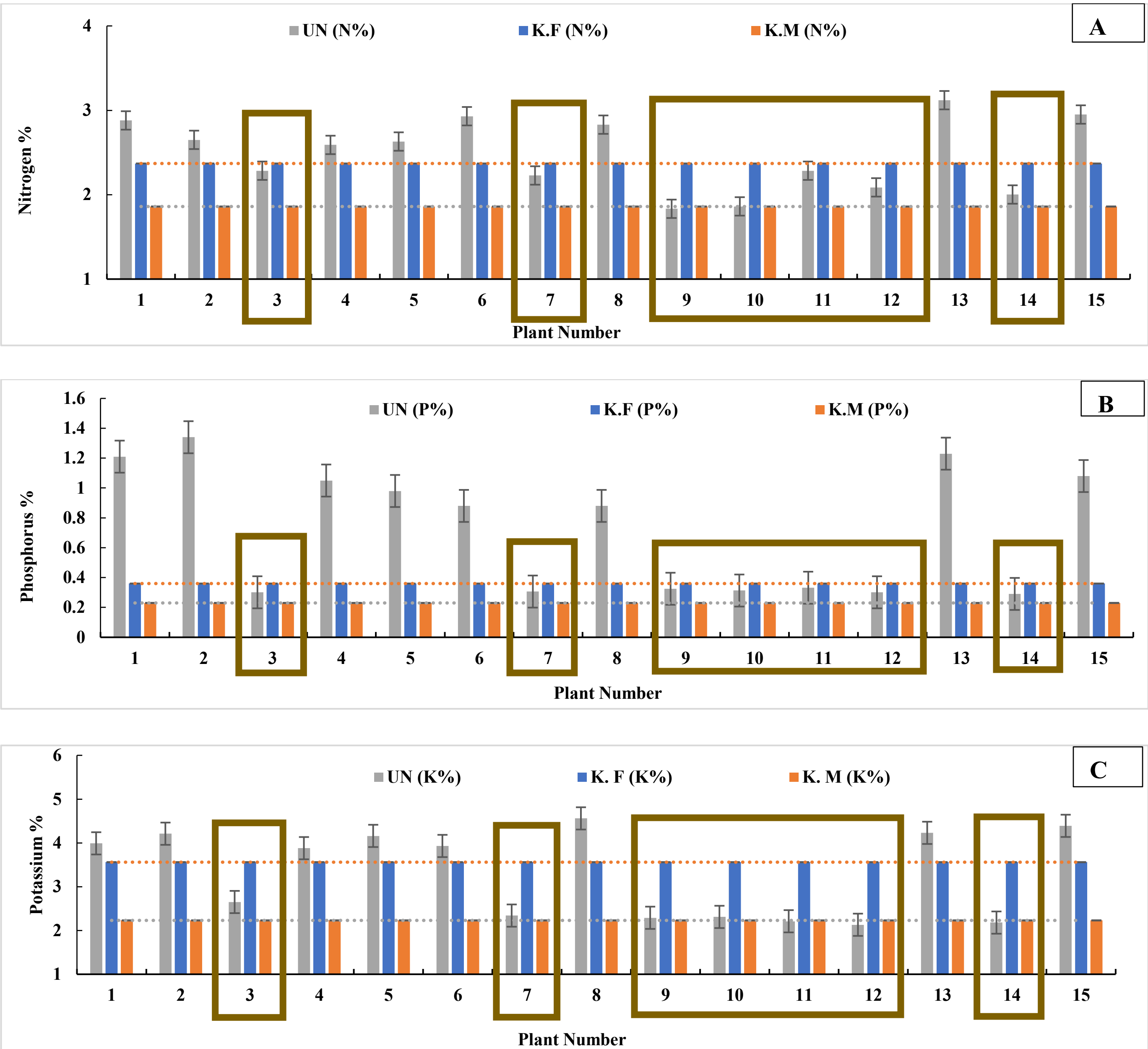
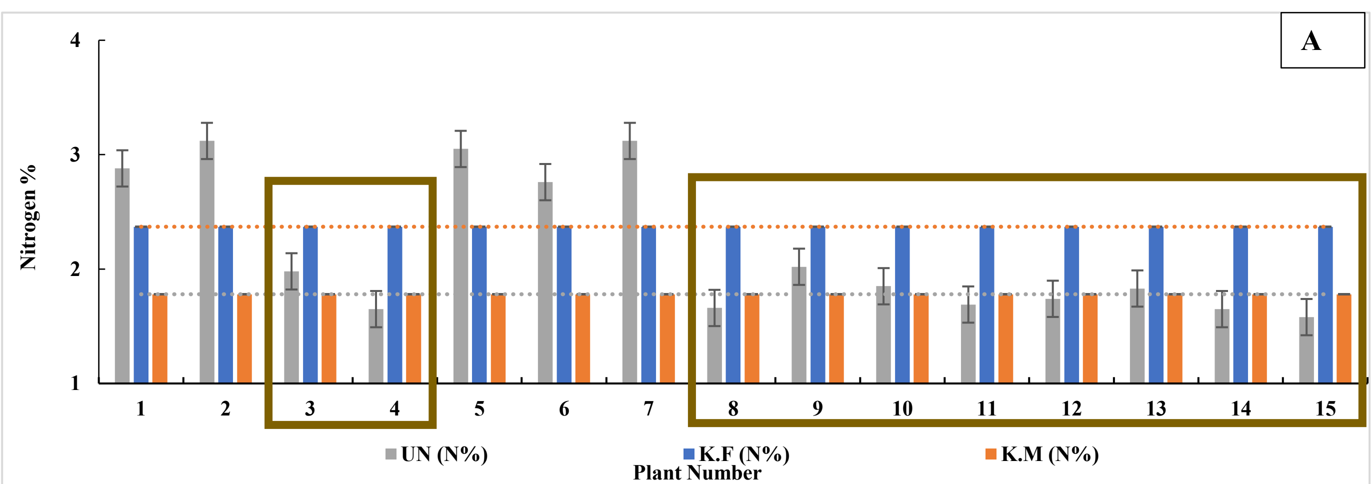


Figure 6. Mean comparison for biochemical parameters (NPK) of Amber with unknown seedling of Amber.



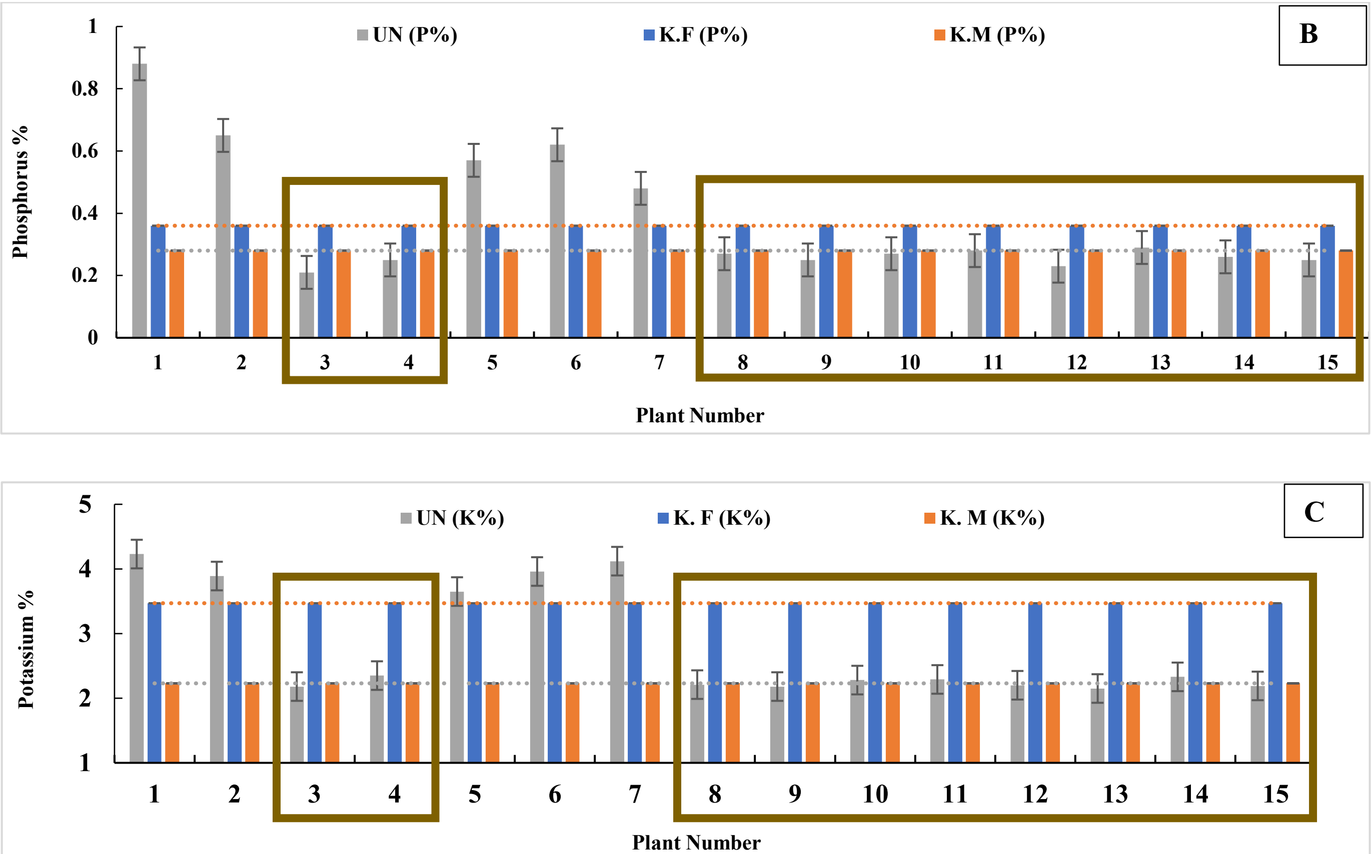


Figure7. Mean comparison for biochemical parameters (NPK) of Medjool with unknown seedling of Medjool.

Biochemical analysis may be considered to determine the sex. Both female and male plants exhibit varied resource distribution. Nitrogen (N), potassium (K) and phosphorus (P) are the essential macronutrients, and their deficiency severely slows down plant development and productivity (Warren, 2011). In addition, Benomar et al. (2011) showed that the female and male plants exhibit different concentrations of macro and micronutrient and thereby respond differently to deficiency of the nutrients. Li et al. (2007) showed that a variety of biochemical traits play important role in identifying sex in different plant species. Delph and Herlihy (2012) also noted that as compared to male plants, female plants had a higher concentration of NPK which might be attributed to their role in sexual reproduction. The requirement of male plants for nitrogen was higher due to more nitrogen assimilation to produce pollen. Therefore, it has been inferred that, the male plants had a lower performance compared to female plants in terms of producing above-ground biomass. Comparing males, the females are more susceptible to nutritional stress and have less capacity to continue growing at low NPK concentrations (Chen et al., 2014). Female plants appear to have a greater NPK percentage compared to male plants. Our results are in line with those of Alghool and Benismail (2007) who studied the chemical composition of date palm trees and observed that the female plants continuously maintain higher NPK percentages in comparison to the male plant. Similarly, Ageez and Madboly (2011) also showed that the male date palm plants exhibit lower percentage of NPK compared to the female plants. According to Chen et al. (2014) female *P. cathayana* would show increased flexibility to physiological changes if they were acclimated to N enrichment settings. They also found that the females are more responsive to the changes in photosynthesis, growth, and N allocation with respect to the males. Consequently, females exhibit more seedling growth compared to the males, which could be associated to greater phenotypic flexibility. Our results showed that the female date palm plants maintained higher biochemical activity compared to the male plants. Our results suggested that these biochemical characteristics might be used to differentiate the sex of date palm plants at early stage.

CONCLUSIONS

The morphological and physiological traits differed significantly among male and female suckers of date palms. However, the inconsistences in these differences indicated that these traits alone are not a reliable criterion for sex differentiation in plants. Whereas biochemical traits of selected date palm genotypes were more consistent for better distinguishing the sexes, suggesting their potential as a reliable criterion for early sex determination. Further comprehensive studies on morphophysiological and biochemical parameters are required to refine the identification of sex in date palm seedlings at early growth stages. The development of reliable sex determination technologies will help in designing and planting date palm orchards, contributing to enhanced yield and economic production in the future.

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AUTHOR CONTRIBUTIONS

AAK and ZK conceptualized the idea. PK did experimentation and wrote the manuscript. IAK reviewed the draft for improvements.

COMPETING OF INTEREST

No conflicts of interest have been disclosed by the authors.

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