Advances in Life Science and Technology
ISSN 2224-7181 (Paper) ISSN 2225-062X (Online)
Vol.34, 2015
www.iiste.org

Comparative Leaf Anatomy of the Genus *Hordeum* L. (Poaceae) in Iraq

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Abstract
In this study leaf anatomical characters among the species of the genus *Hordeum* L. have been evaluated. In Iraq, *Hordeum* is represented by eight species, namely *Hordeum bulbosum* L., *H.distichon* L., *H.geniculatum* All., *H.glaucum* Steud., *H.leporinum* Link, *H.marinum* var. *marinum* Huds., *H.marinum* var. *pubescens* (Guss.) Nevski, *H. spontaneum* var. *spontaneum* C. Koch, *H.spontaneum* var. *proskowetzii* Nab., and *H. vulgare* L. This genus one of the most economically important cereal crops in the tribe Triticeae, has a worldwide distribution mainly in temperate and dry regions of the world.
The main objective of this study is to asses the significance of anatomical characteristics of the leaves. For this purpose transverse sections and leaf surfaces were examined. Anatomic features show that leaf blades vary between the taxa in both qualitative and quantitative values. Sclerenchymatic cells, silica bodies, and stomata, furrow and ribs properties, the existence of midrib and bulliform cells, and indumentum properties such as length of prickles and macro-hairs are all included in these diagnostic characteristics .
Keywords: Leaf anatomy, *Hordeum*, Poaceae.

Introduction

Hordeum is an important genus of approximately 32 species around the world (Bothmer *et al*., 2009). This genus is one of the genera of the tribe Triticeae Dumort. Given in the flora of Iraq by eight species comprises annual and perennial grasses with wide geographical distribution (Bor, 1968),. As well as morphological studies of the genus (Bor, 1968; Bothmer *et al*., 2003& 2009: OGTR, 2008) most of the research studies related to molecular (Knupffer, 2009; Houben and Pickering, 2009) genetic (Blattner, 2004; 2009) and anatomical structures (Islam *et al*., 2009) of the members of the genus, especially the cultivated species, *H. vulgare* .

Dube and Morisset (1987) and Jarves & Barkworth (1992) reported that the leaf transverse sections anatomy provides taxonomic data related to grasses, occurrence of sclerenchyma and bundle sheath (Khraz sheath), the width of sclerenchyma, the indumentum of leaves are important features that can identify relationships among the genera of Poaceae. The position of vascular bundles in the blades appears to be a useful diagnostic characters above the generic level (Ellis, 1976). Wenzel *et al*. (1997) studied the mutations of *H.vulgare* and found variations in epidermal cell length and number. In a more recent study, Mavi *et al* . (2011) revealed the diagnostic anatomical characterstics of leaves of the *Hordeum* taxa found in Turkey .

In spite of all these previous studies, there has hardly necessity for a comparative anatomical study of the genus *Hordeum* in Iraq, therefore the aims of present study is to determine the variation in leaf epidermis and transverse sections and to use of constant leaf anatomical characters which can be effected in taxonomical treatments .

Materials and methods

Both herbarium materials collected in Iraq as well as freshly obtained samples were used in this study. A complete list of material used including of scientific name, exact localities, collector(s) and herbarium numbers are given in table 1. The herbarium samples were first softened by boiling in distilled water. Then all the samples sectioned by hand from the middle portion of the leaf with a razor and stained with safranin. Next they were examined using Olympus compound microscope and photographed by different magnification using a digital microscopic camera .

Table 1: speciemens used for anatomical studies (the species arranged alphabetically)

Taxa	Locality	Collector(s)	Speciemen No.
H.bulbosum	15 km. Hagi Umran road	A. Al-Bermani & R. Alnomani	Hor.26
	near Rayat	A. Al-Bermani & R. Alnomani	Hor.27
	Near Dohuk (in Erbil-Dohuk road)	A. Al-Bermani & R. Alnomani	Hor.28
	Qizil Robat, Diyala	A.D.Q.Agnew, Z.Chalabi, F.Chiad& 2nd year Bot. class	3810
	Between Bîyara and Tawila	A. Al-Bermani & R. Alnomani	Hor.29
	Bîyara	A. Al-Bermani & R. Alnomani	Hor.30
	Halabja road toward Tawila	A. Al-Bermani & R. Alnomani	Hor.85
H.distichon	Emaria near Rawa	Rawi& Gillett	7084
	Dohuk, Sarsang road	A. Al-Bermani & R. Alnomani	Hor.31
	near Rayat	A. Al-Bermani & R. Alnomani	Hor.32
H.geniculatum	Avroman (Horaman) mt., Kanishit, between Tawila & Halabja, in Sulaimaniya liwa	K.H.Rechinger	10389
	Amara	Al-Mousawi& Al- Hilli	0040563
	Waste land 15 km. N. of Baghdad, Baghdad liwa	F.A. Barkley, Khalid Dabbagh& H.Abbas	1619
	Galala near Taynal, Sulaimaniya-Kirkuk road	H.C. Thorpe	33154
	Babyl Government, Al-Kifel, Al-Maleuaiya region	R.Alnomani	Hor.33
	near Rayat	A. Al-Bermani & R. R.Alnomani	Hor.34
	Sersang	R.W. Haines	2746
H.glaucum	Babylon University	R. Alnomani	Hor.35
	Najaf Gonernment, Kufa-Najaf road	R. Alnomani	Hor.36
	Baghdad University	L.Asbarg	Hor.37
	Kadumia	A.H.Al Mousawi	0001330
	Tuz Khurmatü	A. Al-Bermani & R. Alnomani	Hor.38
	Al-Razazah	A. Al-Bermani & R. Alnomani	Hor.39
	Hamrin hills -Adhaim	A. Al-Bermani & R. Alnomani	Hor.40
	Babylon University	R. Alnomani	Hor.41
	Kufa University	R. Alnomani	Hor.42
H.leporinum	Qara Hasan	F.Karim, H.Hamid & M.Jasim	40470
	Tawila	A. Al-Bermani & R. Alnomani	Hor.43
	Sinjar mot., Gulley of Dair Asi	I.Al-Shehbaz, A.R.Mayah & F.Sharifi	0030591
	Near Koma Sang(Harran) Police Post NE. of Mandali	I.Al-Shehbaz& A.R.Mayah	0030258
	Dohuk, Sarsang road	A. Al-Bermani & R. Alnomani	Hor.44
	Near Amadiya	A. Al-Bermani & R. Alnomani	Hor.86
H.marinum* var. *marinum	8 km. NE. of Jassan towards the border	Weinert& Mousawi	0023190
	Between Ramadi & Rutba, Dulaim liwa	C.Regel	420
H.marinum* var. *pubescens	Khurmal, near Tawila	A. Al-Bermani & R. Alnomani	Hor.45
	Ser Amadiya (Gali Mazurka)	Al-Dabbah, Al-Kaisi& H.Hamid	45988
H.spontaneum* var. *proskowetzii	Tuqai between Tasluja and Chemchamal	A. Al-Bermani & R. Alnomani	Hor.46
	Khanzad pass between Erbil& Salahaddin	A.D.Q.Agnew, S.Agnew, F.Chiad& S.Butty	Hor.47
	Dokan	A. Al-Bermani & R. Alnomani	Hor.48
	Entrance of Derbandi Khan	A. Al-Bermani & R. Alnomani	Hor.49

	near Rayat	A. Al-Bermani & R. Alnomani	Hor.50
H.spontaneum* var. *spontaneum	Jabal- Muwaila, near Kauwait (E. of Jabal Hamrin c.70 km. N.of Amara	Guest, Rawi& Rechinger	17636
	Baghdad University	L.Asbarg	Hor.51
	Tawila	A. Al-Bermani & R. Alnomani	Hor.52
	Halabja road	A. Al-Bermani & R. Alnomani	Hor.53
	Near Dohuk	A. Al-Bermani & R. Alnomani	Hor.54
	20 km. from Khalifan toward Sulaimaniya	A. Al-Bermani & R. Alnomani	Hor.55
	Gali	A. Al-Bermani & R. Alnomani	Hor.56
	Dohuk, Sarsang road	A. Al-Bermani & R. Alnomani	Hor.57
	15 km. Haji Umran	A. Al-Bermani & R. Alnomani	Hor.58
H.vulgare	Al-Razazah	A. Al-Bermani & R. Alnomani	Hor.59
	Fields in front of Babylon University	R. Alnomani	Hor.60
	Kerbela center	R. Alnomani	Hor.61
	Ruhba (Bhar Al-Najaf)	R. Alnomani	Hor.62
	Dohuk, Sesank road	A. Al-Bermani & R. Alnomani	Hor.63
	Tal Afar	A.Al- Rawi	5786

Results

Leaf blade

It is clearly observed from the transverse sections of the taxa that all leaves have single- layer vascular bundles parallel to the adaxial and abaxial surfaces in a homogenous mesophyll (figure 1) .

The general appearance of the transverse sections indicates three types of leaf blades: a) flat as in *H.bulbosum* and *H.leporinum*, b) undulating gently as in *H.geniculatum*, *H.glaucum*, *H.spontaneum*, and c) corrugated as in *H.distichon* , *H.marinum* and *H.vulgare* (figure 1) .

A projecting midrib at the abaxial surface gives the appearance of rounded-keel in *H.bulbosum*, *H.distichon*, *H.geniculatum*, *H.marinum*, *H.vulgare* and *H.spontaneum* var. *proskowetzii* . In other studied taxa, leaf blades have not realy distinct keel (figure 2) .

Midrib or median vascular bundle

All taxa have a solitary median vascular bundle. In five of the studied leaf samples and in *H.spontaneum* var. *proskowetzii*, a midrib is conspicuously present, forming a rounded- keel .

The median vascular bundles, forming a rib on the abaxial surface of the leaf, In *H.glaucum*, *H.leporinum*, and *H.spontaneum* var. *spontaneum* the solitary median vascular bundles do not make ribs, so they have no keel, and this is a distinct characteristic usable for the identification. However, they are clearly distinguishable from other vascular bundles of their leaves .

Furrows and ribs

H.geniculatum, *H.glaucum* and *H.spontaneum* have little, shallow and wide furrows between the veins on their upper surfaces (figure 1). In contrast, the furrows on upper surface of *H.distichon*, *H.marinum* and *H.vulgare* are found to be medium or deep (figure 1). While *H.bulbosum* and *H.leporinum* have no ribs on both surfaces. Midrib shape varies between convex in *H.distichon* , *H.vulgare* and *H.marinum* var. pubescens, flat in *H.bulbosum*, *H.glaucum* and *H.leporinum*, while it appear in a rounded- shape in *H.geniculatum*, *H.spontaneum* and *H.marinum* var. *marinum* (figure 2). Midrib length shows considerable variation within the studied species. *H.glaucum* separated by having (195.0-212.5)µm length (figure 2 and table 2). The width of midrib zone varies greatly among the species, the smallest width (170.0-217.5)µm found in *H.marinum* and the maximum value (375.0-500.0)µm found in *H.vulgare* (figure 2 and table 2) .

Vascular bundle sheath

Brown (1975) stated that all non-kranz grasses have both mestome and a parenchyma sheath around all their leaf bundles. Vascular bundles of the taxa are found to have double sheaths. The sclerenchymatic inner sheath is complete and surrounded with an incomplete parenchymatic outer sheath. The size of cells in both sheaths are found to vary between the taxa, but is always higher in the inner one in contrast with the outer one. However, the maximum value (16.0-17.0) for the outer sheath is found in *H.vulgare*, while the maximum value of cell number for the inner sheath (28.0-30.0) belongs to *H.bulbosum* (table 2) .

Sclerenchyma

Sclerenchyma occurs in the leaf transverse-sections as girders or strands (Metcalf, 1960). Most of the first-order vascular bundles of *H.glaucum*, *H.leporinum*, *H.spontaneum*, *H.vulgare* have subepidermal horizontal strip girder at the adaxial side, while it appears as short rectangular girder in *H.bulbosum*, *H.distichon*, and *H.geniculatum*. Except for *H.marinum*, the leaves have strand only on the abaxial and/or adaxial sides of all vascular bundles. However, there seems to be no sclerenchyma girders either on the adaxial or the abaxial sides of third order vascular bundles.

Moreover, there are also a cap of sclerenchymatic cells on the margins of the leaves, the shape of the marginal cap can be classified into two main types :

1- Pointed cap: as in *H.distichon*, *H.glaucum*, *H.marinum*, *H.leporinum*, and *H.spontaneum* (figure 3) .
2- Rounded cap: as in *H.bulbosum*, *H.geniculatum*, and *H.vulgare* (figure 3).

Bulliform cells

Bulliform cells present at the base of furrows and between veins on the adaxial surface of the leaves. In the taxa studied the bulliform cells uniformly have thin walls and are inflated larger than the adjacent epidermal cells, except in *H.marinum* which have small size of bulliform cells. There are usually straight- shaped bulliform cells in *H.bulbosum* and *H.leporinum*, and fan-shaped in *H.distichon*, *H.glaucum*, *H.geniculatum*, *H.marinum*, *H.spontaneum*, and *H.vulgare*. The bulliform cells are found to project above or bellow the level of the epidermis of all taxa studied (figure 2) .

Epidermis

The epidermal characteristics of leaves play an important role indistinguishing the taxa of Poaceae (Metcalf, 1960). Epidermal cells in transverse sections of the taxa have regular or irregular shapes with either uniform or varying sizes. *H.bulbosum*, *H.spontaneum* and *H.vulgare* have regularly arranged uniformly sized epidermal cells (figure 1). However, both the shape and the arrangement of the epidermal cells of *H.distichon*, *H.geniculatum*, *H.glaucum*, *H.leporinum*, and *H.marinum* are irregular. Abaxially, epidermis is differentiated into long cells, stomata, hairs, and short cells such as silica bodies. On the adaxial surfaces of the leaves, in addation to these types of cells, epidermis also has bulliform cells. The type and arrangement of bulliform cells are determined easily from transverse sections of leaves .

Long cells

These are elongated horizontally, parallel with long axis of the leaf. The length of these cells in intercoastal zone shows variation within each taxon and in both stomatal and non-stomatal, but they are always longer in non-stomatal rows in contrast with stomatal rows (table 3). In the abaxial surface, the length of long cells in stomatal rows range from (10.0) µm in *H.vulgare* and *H.marinum* var. *marinum* and (202.5) µm in *H.bulbosum*, while it is range in non-stomatal rows from (55.0) µm in *H.bulbosum* and (962.5) µm in *H.vulgare* (table 3) .

On the adaxial surface, the length of long cells in stomatal rows from (10.0) µm in *H.marinum* var. *marinum* and (125.0) µm in *H.leporinum*, while it is range from (50.0) µm in *H.marinum* var. *pubescens* and (742.5) µm in *H.spontaneum* var. *spontaneum* (table 3) .

However, the thickness as well as the structure of the walls is usually uniform within all leaf samples. The lower surface of the leaves of *H.bulbosum*, *H.marinum* and *H.vulgare* has epidermal long cells with pitted walls in intercoastal zone, whereas all the taxa studied have pitted walls n the adaxial surface of both coastal and intercoastal zone. In addition, all the taxa have both adaxial and adaxial epidermal long cells with straight and slightly thickened walls. The maximum number of long cells rows in the intercoastal zone, are 8, 10, 11, 12 and 13 lines between two coastal zone. The coastal zones consist of 1 to 4 ranks in the adaxial side, while it reach to 6 ranks in the abaxial side in *H.vulgare* (table 3) .

Silica bodies

The cells smaller than the long cells are recognized as short cells, which are equidimensional. Silica bodies are a kind of short cell on the leaf surfaces (Metcalf, 1960). All the taxa of *Hordeum* have coastally arranged silica bodies on the their leaf surfaces. However, *H.bulbosum* and *H. geniculatum* have silica bodies in pairs with the cork cells in the intercoastal zones of their leaves as well. Coastally located silica bodies are generally elongated, rectangular, square or triangular, but they are ellipsoid or circular in intercoastal zones (figure 4) .

Stomata

The intercoastal zones of all the taxa include stomata, which occur in well-defined horizontal bands. Moreover, each band consist of 1-4 rows of stomata. The stomata are arranged regularly in these rows (figure 4) .

According to Metcalf (1960), grass stomata can be classified in terms of the shape of their subsidiary cells and they can used for diagnostic and taxonomic purposes. From this point of view, the type of stomata in

the genus *Hordeum* can be referred to as having parallel-sided subsidiary cells or two sided shape, one side parallel and another low triangular side. However, different taxa exhibit different stomata with great variation in their sizes (Raschke, 1979). Measurments of the length of the stomata for the taxa are given in table 4. According to these results, the shortest length (27.5)µm in the abaxial surface in *H.vulgare* and the highest length (67.5)µm in *H.spontaneum* var. *spontaneum* . In the adaxial surface the shortest length (30.0)µm in *H.spontaneum* and *H.marinum* var. *marinum*, while the highest length (60.0)µm in *H.vulgare* (table 4) .

Although stomatal density is affected by environmental factors, its genetic background is certainly evident (Hetherington and Woodward, 2003). Comparing the stomatal densities of the taxa (table 4), *H.marinum* var. *marinum* has the highest value (21.86)µm and (25.5)µm in both abaxial and adaxial surfaces respectively .

Indumentum

All the studied taxa have coastally and intercoastally prickles on their adaxial and abaxial surfaces. In addition, *H.bulbosum*, *H.glaucum* and *H.leporinum* have hard macro-hairs in both surfaces of their leaves. The average lengths of the prickles on the abaxial surface (35.0)µm and (168.0)µm, while it range on the adaxial surface from (33.9)µm and (306.1)µm (table 5) .

Moreover, there are intercoastally located hard macro-hairs. However, the lengths of these macro-hairs vary geatly within the taxa. The longest macro-hairs on the abaxial surface (480.0)µm belongs to *H.glaucum* and (762.5)µm in *H.leporinum* on the adaxial surface (table) .

Discussion

The analysis of the leaf structure of the eight studied species has revealed characteristics, which correspond to those mentioned by Ellis (1976, 1979) and Esau (1977) for the Poaceae family .

The Poaceae epidermis, in surface view, is divided in zones or conspicuous bands. In general it is possible to distinguish two main zones: intercoastal and coastal zones. In the studied species the epidermis is similarly organized, which agree with Metcalf 's observations (1960) .

In general the coastal and intercoastal zones of the studied species consist of long and short cells. The shape and outline of the long cells is rectangular with straight and slightly thickened walls. The size of the epidermal cells may vary over and between successive bundles as well as the cells of adaxial and abaxial epidermis being of different size (Cutler *et al*., 2007; Al-Bermani, 1996) . The short cells occur in solitary almost but may occur in pairs in *H.bulbosum* and *H.geniculatum*, they are generally classified either as siliceous cells or as suberose cells

The presence of epidermal cells contain silica bodies is an important character in the Poaceae family (Metcalf, 1960, 1963). Although the exact physiological role of silicose deposition in leaves is not yet known, Haberlandt (1928) and Hopkins (1995) consider that silica impregnated walls prevent attacks by insects and fungi. Campos and Labouriau (1969) assume that silica plays an important role in hydric balance, thermic changes and radiation reflection. Besides, Lanning *et al*. (1958) and Moore (1984) state that silica is a complementary structural element, contributing to vegetative support .

In the *Hordeum* species, two kinds of epidermal appendages, in general, occur: prickles and macro-hairs (Mavi *et al*., 2011). Prickles are easily observed in the studied species, and they have been already mentioned by Halvorson (2003) and Bothmer *et al*. (2009) for some species of the genus .

According to Ellis (1979), the Poaceae stomata generally occur in well-defined bands in intercoastal zones, and they may be classified according to the shape of subsidiary cells. Thus in all studied species subsidiary cells are parallel shaped but it may appear in two sided shape, one side parallel and another low triangular side .

All the studied species have open leaf blades, and the two halves of the lamina on either side of the median vascular bundle are relatively wide and usually symmetrically arranged about the median region .

Hordeum species posses a distinguished midrib which consist a single larger midian vascular bundle, the species varies from containing a rounded- keel or have no really distinct keel .

The ground tissue (mesophyll) of a Triticeae consist of short chlorenchyma cells which are irregular in shape (Brown, 1958; Gibson, 2009). The vascular bundles are surrounded by a bundle sheath comprising two cell layers. The outer layers is a parenchyma sheath composed of thin-walls. The inner cell layer (the endodermis or mesotome sheath) is comprised of small cells with thickened inner and radial walls (Cutler *et al*., 2007; Gibson, 2009) .

The supporting tissue of the Poaceae is represented by sclerenchyma which can present several patterns of distribution occurring in the form of sub-epidermal layers, sheath extensions, or in the leaf margin (Ellis, 1976; Rudall, 2007). In the present taxa the sclerenchyma is associated with vascular bundles, which helps in distinguish among the different taxa studied. Mechanical tissue of the leaf margin occur in the form of cap .

Bulliform cells present in the adaxial surface of leaves, which defines by (Brown, 1958) as being intrinsic part of the epidermis, differing from other epidermal elements proper for being generally larger and

more inflated. Shields (1951) states that during excessive water losses, bulliform cells become flaccid allowing the plant to bend or enfold, which leads to a reduction of the leaf transcription.

Anatomical features of leaf-blade have been recognized as valuable in the diagnosis of the Poaceae sub-families. Thus the features observed in the genus *Hordeum* such as presence of keel, complex epidermal tissue of long and short cells, prickles, macro-hairs, and silica bodies correspond to the festucoid type of leaf anatomy, defined by Metcalf (1956) .

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Table 2: Quantitative characters of midribs zone in leaf transverse sections

species	Length of midrib zone	Width of midrib zone	No. of parenchymatic sheath cells	No. of sclerenchymatic sheath cells
H.bulbosum	(375.0-437.5) 391.0	(312.5-375.0) 348.0	(13.0-15.0) 13.8	(28.0-30.0) 29.6
H.distichon	(252.5-280.0) 266.0	(337.5-377.5) 351.5	(10.0-14.0) 12.5	(20.0-21.0) 20.0
H.geniculatum	(172.5-192.5) 178.8	(362.5-275.0) 309.4	(7.0-10.0) 8.25	(16.0-17.0) 16.25
H.glaucum	(95.0-212.5) 203.0	(250.0-275.0) 268.5	(11.0-15.0) 13.2	(21.0-22.0) 21.8
H.leporinum	(142.5-185.0) 166.0	(312.5-375.0) 350.0	(11.0-14.0) 12.6	(17.0-19.0) 18.6
H.marinum* var. *marinum	(160.0-170.0) 165.5	(170.0-217.5) 186.0	(11.0-13.0) 11.4	(16.0-18.0) 16.8
H.marinum* var. *pubescens	(145.0-187.5) 169.4	(187.5-212.5) 205.0	(8.0-9.0) 8.6	(13.0-14.0) 13.2
H.spontaneum* var. *proskowetzii	(302.5-315.0) 305.0	(400.0-467.5) 428.5	(13.0-14.0) 13.8	(20.0-21.0) 20.9
H.spontaneum* var. *spontaneum	(227.5-287.5) 264.0	(387.5-475.0) 440.0	(11.0-12.0) 11.2	19.0
H.vulgare	(402.5-442.5) 416.5	(375.0-500.0) 427.5	(16.0-17.0) 16.75	(22.0-24.0) 22.75

Table 3: Quantitative characters of long cells in leaf epidermis

species	Abaxial epidermis		Adaxial epidermis		No. of cell rows in intercoastal zone	No. of cell rows in coastal zone
	Long cells length in stomatal rows	Long cells length in non-stomatal rows	Long cells length in stomatal rows	Long cells length in non-stomatal rows		
H.bulbosum	(25.0-202.5) 89.7	(55.0-470.0) 238.3	(17.5-67.5) 44.4	(90.0-187.5) 142.8	(7.0-10.0) 8.5	(3.0-5.0) 3.83
H.distichon	(30.0-87.5) 55.0	(77.5-442.5) 224.0	(27.5-82.5) 45.8	(95.0-412.5) 250.0	(9.0-11.0) 10.0	(2.0-5.0) 3.29
H.geniculatum	(42.5-120.0) 83.3	(85.0-367.5) 199.0	(25.0-82.5) 49.3	(65.0-227.5) 162.8	(7.0-12.0) 9.33	(2.0-3.0) 2.6
H.glaucum	(25.0-105.0) 57.95	(60.0-415.0) 171.85	(27.5-110.0) 67.27	(82.5-230.0) 135.5	(9.0-12.0) 10.33	(2.0-4.0) 2.75
H.leporinum	(17.5-132.5) 71.0	(70.0-370.0) 217.0	(45.0-125.0) 66.9	(87.5-162.5) 131.9	(9.0-13.0) 10.75	(1.0-4.0) 2.3
H.marinum* var. *marinum	(10.0-117.5) 42.0	(70.0-230.0) 127.3	(10.0-72.5) 35.3	(60.0-165.0) 104.8	(9.0-12.0) 10.43	(2.0-3.0) 2.2
H.marinum* var. *pubescens	(40.0-185.0) 93.0	(102.5-290.0) 175.3	(17.5-87.5) 57.5	(50.0-285.0) 176.8	(8.0-11.0) 9.0	(1.0-3.0) 2.0
H.spontaneum* var. *proskowetzii	(12.5-127.5) 38.3	(70.0-1230.0) 348.3	(15.0-62.5) 40.8	(70.0-322.5) 188.3	(11.0-16.0) 12.63	(3.0-4.0) 3.33
H.spontaneum* var. *spontaneum	(40.0-142.5) 91.5	(105.0-525.0) 260.25	(20.0-90.0) 46.0	(100.0-742.5) 293.3	(10.0-12.0) 10.86	(2.0-4.0) 2.75
H.vulgare	(10.0-47.5) 27.5	(77.5-962.5) 333.6	(15.0-52.5) 34.0	(90.0-485.0) 221.8	(7.0-13.0) 10.89	(3.0-6.0) 4.29

Table 4: Quantitative characters of stomata in leaf epidermis

species	Abaxial epidermis		Adaxial epidermis	
	Length of stomata	No. of stomata in microscopic field	Length of stomata	No. of stomata in microscopic field
H.bulbosum	(37.5-55.0) 45.4	(12.0-21.0) 16.1	(37.5-47.5) 42.3	(15.0-21.0) 16.8
H.distichon	(37.5-50.0) 44.8	(10.0-11.0) 10.33	(40.0-55.0) 48.0	(11.0-14.0) 11.75
H.geniculatum	(45.0-60.0) 50.0	(9.0-10.0) 9.6	(50.0-57.5) 53.3	(14.0-17.0) 15.6
H.glaucum	(35.0-40.0) 38.0	(14.0-22.0) 17.0	(35.0-42.5) 40.83	(19.0-21.0) 19.5
H.leporinum	(40.0-52.5) 45.0	(10.0-13.0) 11.2	(45.0-50.0) 47.2	(7.0-9.0) 7.8
H.marinum* var. *marinum	(32.5-40.0) 35.8	(20.0-24.0) 21.86	(30.0-37.5) 33.5	(21.0-29.0) 25.5
H.marinum* var. *pubescens	(42.5-55.0) 49.2	(12.0-15.0) 13.2	(40.0-57.5) 48.3	14.0
H.spontaneum* var. *proskowetzii	(30.0-50.0) 43.8	(9.0-14.0) 12.0	(30.0-57.5) 44.8	(8.0-20.0) 14.5
H.spontaneum* var. *spontaneum	(40.0-67.5) 57.0	(5.0-12.0) 8.0	(30.0-45.0) 39.3	(12.0-23.0) 17.6
H.vulgare	(27.5-62.5) 44.4	(11.0-14.0) 13.2	(42.5-60.0) 52.5	(9.0-12.0) 12.2

Table 5: Quantitative characters of indumentum in leaf epidermis

species	Abaxial epidermis		Adaxial epidermis	
	Length of prickles	Length of macro-hairs	Length of prickles	Length of macro-hairs
H.bulbosum	(22.5-125.0) 44.6	(180.0-337.5) 115.8	(25.0-75.0) 47.2	(87.5-712.5) 359.8
H.distichon	(27.5-67.5) 43.8	-	(35.0-70.0) 48.8	-
H.geniculatum	((47.5-322.5) 168.0	-	(40.0-412.5) 150.0	-
H.glaucum	(25.0-97.5) 64.25	(167.0-480.0) 323.89	(42.5-160.0) 82.36	(280.0-342.5) 311.25
H.leporinum	(30.0-102.5) 54.2	(147.0-340.0) 237.0	(25.0-85.0) 47.6	(55.0-762.5) 676.7
H.marinum* var. *marinum	(37.5-90.0) 62.5	-	(55.0-175.0) 112.3	-
H.marinum* var. *pubescens	(40.0-175.0) 97.0	-	(55.0-375.0) 247.5	-
H.spontaneum* var. *proskowetzii	(32.5-92.5) 59.1	-	(17.5-67.5) 39.8	-
H.spontaneum* var. *spontaneum	(37.5-90.0) 61.4	-	(30.0-42.5) 33.9	-
H.vulgare	(22.5-52.5) 35.0	-	(27.5-82.5) 39.5	-

Figure 1: General appearance of leaf transverse section

Figure 2: Keel structure and midrib of *Hordeum* species

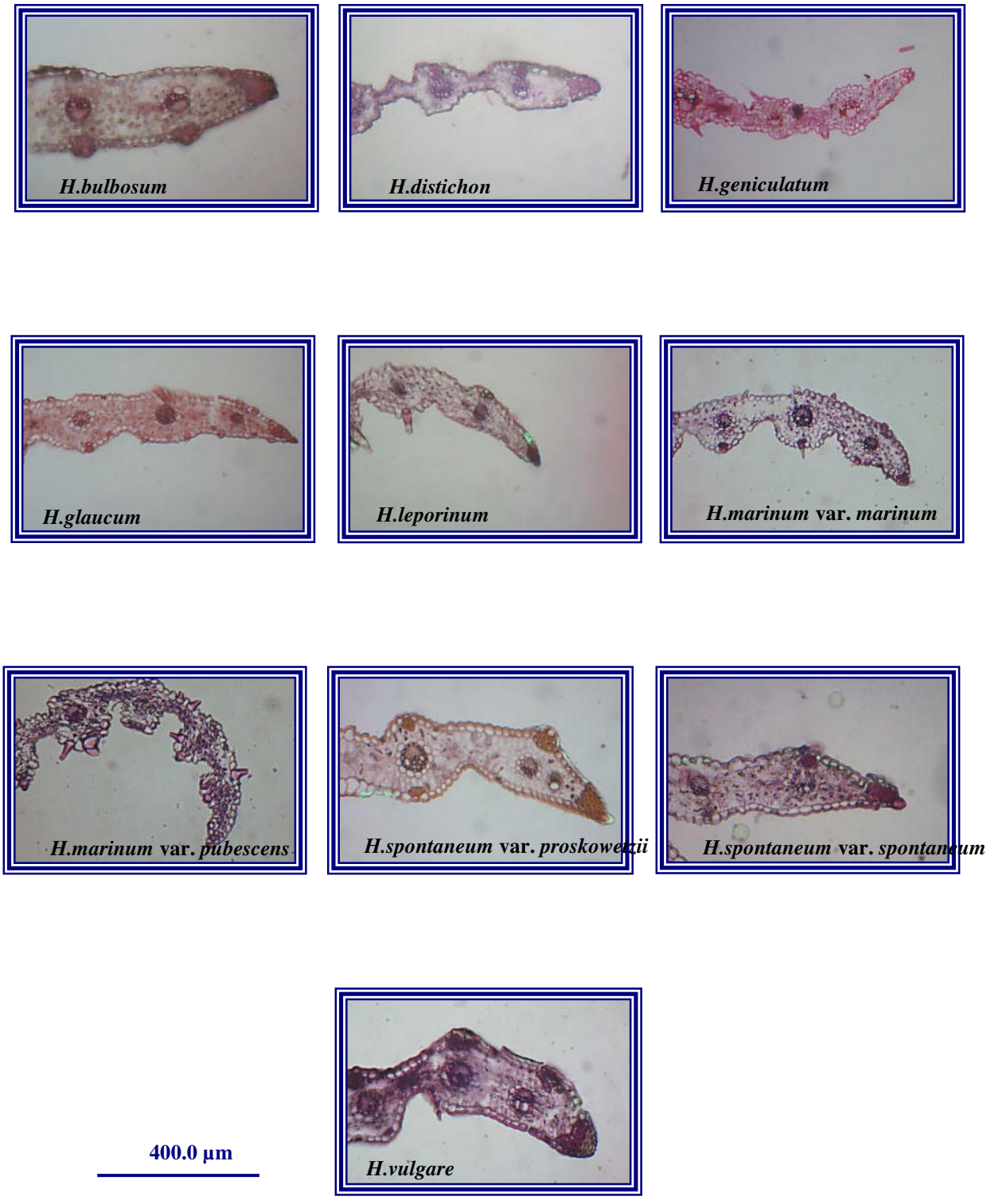

Figure 3: Variation in shape of marginal sclerenchyma cap

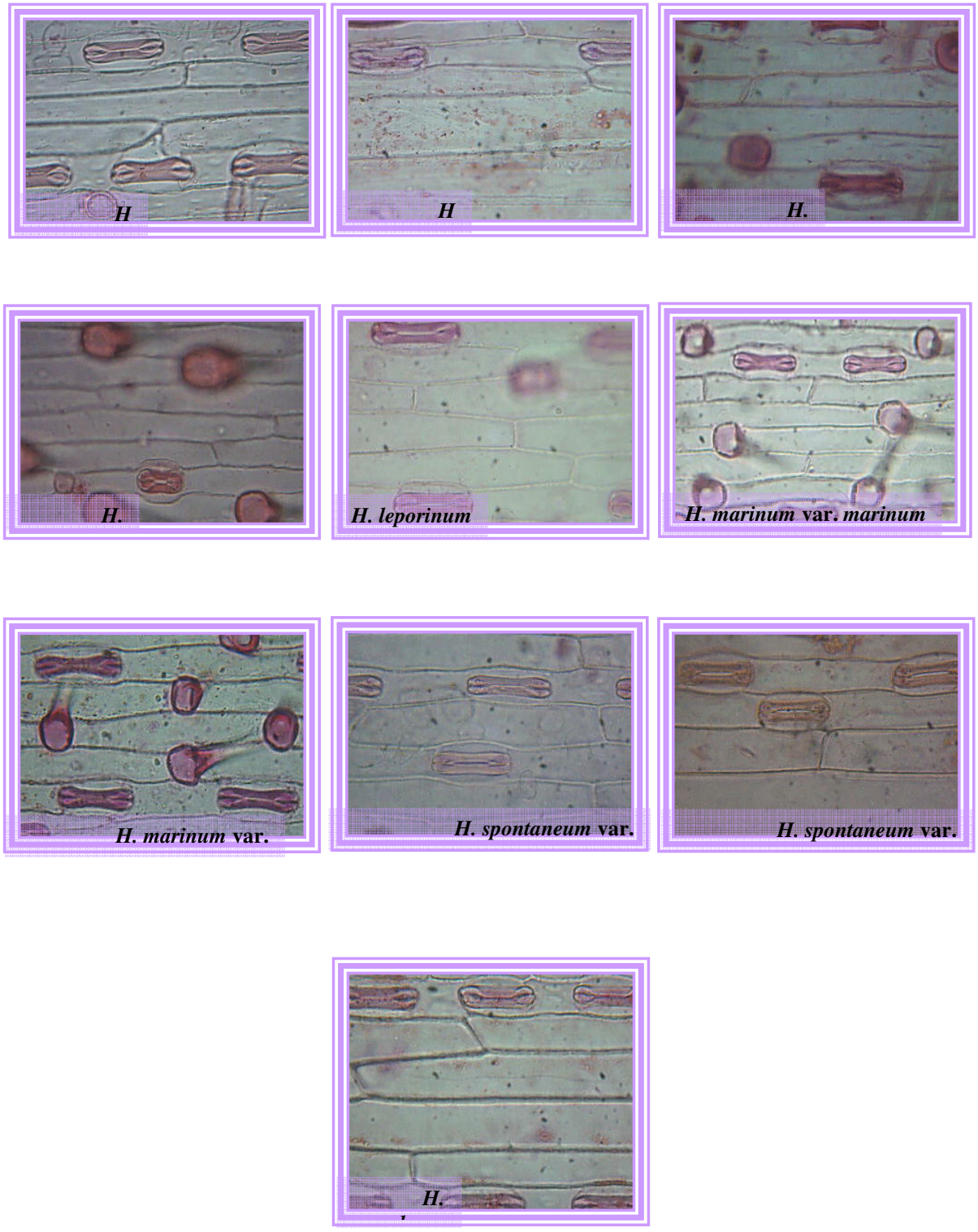

Figure 4: Abaxial epidermis of *Hordeum* species

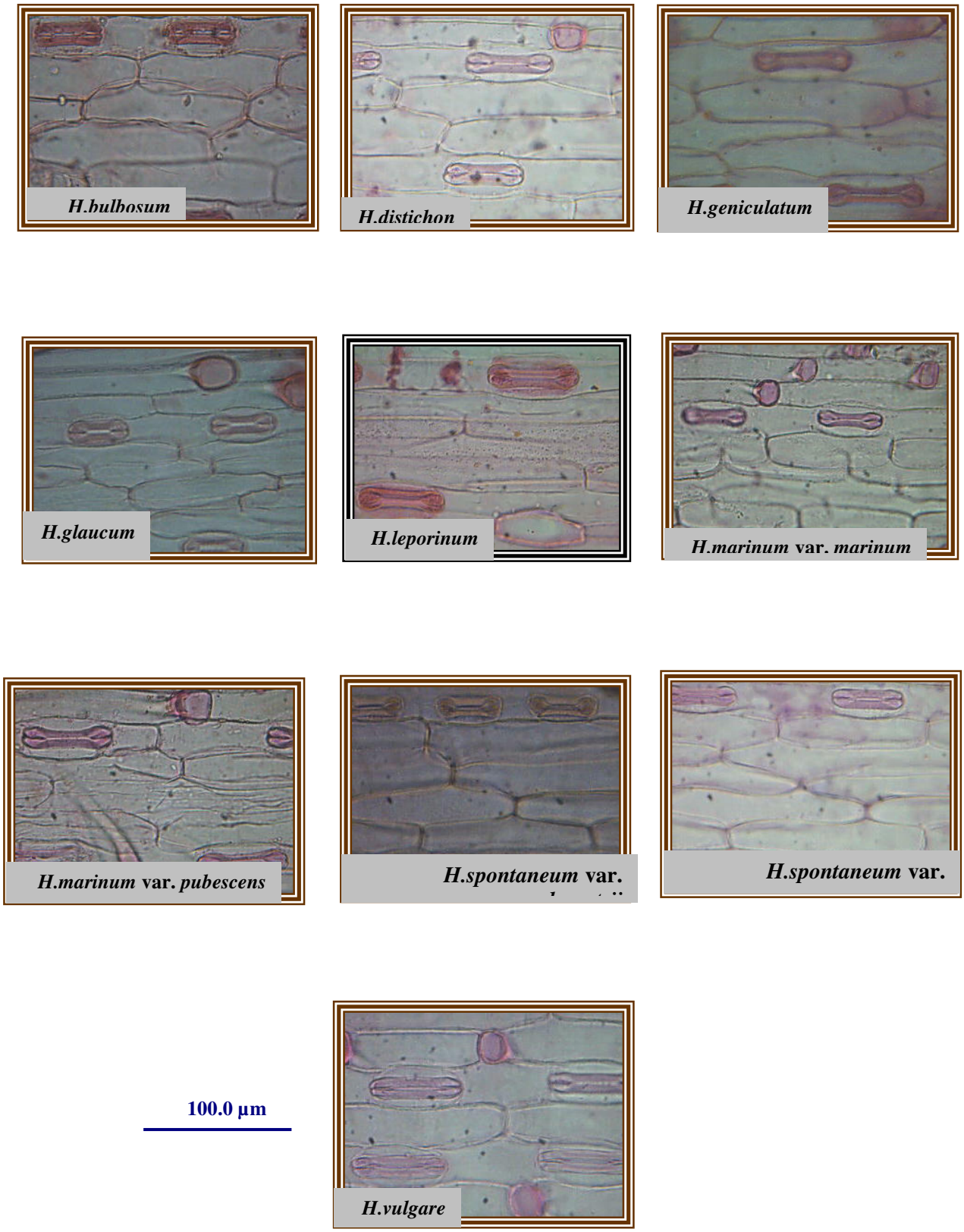

Figure 5: Adaxial epidermis of *Hordeum* species

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