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Whorl-Wise Variation in Spath Morphology and Fruit Physicochemical Characteristics of Date Palm (*Phoenix dactylifera* L.) Cultivars Grown in Dera Ismail Khan, Pakistan

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ABSTRACT

The present study was conducted to investigate the whorl-wise variation in vegetative and fruit physicochemical characteristics of six date palm (*Phoenix dactylifera* L.) cultivars, namely Zaidi 1, Zaidi 2, Hilawi, Basra, Dhakki and Gulistan grown at the Date Palm Research Orchard, Gomal University, D.I. Khan, Pakistan. The experiment was arranged in a split-plot design with three replications, where cultivars were assigned to the main plots and whorls (W1, W2 and W3) to the subplots. Pollination was performed using pollen from a single male source to eliminate pollen-source variability. Data were recorded on vegetative traits, including spath length, spath width, number of strands per spath, number of fruits per strand and number of fruits per spath as well as fruit physicochemical attributes, including fruit size, fruit weight, pulp weight, seed weight, moisture content and TSS. The results revealed that first whorl recorded the greatest spath length (141.28 cm), spath width (4.28 cm) and number of strands per spath (66.0). The second whorl produced the highest number of fruits per strand (19.56), number of fruits per spath (1196.0), fruit bunch weight

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(6.12 kg), fruit weight (10.59 g), pulp weight (9.68 g), fruit width (2.28 cm) and moisture content (53.89%). Among the cultivars, Dhakki exhibited superior performance, recording the maximum spath length (126.78 cm), spath width (4.81 cm), number of fruits per strand (24), fruit bunch weight (8.68 kg), fruit weight (20.28 g), pulp weight (20.0 g), fruit length (4.55 cm) and fruit width (2.44 cm). The highest fruit set (88.11%) was observed in Zaidi 2, whereas Zaidi 1 recorded the highest TSS (39.78 °Brix). Hilawi produced the maximum number of fruits per spath (1688) and the highest moisture content (61.33%), while Gulistan recorded the highest seed weight (1.54 g). Whorl position significantly affected vegetative growth, yield and fruit quality, while Dhakki proved to be the most promising cultivar for commercial cultivation under the agro-climatic conditions of Dera Ismail Khan, Pakistan.

Keywords: Date palm, Hilawi, Basra, Dhakki, Fruit size, Pulp weight, TSS.

INTRODUCTION

Date palm (*Phoenix dactylifera* L.) belongs to family Areaceae. It has been cultivated in North Africa and Middle East countries at least 5000 years ago (Chao & Krueger, 2007). Date palm have long history and exact origin is unknown. But most likely originated from ancient Mesopatina area (Southern Iraq) or Western India (Wsingly, 1995). Phoenix genus have 19 species in which most important is date palm. It is monocotyledonous woody diploid (2n=2x=36) and having dioeious nature (male and female flower are initiate on separate palm (Barrow, 1998).

Due to its nutritious, and high energy value dates are consumed both fresh and dry throughout the world. It is called the power source of energy because a single date contains 31 grams of carbohydrates. The date has permanently been considered useful to the mothers. Date fruit possess carbohydrates, water, protein, gelatin, fat, slag, unrefined fiber and polyphenols. In addition, compared to other foods and fruits like apricot, banana, orange, rice, wheat bread and meat, dates give more calories per kilogram. It has been reported that green dates at kimiri stage which are not suitable for human consumption due to having insoluble pectin but used as animal feed, for increasing milk production. Beside this it has cleaning activity and contraction of skin cells and other body tissues. Relieves fever, cystitis, gonorrhea, edema, liver and abdominal diseases. The excreted gum from the injured trunk is used conventionally

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to treat diarrhea and genitourinary diseases (Morton, 1987; Sawaya et al., 1983).

The date palm is an erected growing tree having trunk height (30-35m) and (>50 cm) diameter. The trunk is overlapping, by persistent older leaf basis from base to upward point starting of fronds or feathery leaves. Numerous sucker (off shoot) produce on the base of the stem after 6-16 years planting. Each leaf emerges from a sheath that splits into a network of fibers remaining at the leaf base. Small fragrant flowers (the female whitish, the male waxy and cream colored), are borne on a branched spadix divided into 25 to 150 strands. One large inflorescence may produce 6000 to 10000 flowers.

The fruit is developed from female palm having whitish flowers and male produce flowers the pollen. After pollination the female flowers produce the fruits. The stalk holding the cluster of fruit bent down word due to its length and increasing weight. Date fruit is single, elliptical or oblong with terminal stigma, fine membranous endocarp and fleshy peel, single seeded berry (Mansour et al., 2005). Date fruit maturity takes 150 - 200 days from pollination to maturity. A fully productive palm can produce 10-20 bunches weighing as much as 120–200 kg (Zaid and Arias, 2002).

There are four main stages of date fruit from fruit setting to harvesting. These 4 stages are known by their Arabic names (Kimri, Khalal, Rutab and Tamar). The small green, non-edible and hard texture stage is known as Kimri stage. The second yellowish or reddish colored, hard stage is known as Khalal stage. The third to some extent brown tips, softened with low moisture stage is known as Rutab stage. The last stage in which the color turned to yellowish to dark brown and soft nature with moisture below then 5 to 25% is known as Tamar stage. At maturity stage the date fruit have different colours like Brown, reddish or yellowish brown etc. (Al-Hooti et al., 1997).

There are almost 3,000 varieties of date palms around the world. About 250 in Tunisia, 244 in Morocco, 400 in Iran, 370 in Iraq, as well as many other varieties are being grown in different date producing states (Rani et al., 2007). In Pakistan there are approximately 300 date varieties are grown in district of Khairpur, Mekaran, Muzafrgarh, Multan, D.G. Khan, Jhang, Bannu and D.I.Khan. In these areas the following varieties i.e. Basra, Aseel, Begam Jhangi, Gulistan, Dhakki, Khudrawi,

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Shakri, Mazavati, Zahidi, as well as Hillawi are grown commercially. These cultivars play a significant role in the socio-economic development of cultivators as well as played an important role in foreign exchange earnings.

Date Palm can be grown in tropical and sub-tropical climate. It is one of most valuable plants economically grown in semi-arid and arid area of the world. Dates possess high value due to the reason that they provide ample food in very harsh climatic conditions. One hundred gram dried dates (Tamar) deliver energy (285kcal). Pakistan has also a significant role in production and export of dates Pakistan produced 560184 tons' dates over an area of 95619 hectares during 2020-21. (PBS, 2022). In Khyber Pakhtunkhwa, date palms are commercially grown in the Dera Ismail Khan District, in Paniala, Paharpur, Chawdwan and Dhakki. Due to the opening of the right bank of Chashma canal and the availability of irrigation facilities in the zone, date planting has spread quickly. Owing to the appropriateness of soil and climatic environments, there are many date varieties in this area. (Iqbal et al., 2012).

Date palm is highly tolerant of saline and moderately waterlogged soils and is well adapted to hot arid environments. The crop performs optimally under high temperatures, with successful growth and fruit development occurring at temperatures around 43°C. However, excessive rainfall, particularly during fruit ripening, adversely affects fruit quality by increasing fruit cracking, fermentation, and fungal decay (Zaid and de Wet, 2002). Also best thrives in sandy loam, clay and other heavy soils. The date palm roots need heavy moisture and its top need scorching heat during fruit maturity. (Fatima et al., 2017). Date palm play an important role in economic development of many countries of the world (Chao et al., 2007). According to FAO statistics, globally dates have 6 million metric tons' production. Major producers are Egypt, Iran, UAE, Saudi Arabia and Pakistan. Pakistan exports dates to countries like Bangladesh, India, Germany, Italy, Denmark, Japan, Canada, United Arab Emirates, Africa, Australia, UK as well as US (Solangi et al., 2024).

The Date palm have unique flowering behavior i.e. Spath appear in different whorls at different time and fruits have different sizes and qualities in different whorls. The first spath appears at the top of the 2 year aged leaf and is called the top whorl. Below the top whorl, the spath appear under the axil of the old leaves called the second whorl.

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Below second whorl, the spath appear under the axil of eldest leaves is called the third whorl of spath. Below the third whorl the spath appearing on the axis of the oldest leaf is referred as fourth whorl of the spath. In some varieties, the whorls may be 5th to 7th. There are 3 to 4 spathes per whorl. Among the different whorls, the fruit of the date palm have different characteristics.

In many countries, extensive research has been conducted on the vegetative and fruit physico-chemical characteristics of date palm. However, limited information is available regarding the influence of whorl position on spath development, fruit physical attributes and overall productivity. Although some studies have investigated the effects of male whorl characteristics and pollen source on the fruit quality of the Dhakki cultivar (Iqbal et al., 2007), comprehensive information on whorl-wise vegetative and fruit characteristics across different date palm varieties remains scarce. Therefore, the present study was undertaken to evaluate the whorl-wise spath characteristics and fruit physical traits of different date palm varieties grown under the agro-climatic conditions of Dera Ismail Khan. The findings are expected to improve the understanding of whorl-wise variation in growth and fruit development and provide useful information for enhancing date palm productivity and fruit quality.

MATERIALS AND METHODS

A research was conducted at Date Palm Research orchard, Gomal University, Dera Ismail Khan, KPK, Pakistan. Date palm varieties i.e. Gulistan, Zaidi 1, Basra, Hillawi, Zaidi 2 and Dhakki were selected. These varieties possessed 20 years of age and having vigorous growth. All these female trees were tagged before one month start of research. Three whorls-wise 1st, 2nd and 3rd spath from each variety was selected for vegetative (spath) and fruit physicochemical characteristics. The experiment was laid out in Split Plot Design which contained 6 varieties as the main plot and sub plots of three whorls. The experiment was replicated thrice and for pollination similar pollen source were used.

After 2nd day of spath opening at 12:00 pm all the female trees were pollinated manually by placing 4 fresh male strands on the female spath. The spathes were covered after the pollination with waxy papers in order to avoid the natural crossing. The waxy bags were removed after three weeks. All the usual cultural practices i.e.

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irrigation, fertilization, weeding and insect's pest control measures were accordingly. Whorls was tagged for data reading.

Data were recorded on the these **vegetative and pomological parameters** following the recommended protocols and standard procedures: Spath length (cm), spath width (cm), number of strands per spath, number of fruits per strand, fruit length (cm), fruit width (cm), fruit weight (g), pulp weight (g) and seed weight (g).

Chemical characteristics: Data on moisture content and total soluble solids (TSS) were recorded according to standard analytical procedures.

Moisture content (%)

Fruit moisture content percentage was determined by using oven dry method as suggested by AOAC, (2005). A 10 gram prepare sample was kept in oven at 100 ċ until successive weighing showed no further loss in weight. The sample was then cooled in a desiccator and weighed. The moisture content was ascertained from the loss in weight. Moisture content percentage was determined by using following formula:

$$\text{Moisture Content (\%)} = \frac{\text{Fresh Weight} - \text{Dry Weight}}{\text{Fresh Weight}} \times 100$$

TSS (°Brix) and Bunch weight (kg)

Total soluble solids (°Brix) were determined from the juice extracted from ten randomly selected fruits of each variety using a digital refractometer, while bunch weight (kg) was recorded immediately after harvesting using a calibrated weighing balance.

Statistical Analysis

The recorded data were subjected to analysis of variance (ANOVA) using Statistix 8.1 statistical software. Treatment means were compared using Fisher's Least Significant Difference (LSD) test at the 5% probability level ($P \leq 0.05$), following the procedure described by Steel et al. (1997).

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RESULTS AND DISCUSSION

Length of Spath (cm)

Significant variation in spath length was observed among different whorl positions and date palm cultivars, as shown in Table 1. Amongst varieties the maximum length was found in Hilawi (129.78cm). The minimum length was found in Gulistan (107.00 cm). Maximum spath length was found in W1 (141.28 cm) and minimum in W3 (95.78 cm). As for as interaction in varieties and whorls the maximum spath length was found in W1 of Basra (157.00 cm). Minimum length of spath was observed in W3 of Gulistan (79.67 cm). All the whorls of different varieties were differed from one another and all the three whorls of the same variety were also differed regarding with the length of spath (Islam et al., 2017). All the three whorls differed significantly in spath length. It ranged from 49.55 to 72.81 cm respectively being maximum in W1 and minimum in W3. Variation in whorls are due to genetic makeup of the date palm tree. The results are agreed with findings of Iqbal et al. (2004 and 2011) they noted variation in spath length of diverse male palm whorls.

Table 01: ***Showing the spath length (cm), spath width (cm), number of strands per spath and number of fruit per strand of various whorls of date palm cultivars.***

Varieties	Spath length (cm)	Width of spath (cm)	Nos. of strands per spath	Number of fruits per strand
Basra	119.56 ab	3.86 b	58.00 c	17.11 d
Dhakki	126.78 a	4.81 a	70.89 b	24.00 a
Gulistan	107.00 b	4.38 a	58.56 c	17.00 d
Hilawi	129.78 a	4.81 a	86.11 a	20.00 b
Zaidi 1	111.33 b	3.79 b	61.56 bc	18.44 c
Zaidi 2	112.56 b	2.78 c	48.50 d	18.89 c
Basra	119.56 ab	3.86 b	58.00 c	17.11 d
Dhakki	126.78 a	4.81 a	70.89 b	24.00 a
$LSD_{0.05}$	13.88	0.47	9.41	0.93
Whorls				

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W1	141.28 a	4.28 a	66.06 a	19.33 ab
W2	116.44 b	4.07 ab	65.56 a	19.56 a
W3	95.78 c	3.87 b	60.19 a	18.833 b
LSD for (VxW)$_{0.05}$	24.04	0.8204	16.30	1.62

Mean followed by similar letter(s) do not differ significantly at 5% level of significance.

Width of Spath (cm)

Maximum spath width was observed in cultivar Dhakki and Hilawi (4.81 cm). Minimum width of spath was observed in cultivar Zaidi 2 (2.78 cm). Maximum width of spath was observed in W1 (4.28 cm). In interactive effect of varieties and whorls, the maximum width of spath was noted in W3 of Dhakki (5.00 cm) and minimum width of spath was observed in W3 of Zaidi 2 (2.63 cm).

Variation in spath width among date palm cultivars is primarily attributed to genetic differences, while environmental conditions, nutritional status and orchard management practices also influence inflorescence development and flowering characteristics (Zaid and de Wet, 2002). Similar cultivar-dependent variation in reproductive traits of date palm has also been reported by El-Juhany, (2010).

Number of strands per spath

A significant effect of date palm cultivar on the number of strands per spath was observed during the study. The number of strands per spath ranged from 48 to 86 among the evaluated cultivars. The highest number of strands per spath was noted in Hillawi (86.11), while the lowest number of strands per spath was determined in Zaidi 2 (48.50). The findings are agreement with the results of Shahid et al. (2017), they reported variation in number of strand per spath of different male palm. In whorls, highest number of strands per spath was noted in W1 (66.06) and lowest in W3 (60.19). Interaction of varieties and whorls, the highest number of strands per spath was observed in W2 of Hilawi (90.66) followed by W1 of Hilawi (85.00) and lowest number of strands per spath was noted in W3 of Zaidi 2 (36.50). The number of strands per spath varied from 60 to 66 in different whorls. Results regarding number of strands per spath of different whorls shows that the maximum number of strands

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per spath are found in whorl 1 and whorl 2 and minimum in whorl 3. Similar variation in inflorescence characteristics among date palm genotypes and flowering structures has been reported by Zaid and de Wet, (2002). The present findings are also consistent with those of Iqbal et al. (2004), who reported differences in the number of strands among male date palm whorls under the agro-climatic conditions of Dera Ismail Khan.

Number of fruits per strand

A significant variation in the number of fruits per strand was observed among the date palm varieties. Dhakki exhibited the maximum number of fruits per strand (24.00), whereas Hilawi ranked second with a mean of (20.00) fruits per strand. Minimum number of fruits per strand was found in Gulistan (17.00). Maximum number of fruits per strand was noted in W2 (19.56) and in W3 (18.83) respectively for whorls interaction. Interaction of varieties and whorls, maximum number of fruits per strand was found in W2 of Dhakki (24.67) followed by W1 of Dhakki (24.00) and minimum number of fruits per strand was observed in W3 of Gulistan (16.00). The superior performance of Dhakki suggests a greater capacity for flower retention and successful fruit set. Likewise, variation among whorls may be associated with differences in flower density, assimilate availability and pollination efficiency, with whorls having a higher initial flower number generally producing more fruits (Chao and Krueger, 2007). The present findings are consistent with Iqbal et al. (2004), who reported the highest number of flowers per strand in the second whorl and the lowest in the third whorl. Similar observations by Nixon and Carpenter, (1978) and Zaid and de Wet, (2002) further indicate that cultivar characteristics, inflorescence morphology and efficient pollination are key factors governing fruit number and overall productivity in date palm.

Number of fruit per spath

Data regarding number of fruit per spath of various date varieties was significantly affected during study. The maximum number of fruit per spath was recorded in Hilawi (1688). Minimum number of fruit per spath was recorded in Zaidi 2 (873.6). Maximum number of fruit per spath/whorl was recorded in W2 (1196) followed by W1 (1172) and minimum in W3 (1124) respectively. Interactional effect of varieties and whorls, the maximum number of fruit per spath was recorded in W2 of Hilawi (1781) followed

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by W1 of Hilawi (1657) and minimum number of fruit per spath was observed in W2 of Zaidi 2 (841). This may be due to a higher number of flowers per strand, improved pollen reception, and better assimilate allocation to developing fruits. Iqbal et al. (2004) similarly reported that the second whorl contained the highest number of flowers per strand, which subsequently resulted in a greater number of fruits per spathe. Because fruit number is directly dependent on the initial flower population and the efficiency of pollination and fertilization, spathes with more flowers generally produce more fruits, provided environmental conditions are favorable.

Fruit bunch weight (kg)

A significant variation in fruit bunch weight was observed among the evaluated varieties. Dhakki exhibited the highest fruit bunch weight (8.68 kg), followed by Basra (6.54 kg), whereas the lowest value was recorded in Zaidi 1 (4.19 kg). As for whorls interaction heaviest fruit bunch weight was found in W2 (6.12 kg) followed by W1 (5.87 kg) and lightest in W3 (5.38 kg). As for as interaction in varieties and whorls the heaviest fruit bunch weight was found in W1 of Dhakki (9.32 kg) and lightest fruit bunch weight was found in W3 of Zaidi 1 (3.73 kg). The overall maximum fruit bunch yield among the six varieties was obtained from cultivar Dhakki and among the three whorls maximum fruit bunch weight was obtained from whorl 2 and minimum in whorl 1 and whorl 3 respectively. Maximum fruit bunch weight of Dhakki was achieved by whorl 2. Difference in fruit bunch weight from different whorls was reported by Iqbal et al. (2004) which agree with the current study.

Fruit weight (g)

Fruit weight of various date varieties was significantly affected during the study. Amongst varieties Dhakki has heaviest weight of (20.28 g). The minimum fruit weight was recorded in Hilawi (6.74 g). Variation of fruit weight of each variety is due to genetic characteristics of date varieties, similar results were reported by Iqbal et al. (2004). In whorls maximum fruit weight was recorded in W2 (10.59 g) followed by W1 (10.51 g) and minimum fruit weight in W3 (10. 36 g). As for as interaction in varieties and whorls the maximum fruit weight was recorded in W2 and W3 of Dhakki (20.53 g) (20.50 g). Minimum fruit weight was recorded in W3 of Hilawi (6.45 g). Although studying date palm cultivars from Pakistan also perceived Dhakki variety

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to have heaviest volume and weight. Dhakki has more fruit weight than the heaviest fruit weight (12.78gm) of the date palm cultivars from Sudan by Al Yahyai, (2008). The data on single fruit weight also shows significant variances among varieties with maximum fruit weight in Dhakki (21.46 g). Rehman and Wazir (2006) also noted maximum fruit weight in Dhakki. Maximum fruit weight in Dhakki is due to its supreme size and also genetic character which persist dominant in every atmosphere. In cumulative effect of heaviest fruit weight was produced by cultivar Dhakki (24.45 g) at Khalal stage and minimum by Gulistan at Khalal stage (8.35 g). The results are agreeing with the findings of Iqbal et al. (2011).

Table 02: ***Showing the number of fruit per spath, fruit bunch weight (kg), fruit weight (g), length of fruit (cm) of various whorls of date palm cultivars.***

Varieties	Number of fruit per spath	Fruit bunch weight (kg)	Fruit weight (gm)	Length of fruit (cm)
Basra	944.6 d	6.54 b	7.37 de	3.77 a
Dhakki	1405.4 b	8.68 a	20.28 a	4.55 b
Gulistan	928.9 d	4.44 c	11.51 b	4.45 c
Hilawi	1688.4 a	6.42 b	6.74 e	3.03 e
Zaidi 1	1146.9 c	4.19 c	7.69 d	3.46 d
Zaidi 2	873.6 d	4.45 c	9.32 c	3.51 d
Basra	944.6 d	6.54 b	7.37 de	3.77 a
Dhakki	1405.4 b	8.68 a	20.28 a	4.55 b
$LSD_{0.05}$	142.09	0.9795	0.89	0.0860
Whorls				
W1	1172.9 a	5.87ab	10.51 a	3.80 a
W2	1196.9 a	6.12 a	10.59a	3.79 a
W3	1124.1 a	5.38 b	10.36 a	3.78 a
$LSD_{0.05}$	100.47	0.6926	0.63	0.0608
LSD for (VxW)$_{0.05}$	246.10	1.6966	16.30	0.1490

Mean followed by similar letter(s) do not differ significantly at 5% level of significance.

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Length of fruit (cm)

The fruit length varied significantly among the evaluated date palm varieties. The maximum fruit length was recorded in Dhakki (4.55 cm), followed by Gulistan (4.45 cm), whereas the minimum fruit length was observed in Hilawi (3.03 cm). These results are agreeing with the findings of Iqbal et al. (2012). In whorls maximum length of fruit was observed in W1 (3.80 cm) followed by W2 (3.79 cm) and smallest length of fruit in W3 (3.78 cm). These results are agreeing with the findings of Iqbal et al. (2004). As for as interaction in varieties and whorls the lengthiest length of fruit was found in W3 of Dhakki (4.63 cm) followed by W1 of Dhakki (4.55 cm) and smallest length of fruit was observed in W3 of Hilawi (2.90 cm).

Dhakki have lengthiest (5.09 cm) and mallest fruit length was found by Shakri and Zahidi (3.447 and 3.42 cm) respectively. Khan and Ghaffoor, (1993) and Iqbal et al. (2004) also reported maximum fruit length in whorl 2 of Dhakki among other cultivars grown in Dera Ismail Khan. Similar varietal differences in fruit length have been reported by Iqbal et al. (2012), who found Dhakki to produce significantly longer fruits than several other commercial cultivars under the agro-climatic conditions of Dera Ismail Khan. Likewise, Nadeem et al. (2011) reported maximum fruit length in Dhakki, whereas Zaidi produced comparatively shorter fruits. The slight variation among whorls may be associated with differences in assimilate distribution and microenvironment during fruit development. Comparable observations were reported by Iqbal et al. (2004) and Khan and Ghafoor, (1993), who found that fruit size traits, including fruit length, varied with whorl position and were generally superior in the upper and middle whorls of Dhakki. These findings indicate that both cultivar and whorl position significantly influence fruit length in date palm.

Width of fruit (cm)

Fruit width differed significantly among the evaluated date palm varieties. The highest fruit width was observed in Dhakki and Zaidi 1 (2.44 cm each), whereas Basra exhibited the lowest fruit width (1.90 cm). AS for whorls widest width of fruit was observed in W2 (2.28 cm) followed by W3 (2.25 cm) and narrowest width of fruit in W1 (2.22 cm). As for as interaction in varieties and whorls the widest width of fruit was observed in W3 of Dhakki (2.53 cm) and narrowest width of fruit was observed

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in W1, W2 and W3 of Basra (1.90 cm). Among the six varieties the highest diameter was observed in cultivar Dhakki (3.07 cm) and lowest in cultivar Shakri (2.25 cm). In different maturity stages Rutab stage out classed in width (2.57 cm) with minimum (2.42 cm) at Kimri stage. However, fruit dia (width) were greater in cv. Dhakki at maturity stage of Rutab (3.16 cm) while it was least in Shakri at Kimri stage (2.07 cm). The observed variation in fruit width among the cultivars may be attributed to inherent genetic differences governing fruit growth, cell expansion, and assimilate accumulation during fruit development (Zaid and de Wet, 2002). The superior fruit width of Dhakki reflects its greater genetic potential for developing larger fruits, while the comparatively smaller width of Basra indicates cultivar-specific differences in fruit morphology. Therefore, the present results are in agreement with the findings of Iqbal et al. (2011), confirming that fruit width is predominantly influenced by cultivar characteristics and, to a lesser extent, by whorl position.

Pulp weight (g)

Data regarding the pulp weight of various date varieties was significantly affected. Amongst varieties the maximum pulp weight was found in Dhakki (20.02 g) followed by Gulistan (9.80 g). The minimum pulp weight was found in Hilawi (5.67 g). As for whorls interaction maximum pulp weight was observed in W2 (9.65 g) and minimum pulp weight in W3 (8.83 g). As for as interaction in varieties and whorls the maximum pulp weight was found in W2 of Dhakki (22.47 g) and minimum pulp weight was observed in W3 of Hilawi (5.35 g).

The present findings are consistent with those of Iqbal et al. (2011), who reported the highest pulp weight in the cultivar Dhakki (19.97 g), whereas the lowest pulp weight was recorded in Shakri (8.78 g). Similarly, Iqbal et al. (2004) observed that the maximum pulp weight was obtained from fruits borne on Whorl-2 and Whorl-3 when pollination was carried out on the day of spathe opening. The observed variation in pulp weight among date palm cultivars may be attributed primarily to genetic differences that regulate fruit growth, mesocarp development and assimilate accumulation. The agreement between the present and previous studies indicates that both genotypic characteristics and whorl position, together with appropriate pollination timing, play important roles in determining pulp development.

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Table 03: ***Showing the width of fruit (cm), pulp weight (g), single seed eight (g), moisture content (%), TSS content (°Brix) of various whorls of date palm cultivars.***

Varieties	Width of fruit (cm)	Pulp weight (g)	Single seed weight (g)	Moisture content (%)	TSS (°Brix)
Basra	1.90 d	6.14c	1.24 b	55.22 b	23.89 c
Dhakki	2.44 a	20.02 a	1.33 b	51.22 c	10.88 d
Gulistan	2.28 b	9.80 b	1.54 a	50.00 d	8.89 e
Hilawi	2.08 c	5.67 c	1.03 c	61.33 a	25.22 c
Zaidi 1	2.44 b	6.40 c	1.28 b	48.56 e	39.78 a
Zaidi 2	2.35ab	6.97 c	1.49 a	51.00 c	33.33 b
Basra	1.90 d	6.14c	1.24 b	55.22 b	23.89 c
Dhakki	2.44 a	20.02 a	1.33 b	51.22 c	10.88 d
$LSD_{0.05}$	0.0993	1.8558	0.1136	0.6818	1.7939
Whorls					
W1	2.22 a	9.02 a	1.3144 a	52.44 b	24.11 a
W2	2.28 a	9.65 a	1.3150 a	53.89 a	23.44 a
W3	2.25 a	8.83a	1.3272 a	52.33 b	23.44 a
$LSD_{0.05}$	0.0702	1.3123	0.0803	0.4821	1.2685
LSD for (VxW)$_{0.05}$	0.1720	3.2143	0.1967	1.1810	3.1072

Mean followed by similar letter(s) do not differ significantly at 5% level of significance.

Single seed weight (g)

Single seed weight varied significantly among the evaluated date palm varieties. The highest single seed weight was recorded in Gulistan (1.54 g), whereas the lowest single seed weight was observed in Hilawi (1.03 g). As for whorls interaction highest single seed weight observed in W3 (1.327 g) and lowest single seed weight in W1 (1.314 g). As for as interaction in varieties and whorls the highest single seed weight was found in W3 of Gulistan (1.57 g) followed by W1 of Gulistan (1.53 g) and lowest single seed weight was observed in W1 of Hilawi (1.00 g). Amongst varieties, heaviest

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mean seed weight was reported in Zahidi (1.41 g) against minimum in CV Khudrawi (1.14 g) Iqbal et al. (2011). The seeds possessing minimum weight (1.51 g and 1.30 g) were obtained from dusting method and control during both years (Iqbal et al., 2010).

Moisture content (%)

Moisture is one of the principal components of date fruit and plays a vital role in determining fruit quality, shelf life and suitability for processing and preservation. Date fruits are consumed at different stages of maturity, including Khalal, Rutab and Tamr**,** depending on the cultivar. Moisture content was determined by oven-drying 5 g of fruit pulp. The weighed pulp was evenly spread in a pre-weighed porcelain dish and dried at 70°C for 48 hours**.** The dried sample was then weighed using a digital balance, and the moisture content (%) was calculated according to the method described by Latimer, (2019).

The moisture content of the evaluated date palm varieties differed significantly. Among the varieties, Hilawi recorded the highest moisture content (61.33%), followed by Basra **(**55.22%), whereas the lowest moisture content was observed in Gulistan (50.00%). Among the whorls, Whorl-2 exhibited the highest moisture content (53.89%), followed by Whorl-1 (52.44%), while the lowest moisture content was recorded in Whorl-3 (52.33%). The interaction between variety and whorl position was also significant, with W2 of Hilawi recording the highest moisture content (62.33%), followed by W1 of Hilawi (61.00%), whereas the lowest moisture content was observed in W1 of Zaidi 1 (48.00%).

The observed variation in moisture content among the cultivars may be attributed to genetic differences in fruit composition and the rate of moisture loss during fruit maturation and ripening. Cultivars with higher moisture content generally retain more water at harvest and are often characterized by softer fruit texture, whereas cultivars with lower moisture content tend to produce firmer fruits with improved storage potential (Zaid and de Wet, 2002). The slight differences observed among whorls may be associated with variation in fruit development and assimilate accumulation within the canopy. Sawaya et al. (1983) reported that moisture content in date fruits varies considerably with cultivar and stage of maturity, generally ranging from 70% to 20% during fruit development. In the present study,

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moisture content ranged from 50.00% to 61.33%, which falls within the reported range. Similar variation among date palm cultivars was also reported by Iqbal et al. (2011). Therefore, the present findings are in agreement with those of Sawaya et al. (1983) and Iqbal et al. (2011), confirming that moisture content is largely influenced by cultivar characteristics and fruit maturity.

Total soluble solids content (°Brix)

Total soluble solids (TSS) differed significantly among the evaluated date palm varieties. The highest TSS was recorded in Zaidi 1 (39.78 °Brix), followed by Zaidi 2 (33.33 °Brix), whereas the lowest TSS was observed in Dhakki (10.88 °Brix). The minimum total soluble solids percentage was found in Dhakki (10.88 °Brix). As for whorls interaction maximum total soluble solids percentage was observed in W1 (24.11 °Brix) followed by W2 and W3 (23.44 °Brix). As for as interaction in varieties and whorls the maximum total soluble solids percentage was found in W1 of Zaidi 1 (43.33 °Brix) followed by W2 of Zaidi 1 (42.67 °Brix) and minimum total soluble solids percentage was observed in W2 of Gulistan (8.00 °Brix). Similar cultivar-dependent differences in TSS have been reported by Sawaya et al. (1983), who observed considerable variation in soluble solids among commercial date cultivars during fruit maturation. Chao and Krueger, (2007) also reported that TSS is one of the principal quality attributes of date fruits and is largely controlled by genotype and stage of maturity. Furthermore, Iqbal et al. (2011) found significant differences in TSS among date palm cultivars grown under the agro-climatic conditions of Dera Ismail Khan, with sweeter cultivars exhibiting higher °Brix values. Therefore, the present findings are in close agreement with earlier reports, confirming that cultivar, fruit maturity and whorl position collectively influence TSS accumulation in date palm fruits.

CONCLUSION

The results of this study demonstrated that whorl position significantly affected the growth, yield, and fruit quality characteristics of date palm. Among the evaluated whorls, Whorl-1 produced the maximum spath length, whereas Whorl-2 recorded the highest number of fruits per strand and per spath, along with superior fruit weight, pulp weight, fruit width and moisture content. Among the evaluated cultivars, Dhakki consistently exhibited the best performance, producing the maximum spath length

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and width, number of fruits per strand, bunch weight, single fruit weight, pulp weight, fruit length and fruit width. Overall, the findings indicate that Whorl-2 is the most productive for fruit yield and quality, while Dhakki is the most promising cultivar for achieving higher productivity and superior fruit characteristics. Therefore, it can be concluded that Dhakki is the most promising cultivar for commercial cultivation under the agro-climatic conditions of Dera Ismail Khan, Pakistan.

Author Contributions

All authors contributed to the conceptualization, experimental design, data collection, experimentation, data analysis and interpretation, manuscript writing, review and editing. All authors provided technical support, critically reviewed the manuscript and approved the final published version. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this manuscript.

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