INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
13–766/2014/16–4–795–800
http://www.fspublishers.org

Full Length Article

Ecological Significance of Root Anatomy in Date Palm (*Phoenix dactylifera*) Cultivars from Diverse Origins

Ghayoor Fatima[1,2*], Iqrar Ahmad Khan[2], Muhammad Jaffar Jaskani[2] and Fakhara Khanum[3]
[1]*Organic Plant Production & Agroecosystems Research in the Tropics and Subtropics, University of Kassel, Germany*
[2]*Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan*
[3]*National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan*
[*]For correspondence: ghayoor.fatima@gmail.com

Abstract

Date palm (*Phoenix dactylifera* L.) is one of the major fruit crops in Pakistan and country ranks among the seven leading producers worldwide. It shows wide variations in its morpho-anatomical characteristics. For root anatomical studies, twenty two date palm cultivars were collected from Date Palm Research Station, Jhang, Pakistan and were cross-sectioned free hand. Root parameters were measured with the help of using a compound microscope. Results showed that sclerenchyma thickness, sclerenchyma bundle area and cortical cell area were largest in Zaidi (305.40; 18950.3; 5174.6 µm) while Karbalaen (62.63 µm), 'Khudrawi-2' (2867.0 µm) and Saib (1206.2 µm) showed smallest values, respectively. Highest cortical thickness, metaxylem area and phloem area were observed in Makran. All the cultivars displayed significant variations in the root structures, which indicate different evolutionary routes for date palm cultivars. Further molecular genetics studies are needed to decipher the diversity in date palm cultivars. © 2014 Friends Science Publishers

Keywords: Diversity; Endodermis; Epidermis; Metaxylem; Sclerenchyma

Introduction

Pakistan is one of the biggest producers of dates (*Phoenix dactylifera* L.) on the global scale (Markhand *et al*., 2010). About 325 varieties of date palm are introduced from several native and exotic sources in Pakistan (Jamil *et al*., 2010) and country's date production was above 557 metric tonnes and cultivation area was 93,088 ha in 2011 (FAO, 2011). It is one of the oldest fruit trees and widely cultivated for its edible syrupy fruit. Having long history of date palm cultivation, its exact native distribution is unidentified but perhaps instigated somewhere in southwest Asia and possibly also from the desert of northern Africa (El-Shibli and Korelainen, 2009).

Development of the root structure is considered important in the survival and growth of date palm (Ogburn and Edward, 2009). Differentiation of root cortex proves key factor in controlling the transport of water and nutrients inside and outside of the root, and subsequently to other parts of the plant body. Endodermis, the internal layer of cortex, acts like an apoplastic barrier and is crucial for selective transport in the stele (Clarkson and Robards, 1975). Like endodermis, the exodermis also has the properties of the apoplastic barrier, but it is differentiated in sub epidermal layer of cortex periphery. It enables exodermis to protect the tissue of middle part of cortex (Zimmerman and Steudle, 1998).

Formation of aerenchyma may enhance diffusion of the photosynthetic and atmospheric oxygen from shoot to roots (Baruch and Merida, 1995; Hameed *et al*., 2009). Compactness of exodermal and hypodermal layers in the roots can play active role in preventing the collapse of cortex and prove important structural framework for the aereanchyma formation (Seago and Marsh, 1989).

Anatomical characteristics greatly help in the identification of plant species and cultivars. Structural modifications are important in assessing degree of tolerance in plant species against a variety of environmental stresses in addition to other physiological and biochemical processes (Hameed *et al*., 2009). Abiotic stresses result in changes in structure, size and nature of different plant tissues, which contribute in adaptation to unfavourable environmental conditions (Patakas, 2012).

Keeping in view the above considerations the present study was designed to report the comparison between root anatomical structures of different cultivars of date palm, which have been introduced from different origins. Structural modification in the root of date palm has been studied in relation to their productivity and tolerance to environmental stresses.

Materials and Methods

The date palm cultivars in Date Palm Research Station, Jhang, have been introduced not only from all over Pakistan

To cite this paper: Fatima, G., I.A. Khan, M.J. Jaskani and F. Khanum, 2014. Ecological significance of root anatomy in date palm (*Phoenix dactylifera*) cultivars from diverse origins. *Int. J. Agric. Biol.*, 16: 795–800

but also from Saudi Arabia, Iran, Iraq and Egypt. Root anatomical structures of 22 cultivars i.e., Aseel, Berehmi, Karbalaen, Khudrawi-1, Khudrawi-2, Koharba, Kokna, Kuzanabad, Makraan, Neelam, Peela Dora, Peeli Sundar, Qantar, Rachna, Saib, Shado, Shamran, Shamran-2, Wahan Wali, Zaidi, Zardu and Zeerin were studied to know the diversity in them.

A sample of adventitious roots was collected from each cultivar and immediately placed in polythene bags. A 2 cm piece form the root-shoot junction was taken for root anatomy and placed in FAA (formalin acetic alcohol) solution, which contained v/v 5% formalin, 10% acetic acid, 50% ethanol, and 35% distilled water. For long-term preservation, the material was subsequently transferred to acetic alcohol solution (acetic acid 25%, ethanol 75%).

Free hand sectioning technique was done for the preparation of permanent slides of root transverse sections. The sections were passed through a series of ethanol grades for dehydration (Ruzin, 1999). For staining, safranin and fast green were applied. The sections were finally mounted in Canada balsam for permanent slides. The sections were photographed with the help of camera-equipped compound microscope. Measurements of anatomical parameters were taken with the help of ocular micrometer under a compound microscope, which was calibrated with the help of stage micrometer. CRD experimental design was applied and collected data on dermal, ground, and vascular tissues subjected to ANOVA and means were compared by Duncan's multiple range (DMR 0.05).

Results

Different root anatomical parameters i.e. Epidermis thickness, Epidermis cell area, Sclerenchyma thickness, Sclerenchyma area, Sclerenchyma bundle area, Cortical region thickness, Cortical cell area, Endodermis thickness, Endodermis cell area, Phloem area, Pith area, Metaxylem area and Vascular region thickness were measured (Table I). Root sections of all cultivars were labelled (Fig. 1) as Aseel (Fig. 1a), Berehmi (Fig. 1b), Karbalaen (Fig. 1c), Khudrawi-1 (Fig. 1d), Khudrawi-2 (Fig. 1e), Koharba (Fig. 1f), Kokna (Fig. 1g), Kuzanabad (Fig. 1h), Makraan (Fig. 1i), Neelam (Fig. 1j), Peela Dora (Fig. 1k), Peeli Sundar (Fig. 1l), Qantar (Fig. 1m), Rachna (Fig. 1n), Saib (Fig. 1o), Shado (Fig. 1p), Shamran (Fig. 1q), Shamran-2 (Fig. 1r), Wahan Wali (Fig. 1s), Zaidi (Fig. 1t), Zardu (Fig. 1u) and Zeerin (Fig. 1v). All the cultivars had very specific anatomical features which help in their taxonomic identification and also indicate their adoption to a variety of environmental conditions. Variation in values of root structures and comparative characteristics of all cultivars are described below.

Epidermis Thickness

Epidermis thickness varied significantly (P<0.01) in all the cultivars of date palm (Table 1). Maximum epidermis thickness was found in Berehmi (57.19 µm) followed by Kozanabad (53.85 µm) while minimum thickness was observed in Karbalaen (19.06 µm).

Sclerenchyma Thickness

Sclerenchyma thickness in all 22 cultivars varied significantly (P<0.01) from each other (Table 1). Zaidi showed the highest Sclerenchyma thickness (305.40 µm) followed by Zardu (305.01 µm). In contrast to this Karbalaen (62.63 µm) showed lowest sclerenchyma thickness.

Cortical Region Thickness

Variations according to the cortical region thickness were significant (P<0.01) in all the studied cultivars (Table 1). More than half of cultivars showed the cortical region thickness greater than 500 µm. Makraan had the highest cortical region thickness (898.60 µm) followed by Khudrawi-1 (814.20 µm) as Kokna had the lowest cortical region thickness (288.60 µm).

Endodermis Thickness

Endodermis thickness varied significantly (P<0.01) in all the studied cultivars (Table 1). The largest endodermis thickness was observed in Saib (49.02 µm) followed by Makraan (43.50 µm) while the lowest value was recorded for Neelam (19.00 µm).

Vascular Region Thickness

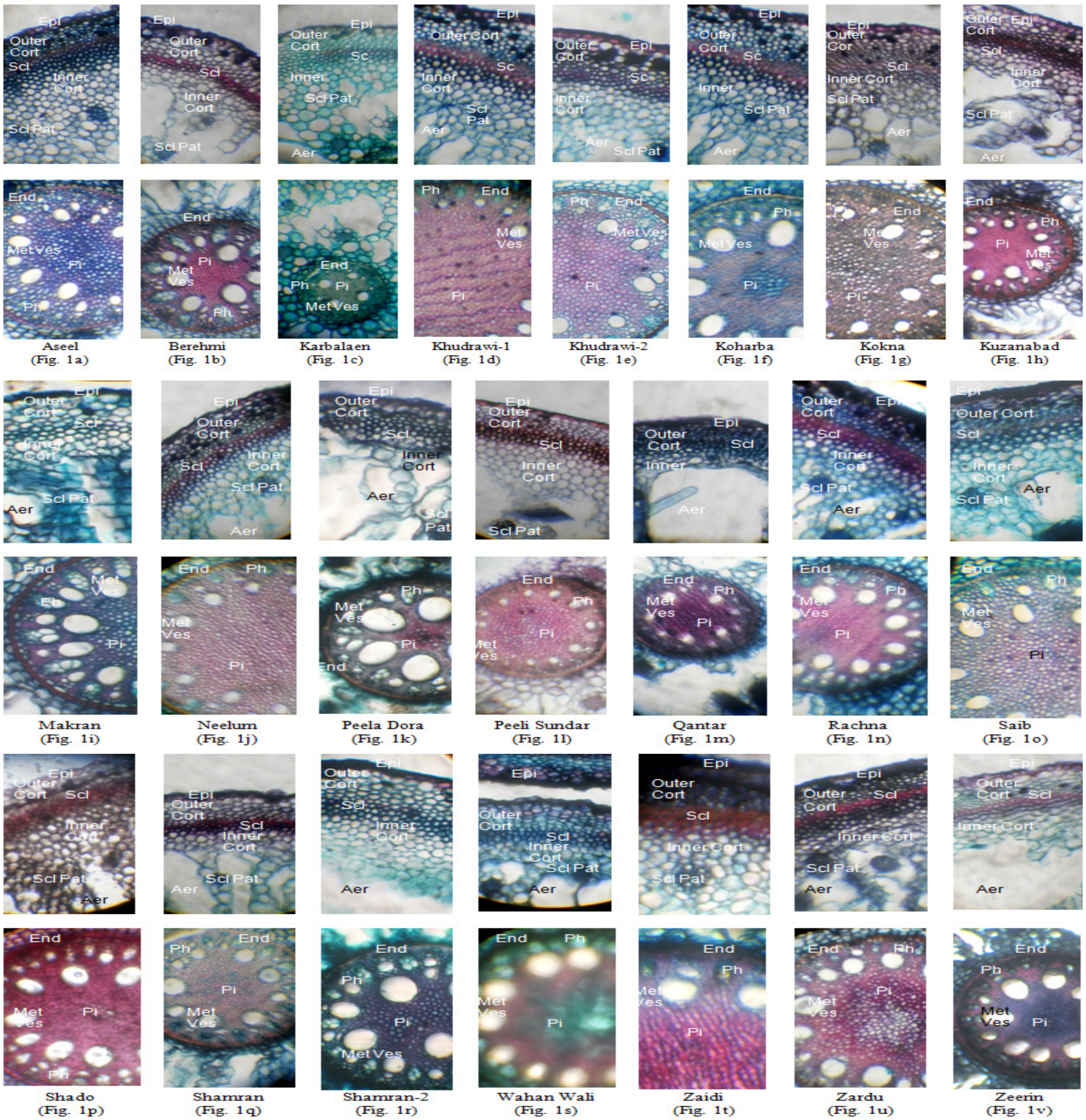
The vascular region thickness in all cultivars varied significantly (P<0.01). Neelam showed the highest vascular region thickness (735.30 µm) followed by Zardu (718.90 µm). However, Zeerin had the smallest vascular region thickness (337.60 µm; Table 1).

Epidermis Cell Area

Variation regarding epidermis cell area in all cultivars was highly significant (P<0.01). Berehmi showed the utmost cell area (2464.90 μm^2) followed by Shamran-2 (1538.40 μm^2) and Makraan (1538.40 μm^2). In contrast to this Wahan Wali showed greatly reduced epidermal cells values (681.79 μm^2; Table 2).

Sclerenchyma Area

Sclerenchyma area was significantly (P<0.01) varied in all studied cultivars (Table 2). Khudrawi-2 (3811.00 μm^2) surpassed all other cultivars in having maximum sclerenchyma area followed by Rachna (1328.60 μm^2) whereas minimum sclerenchyma area was recorded in Kokna (209.78 μm^2).



Outer Cotr= Outer Cortex, Epi= Epidermis, Scl= Sclerenchyma, Inner Cort= Inner Cortex, Scl Pat= Sclerenchyma Patches, Aer= Aerenchyma, End= Endodermis, Met Ves= Metaxylem Vessel, Pi= Pith, Ph= Phloem

Fig. 1: Microscopic picture of different root anatomical structures of date palm cultivars (n=22) collected from Date Palm Research Station, Jhang, Pakistan

Sclerenchyma Bundle Area

Sclerenchyma bundle area varied significantly (P<0.01) in all cultivars (Table 2). Maximum of values of sclerenchyma bundle area was observed in Zaidi (18950.30 μm^2) whilst Khudrawi-2 (2867.00 μm^2) possessed minimum area.

Cortical Cell Area

Variations regarding cortical cell area in all cultivars were varied significantly (P<0.01; Table 2). Zaidi (5174.60 μm^2) had highest cell area followed by Rachna (5017.20 μm^2), while Saib had similar minima (1206.20 μm^2).

Table 1: Comparison of means of Epidermis, Sclerenchyma, Cortical region, Endodermis and Vascular region thickness of root parameters of date palm cultivars

Cultivars	Epidermis thickness (µm)	Sclerenchyma thickness (µm)	Cortical region thickness (µm)	Endodermis thickness (µm)	Vascular region thickness (µm)
Aseel	27.23^{HIJ}	196.0$^{C D}$	738.00$^{BC DE}$	24.50^{GHI}	343.10^{IJ}
Berehmi	57.19^{A}	125.27^{IJ}	659.00^{DEFGH}	29.90^{EFG}	438.40^{FGHE}
Karbalaen	19.06^{J}	62.63^{LM}	566. 40^{GHIJK}	24.50^{GHI}	517.40^{EF}
Khudrawi-1	27.23^{HIJ}	239.65^{B}	814.20^{AB}	24.50^{GHI}	599.10$^{C DE}$
Khudrawi-2	35.40^{EFGH}	239.65^{B}	648.10^{DEFGHI}	24.50^{GHI}	452.00^{FG}
Koharba	43.57$^{C DE}$	70.80^{KLM}	408.50^{KLMNO}	32.60^{DEF}	381.20^{GHIJ}
Kokna	40.80^{CDEF}	253.27^{B}	288.60^{O}	24.50^{GHI}	585.50$^{C DE}$
Kozanabad	53.85^{AB}	160.67^{EFGH}	806.10^{ABC}	40.80^{BC}	354.00^{HIJ}
Makraan	32.68^{FGHI}	70.80^{KLM}	898.60^{A}	43.50^{AB}	514.70^{EF}
Neelam	35.40^{EFGH}	144.33^{FGHI}	639.90^{DEFGHI}	19.00^{I}	735.30^{A}
Peela Dora	29.95^{GHI}	141.61^{GHI}	697.10$^{BC DEFG}$	24.50^{GHI}	343.10^{IJ}
Peeli Sundar	38.10^{DEFG}	122.55^{IJ}	612.70^{EFGHIJ}	21.70^{HI}	345.80^{HIJ}
Qantar	35.40^{EFGH}	136.16^{HI}	590.90^{FGHIJ}	24.50^{GHI}	348.50^{HIJ}
Rachna	29.95^{GHI}	185.18$^{C DE}$	490.20^{JKLM}	24.50^{GHI}	345.80^{HIJ}
Saib	35.40^{EFGH}	166.12^{EFG}	514.70^{IJKL}	49.00^{A}	582.70$^{C DE}$
Shado	35.40^{EFGH}	209.69^{E}	599.10^{FGHIJ}	24.50^{GHI}	411.20^{GHIJ}
Shamran	38.10^{DEFG}	89.87^{KLM}	698.90$^{BC DEF}$	32.60^{DEF}	452.00^{FG}
Shamran-2	29.95^{GHI}	87.14^{KLM}	680.80$^{C DEFGH}$	24.50^{GHI}	422.10^{GHIJ}
Wahan Wali	38.10^{DEFG}	89.87^{KLM}	354.00^{NO}	38.10^{BCD}	375.80^{GHIJ}
Zaidi	40.80$^{C DEF}$	305.40^{H}	675.30$^{C DEFGH}$	40.80^{BC}	460.20^{FG}
Zardu	40.80$^{C DEF}$	305.01^{A}	767.90$^{BC D}$	24.50^{GHI}	718.90^{AB}
Zeerin	49.02^{BC}	89.87^{KLM}	577.30^{FGHIJ}	35.40^{CDE}	337.60^{J}

Table 2: Comparison of means of various root parameters for 22 date palm cultivars (µm^2)

Cultivars	Epidermis cell area (µm^2)	Sclerenchyma area (µm^2)	Sclerenchyma bundle area (µm^2)	Cortical cell Area (µm^2)	Endodermis cell area (µm^2)	Phloem area (µm^2)	Pith area (µm^2)	Metaxylam area (µm^2)
Aseel	996.40^{BCDE}	506.97^{EF}	8198.90^{CDEFG}	1888.00^{DEFG}	367.10^{DE}	3356.50^{FGHIJK}	36.50^{AB}	2797.00^{GH}
Berehmi	2464.90^{A}	594.38^{DEF}	5646.60^{EFGH}	1992.90^{DEFG}	524.40^{CDE}	6520.70^{BCD}	32.80^{BC}	10716.30^{DEF}
Karbalaen	699.20^{DE}	576.90^{EF}	5052.20^{EFGH}	2220.10^{CDEFG}	367.10^{DE}	2325.00^{JK}	20.93^{D}	2727.10^{GH}
Khudrawi-1	716.70^{DE}	594.38^{DEF}	6922.80^{EFG}	3146.70^{CDEF}	367.10^{DE}	4335.40^{DEFGHIJK}	25.60^{CD}	3863.40^{GH}
Khudrawi-2	996.40^{BCDE}	3811.00^{A}	2867.00^{GH}	3111.70^{CDEF}	367.10^{DE}	5908.80^{CDEF}	36.50^{AB}	5052.20^{GH}
Koharba	944.00^{DE}	384.60^{EF}	4859.90^{EFGH}	1293.60^{G}	472.00^{DE}	3321.50^{FGHIJK}	32.80^{BC}	3933.40^{GH}
Kokna	856.60^{DE}	209.78^{F}	10768.80^{CDE}	2132.70^{CDEFG}	367.10^{DE}	5821.40^{CDEFG}	37.08^{A}	5769.00^{FGH}
Kozanabad	1503.40^{BCD}	297.19^{EF}	5769.00^{EFGH}	2116.70^{CDEFG}	524.40^{CDE}	2622.20^{JK}	26.60^{CD}	2797.00^{GH}
Makraan	1538.40^{BCD}	576.90^{EF}	9580.00^{CDEF}	3811.00^{ABC}	4527.80^{A}	9422.70^{A}	32.80^{BC}	16555.30^{A}
Neelam	978.90^{CDE}	594.38^{DEF}	14160.30^{ABC}	3496.30^{BCD}	244.70^{E}	3618.70^{EFGHIJK}	25.60^{CD}	3950.80^{GH}
Peela Dora	944.00^{DE}	472.00^{E}	7447.20^{EFG}	3776.00^{ABC}	367.10^{DE}	4090.70^{DEFGHIJK}	25.60^{CD}	15226.60^{BCD}
Peeli Sundar	839.10^{DE}	664.31^{DEF}	10052.00^{CDEF}	1957. 90^{DEFG}	279.70^{E}	2639.70^{IJK}	25.60^{CD}	2115.30^{H}
Qantar	891.57^{DE}	419.56^{EF}	7342.30^{EFG}	1888.00^{DEFG}	367.10^{DE}	2010.40^{K}	25.60^{CD}	2552.30^{GH}
Rachna	716.70^{DE}	1328.60^{BC}	13461.00^{BCD}	5017.20^{AB}	367.10^{DE}	6101.10^{CDE}	25.60^{CD}	11747.80^{BCD}
Saib	891.57^{DE}	716.75^{DE}	9405.20^{CDEF}	1206.20^{G}	1346.10^{B}	3443.90^{EFGHIJK}	36.50^{AB}	5174.62^{GHI}
Shado	786.60^{DE}	297.19^{EF}	7901.70^{DEFG}	2342.50^{CDEFG}	367.10^{DE}	3146.70^{GHIJK}	36.50^{AB}	6643.10^{FGH}
Shamran	1241.20^{BCDE}	716.75^{DE}	14002.90^{ABC}	2919.40^{CDEFG}	699.20^{CDE}	4160.60^{DEFGHIJK}	32.80^{BC}	10891.10^{CDEF}
Shamran-2	1538.40^{BCD}	576.90^{EF}	5734.00^{EFGH}	1853.00^{DEFG}	367.10^{DE}	3181.60^{GHIJK}	25.60^{CD}	7884.30^{EFG}
Wahan Wali	681.790^{DE}	734.23^{DE}	4265.50^{FGH}	1433.50^{FG}	576.90^{CDE}	3199.10^{GHIJK}	31.30^{BC}	3985.80^{GH}
Zaidi	1485.90^{BC}	472.00^{E}	18950.30^{A}	5174.60^{A}	786.60^{CDE}	7744.40^{ABC}	26.60^{CD}	15908.40^{BCD}
Zardu	1206.20^{BCDE}	489.49^{EF}	16520.30^{AB}	3234.10^{CDE}	367.10^{DE}	4335.40^{DEFGHIJK}	26.60^{CD}	12272.20^{BCDE}
Zeerin	1241.20^{BCDE}	419.56^{EF}	5489.30^{EFGH}	1905.50^{DEFG}	594.30^{CDE}	2429.90^{JK}	25.60^{CD}	6293.40^{FGH}

*Values sharing the same letters do not have significant difference at 5% level of probability

Endodermis Cell Area

Makraan showed the greatest endodermis cell area (4527.80 µm^2), whereas Neelam had lowest values (244.70 µm^2). However significant variation (P<0.01) in endodermis cell area was observed in all the cultivars (Table 2).

Phloem Area

All cultivars varied significantly (P<0.01) in phloem area (Table 2). Makraan (9422.70 µm^2) had biggest phloem area followed by Zaidi (7744.40 µm^2) while Qantar had smallest values (2010.40 µm^2).

Pith Area

Significant variation (P<0.01) was observed in pith area in all the cultivars (Table 2). Kokna had maximum pith area (37.08 µm^2) While Karbalaen showed the minimum pith area (20.93 µm^2).

Metaxylem Area

Metaxylem area varied significantly (P<0.01) in all the cultivars (Table 2). Metaxylem area was recorded utmost in Makraan (16555.32 µm^2) while Peeli Sundar had the least values (2115.30 µm^2).

Discussion

Different date palm cultivars examined during this study showed significant variations in root anatomy. The size of epidermis cells, size and shape of outer cortical region, presence of sclerification in outer cortex, sclerenchyma bundles in cortical region and presence of aerenchyma were quite significantly (P<0.01) variable in these cultivars. Similarly endodermal layer thickness, thickness of outer tangential wall of endodermis, shape and size of phloem region, size and arrangement of metaxylem vessels and sclerification in the pith region showed significant (P<0.01) diversity.

Epidermis in 'Aseel' was comprised of extremely large cells and very well developed sclerenchyma in outer cortical region. Outer cortex was composed of very much reduced parenchymatous cells, whereas inner cortex had larger rounded and densely packed cells. Distinctive sclerenchyma bundles were recorded in inner cortex. However well-developed aerenchyma was present just outside the endodermis. Intensive sclerification was also recorded in the vascular region. The variation in parenchymatous cells that is a small tightly packed cells in the outer cortex. Larger cells in the inner cortex with distinctive sclerenchyma region, sclerenchyma bundles and aerenchyma may indicate the high tolerance level of this cultivar to variety of environmental condition (Nadia *et al*., 2010). Such structural modifications are critical not only for water conservation particularly under water scarcity, but also better moisture storage and even toxic ion compartmentalization (Breckle, 2004; Reinoso *et al*., 2004). Drought decreased the diameter of root metaxylem vessels, thus lowering the risk of embolisms and increasing water-flow resistance, and increased the number of root hairs (Tomar *et al*., 2006), but intensive sclerification may also be involved in preventing water loss through the root in addition efficient translocation of oxygen and solute via aerenchyma as Boris and Michael (1997) examined the plant adaptation to anaerobic stress and reported that mechanisms of tolerance of plants can include metabolic adaptations and developmentally passive tolerance such as in over wintering rhizomes of many wetland species.

Qantar showed very prominent modification in root anatomy with extremely large aerenchyma in inner cortex and intensive sclerification in outer cortex and vascular region. High proportion of aerenchyma is vital for a variety of environmental stresses. Aerenchyma is known to be a feature of aquatic plants, but aerenchyma may be related to high stress tolerance against salinity and drought (Dennis *et al*., 2000).

Structural modifications in the roots of Makraan were large cells in the outer cortex, well developed sclerification, separating outer and inner cortical region and well developed aerenchyma above the endodermis. Moreover endodermis was extremely thick walled, whereas large phloem cells alternating the metaxylem vessels in the vascular region. Intensive sclerification was also recorded in pith region. The sclerification in roots can minimize the water loss through root in addition to controlling the radial flow of water and nutrients (Michael and Ehwal, 2010). Furthermore larger phloem cells and metaxylem vessels are capable of increasing transport of water, nutrients and reserve food more efficiently. Most nutrients, except calcium, are imported through the phloem (Patrick and Offler, 2001).

Zaidi showed extremely large epidermal cells with enormous sclerification in hypodermal region in addition to large closely packed cells. Structural modifications in cultivar Zaidi can be related to high tolerance against abiotic stress modifications like intensive sclerification (Richard *et al*., 2011). Thick epidermis with intensive sclerification in the cortical region not only prevents the water loss from the roots, but also provides mechanical strength to the root and is extremely important under harsh ecological conditions such as drought (Reinoso *et al*., 2004; Breckle, 2004). All these parameters can play a critical role in moisture conservation and this is extremely useful under drought conditions. Similar structural modifications were also recorded in Neelam. However in the latter case vascular region is extremely enlarged. This may be a crucial for water conservation (Beebe *et al*., 2008).

Berehmi showed typical characteristics in the root anatomy with well-developed sclerification in cortical region, large proportion of aerenchyma, highly enlarged phloem and large metaxylem vessels. Moreover intensive sclerification was also recorded in the endodermal cell walls. Such modifications can help in transport of solute and reserve food (Beebe *et al*., 2006) and are helpful in controlling radial flow of water (Beebe *et al*., 2000). Large phloem area may be responsible for increased translocation of photosynthate but few and large metaxylem vessels may resist efficient transport of water and solute. Large metaxylem vessels step changes in xylem pressure applied to the base of roots (Frensch *et al*., 1995). During periods of varying water supply roots are optimized in their abilities to use water resources in the soil (Ernst and Peterson, 1998). Overall root structure in Berehmi indicated relative sensitivity of cultivar to environmental stresses. This may be the reason of its limited cultivation in Jhang and Faisalabad region.

Anatomical features in Zeerin, Kozanabad, Shamran-2, Karbalaen, Peela Dora, Shamran and Peeli Sundar were very similar. All these cultivars showed large epidermal cells and distinct sclerenchyma in the cortical region, large proportion of aerenchyma in inner cortex, thick endodermis and intensive sclerification in vascular region. Epidermis along with intensive sclerification in cortex as well as vascular region is characteristic of drought tolerant plants (Blum, 2005). Therefore all these cultivars can be rated as suitable for arid and semi-arid regions (Rao, 2002).

Highly enlarged vascular region with large metaxylem vessel and large aerenchyma were recorded in cultivars Shado, Khudrawi-1 and Khudrawi-2. These cultivars also showed distinctive sclerenchyma in cortical region, prominent sclerenchyma bundles and high proportion of aerenchyma in the cortex. However large metaxylem vessels collapse, but at the same time they can involve more and efficient transport of water and nutrients. On these bases it can be concluded that these cultivars can perform better under moderate climate (Hameed *et al*., 2009).

Distinct modification in the root anatomy of Koharba was observed. Large ovoid metaxylem vessels were the characteristic feature in the transverse section. In addition, very prominent sclerification was recorded in epidermal and hypodermal region. Both cultivars were characterized by small aerenchyma and highly sclerified pith region. These anatomical features are typical of xeric nature with the main function of efficient transport of water and prevention of water loss through the roots (Ryan, 1993).

Cultivars Kokna and Saib were characterized by relatively poor development of sclerenchyma both in cortical, vascular region and numerous small, numerous metaxylem vessels on the basis of low proportion of sclerification. These cultivars can tolerate mild environmental stresses (Steudle, 2000). Taxonomically important features were the nature of sclerification in the cortical region, distinct outer and inner cortex, shape, number and size of the metaxylem vessel and size and shape of phloem.

In conclusion all studied cultivars may have evolved independently from diverse origin during their evolutionary history. The investigation also explored the anatomical characters of roots of date palm. Such study added precise evidence to taxonomic identity of different cultivars of date palm, which include group of the most important cultivars.

Acknowledgments

The authors are obliged to the staff at Date Palm Research Station Jhang, Pakistan and thankful to International Center for Development and Decent Work (ICDD; DAAD), Germany, for financial support.

References

Baruch, Z. and T. Merida, 1995. Effects of drought and flooding on root anatomy in four tropical forage grasses. *Int. J. Plant Sci*., 156: 514–521

Beebe, S.E., P.W. Skroch, J. Tohme, M.C. Duque, F. Pedraza and J. Nienhuis, 2000 Structure of genetic diversity among common bean landraces of Mesoamerican origin based on Correspondence Analysis of RAPD. *Crop Sci*., 40: 264–273

Beebe, S.E., M. Rojas, X. Yan, M.W. Blair, F. Pedraza, F. Muñoz, J. Tohme, and J.P. Lynch, 2006. Quantitative trait loci for root architecture traits correlated with phosphorus acquisition in Common Bean. *Crop Sci*., 46: 413–423

Beebe, S.E., I.M. Rao, C. Cajiao and M. Grajales, 2008. Selection for drought resistance in common bean also improves yield in phosphorus limited and favourable environments. *Crop Sci*., 48: 582–592

Blum, A, 2005. Drought resistance, water use efficiency, and yield potential. *Aust. J. Agric. Res*., 56: 1159–1168

Boris, B.V. and M.B. Michael, 1997. Plant adaptations to anaerobic stress. *Ann. J. Bot*., 79: 3–20

Breckle, S.W., 2004. Flora, vegetation und ökologie der alpin-nivalen Stufe des Hindukusch (Afghanistan). *In: Results of worldwide ecological studies. Proceed: 2nd Symposium A.F.W.* Breckle, S.W., B. Schweizer and A. Fangmeier (eds.). pp: 97–117. Schimper-Foundation, Stuttgart-Hohenheim, Germany

Clarkson, D.T. and A.W Robards, 1975. *The endodermis, its structural development and physiological role in the development and function of roots.* Academic Press, London. pp: 415–436

Dennis, E.S., R. Dolferus, M. Ellis, M. Rahman, Y. Wu, F.U. Hoeren, A. Grover, K.P. Ismond, A.G. Good, and W.J. Peacock, 2000. Molecular strategies for improving waterlogging tolerance in plants. *J. Exp. Bot*., 342: 89–97

El-Shibli, S. and H. Korelainen, 2009. Biodiversity of date palm (*Phoenix dactylifera* L.) in Sudan: Chemical, morphological and DNA polymorphism of selected cultivars. *Plant Genet. Resour*., 7:194–203

Ernst, S. and C.A. Peterson, 1998. How does water get through roots? *J. Exp. Bot*., 49: 775–788

FAO, 2011. Date Palm Cultivation. *FAO plant production and protection paper*. Food and Agriculture Organization of the United Nation. Rome, Italy

Frensch, J., T.C. Hsiao and E. Steudle, 1995. Water and solute transport along developing maize roots. *Planta*, 198: 348–355

Hameed, M., M. Ashraf and N. Naz, 2009. Anatomical adaptations to salinity in cogon grass [*Imperata cylindrica* (L.) Raeuschel] from the Salt Range, Pakistan. *Plant Soil*, 322: 229–238

Jamil, M.S., R. Nadeem, M.A. Hanif, M.A. Ali, K. Akhtar, 2010. Proximate composition and mineral profile of eight different unstudied date (*Phoenix dactylifera* L.) varieties from Pakistan. *Afr. J. Biotechnol*., 9: 3252–3259

Markhand, G.S., A.A. Abul-Soad, A.A. Mirbahar, N.A. Kanhar, 2010. Fruit characterization of Pakistani Dates. *Pak. J. Bot*., 42: 3715–3722

Michael, F. and R. Ehwal, 2010. Mannitol permeation and radial flow of water in maize roots. *New Phytol*., 189: 210–217

Nadia, A., A. Kikuchi and K.N. Watanabe, 2010. Assessment of somaclonal variation for salinity tolerance in sweet potato regenerated plants. *Afr. J. Biotechnol*., 9: 7256–7265

Ogburn, R.M. and E.J. Edward, 2009. Anatomical variation in Cactaceae and relatives: trait liability and evolutionary innovation. *Amer. J. Bot*., 96: 391–408

Patakas, A., 2012. Abiotic Stress-Induced Morphological and Anatomical Changes in Plants. Biomedical and Life Sciences. Abiotic Stress Responses in Plants. pp: 21–39, Springer, New York, USA

Patrick, J.W., C.E. Offler, 2001. Compartmentation of transport and transfer events in developing seeds. *J. Exp. Bot*., 52: 551–564

Rao, I.M., 2002. Role of physiology in improving crop adaptation to abiotic stresses in the tropics: the case of common bean and tropical forages. *In: Handbook of Plant and Crop Physiology*. 3rd edition, pp: 583–613. Marcel Dekker, Inc., New York, USA

Reinoso, H., L. Sosa, L. Ramírez and V. Luna, 2004. Salt-induced changes in the vegetative anatomy of *Prosopis strombulifera* (Fabaceae). *Can. J. Bot*., 82: 618–628

Richard, L.T., A. Ergul, R.L. Albion, K.A. Schlauch, G.R. Cramer and J.C. Cushman, 2011. Identification of tissue-specific, abiotic stress-responsive gene expression patterns in wine grape (*Vitis vinifera* L.) based on curation and mining of large-scale EST data sets. *Plant Biol*., 11: 86

Ruzin, S.E., 1999. *Plant microtechnique and microscopy*. pp: 322. Oxford University Press, Oxford, UK

Ryan, P.R., J.M. Ditomaso and L.V. Kochian, 1993. Aluminum toxicity in roots: an investigation of spatial sensitivity and the role of the root cap. *J. Exp. Bot*., 44: 437–446

Seago, J.L. and L.C. Marsh, 1989. Adventitious root development in *Typha glauca*, with emphasis on the cortex. *Amer. J. Bot*., 76: 895–909

Steudle, E. 2000. Water uptake by roots: effects of water deficit. *J. Exp. Bot*., 51: 1531–1542

Tomar, R.K., D. Singh, K.S. Gangwar, R.N. Garg, V.K. Gupta, R.N. Sahoo, D. Chakraborty and N. Kalra, 2006. Influence of tillage systems and moisture regimes on soil physical environment, growth and productivity of rice-wheat system in upper Gangetic plains of Western Uttar Pradesh. *Ind. J. Crop Sci*., 1: 146–150

Zimmerman, H.M. and E. Steudle, 1998. Apoplastic transport across young maize root: effect of the exodermis. *Planta*, 206: 7–19

(Received 06 June 2013; Accepted 13 January 2014)