

Morphological, palynological, and anatomical investigations of *Hieracium* L. (Lactuceae, Asteraceae) in Pakistan

SOHAIL JAMIL QURESHI^{1*}, MIR AJAB KHAN², MUHAMMAD ARSHAD³, AUDIL RASHID⁴, MUSHTAQ AHMAD² & MUHAMMAD ZAFAR²

¹*Pakistan Islamia Institute AlAin, Abu Dhabi, United Arab Emirates.*

²*Department of Plant Sciences, Faculty of Biological Sciences, Quaid-i-Azam, University Islamabad, Pakistan.*

³*Department of Botany, PMAS Arid Agriculture University Rawalpindi, Pakistan.*

⁴*Department of Environmental Sciences, PMAS Arid Agriculture University, Rawalpindi, Pakistan.*

ABSTRACT: Morphology, leaf anatomical features and pollen grain characteristics of the genus *Hieracium* (Asteraceae: Lactuceae) have been investigated and illustrated for the first time in Pakistan. *Hieracium* L. and *Pilosella* Hill, are recognized as separate genera. All *Hieracium* species are perennial rhizomatous herbs. In this study five species, i.e. *Hieracium bichlorophyllum*, *H. diaphanoides*, *H. umbellatum*, *H. virosum*, and *H. vulgatum* are described for Pakistan. The stem surface is glabrous in *H. diaphanoides* and *H. umbellatum*, while sparse echinulate and stellate hairs are also present in *H. umbellatum*. *Hieracium bichlorophyllum* has scabrous hairs, while stellate hairs are present in *H. vulgatum*. Basal leaves are sessile in all species but subsessile in *H. vulgatum*. Leaves are bifacial and stomata cells are staurocytic and amphianisocytic. The pollen type of the investigated species is trizonocolporate and tetrazonocolporate.

KEY WORDS: Morphology, palynology, anatomy, *Hieracium* L., scanning electron microscopy, Pakistan.

INTRODUCTION

The large genus *Hieracium* L. belongs to subfamily *Liguliflorae* (Compositae, tribe Lactuceae) and consists of more than 1000 species (Petrović *et al.* 1999). The genus comprises species all over the world with mountainous regions in western Eurasia being especially species-rich (Gottschlich 1996). *Hieracium* spp. introduced from Europe have become weeds of grassland (Hunter 1991, Rose *et al.* 1998) and North America (Birdsall and Quimby 1996, Fernald 1950, Wilson and Callihan 1999). There are more than 11 000 *Hieracium* species names included in the Index Kewensis (Royal Botanic Gardens Kew 1993). A particularly rich nomenclature in *Hieracium* resulted from several objective and partly subjective reasons: (i) the taxa of the subgenus *Hieracium* are mostly apomictic tri- and tetraploids with diplosporic formation of the seeds, only a small fraction of the populations

are sexual diploids (cf. Schuhwerk 1996), while in the subgenus *Pilosella* (Hill) Gray, besides aposporic, apomixes and sexuality, the mode of reproduction is known to be amphimictic (Krahulcová *et al.* 2000); the American representatives of the subgenus *Chionoracium* Sch. Bip. are diploid, sexual (Beaman 1990, Schuhwerk 1996); (ii) the genus has a worldwide distribution; (iii) *Hieracium* taxa occur in a large variety of habitats; (iv) there are different taxonomic approaches to the classification of the apomictic taxa in this genus (Švehliková *et al.* 2002). Without any doubt the genus *Hieracium*, even without genus *Pilosella*, is among the richest and at the same time the most intricate genera of the plant kingdom. The infrageneric classification of *Hieracium* is not yet satisfactorily defined. In its usual sense (e.g. Sell and West 1976), it consists of two subgenera that have often been recognized as separate genera: *Hieracium* and *Pilosella*.

Author

Correspondence: Pakistan Islamia Institute AlAin, Abu Dhabi, United Arab Emirates, P.O. Box # 15778.

sohailjamilqureshi@hotmail.com*

Mobile number: 00971-50-6930626

Hieracium L. is naturalized in Pakistan, probably introduced as contaminants of crop or pasture seeds, although some species have been propagated for their ornamental appeal. To date no comprehensive morphological, palynological, and anatomical study has been undertaken. Species of *Hieracium* are often difficult to distinguish from each other and their infra-generic classification can only be considered preliminary.

As a chemical marker in the genus *Hieracium*, the widespread presence of umbelliferone in the section *Pilosella* and its absence in representative species from nine other sections has been used to support the recognition of *Pilosella* as a separate genus (Bate-Smith *et al.* 1968). Two main approaches concerning the taxonomic concept of species versus subspecies (or lower ranks) in *Hieracium* evolved in European hieraciology during the last two centuries. The so-called German school (based on the classical works of Nägeli and Peter, later developed by Zahn), working with a wide species concept, recognized many infraspecific ranks such as subspecies, variety and forma below the rank of species, but also grex or subgrex (ranks between the species and subspecies not explicitly mentioned in the present International Code of Botanical Nomenclature (ICBN, McNeill *et al.* 2005). Nägeli and Peter (1885) described 21 groups and 117 subspecies after growing many variants in a common garden to determine constant characters.

The origin of *H. rubrum* Peter (1881) is assumed to be via a spontaneous hybridization between *H. aurantiacum* L. (1753) and *H. pilosella* L. (1753), or, especially in the Alps, *H. hoppeanum* Schultes and *H. aurantiacum*. The morphological characters of *H. rubrum* more resemble *H. aurantiacum* than either of the other putative parents (Peter 1881, Nägeli and Peter 1885, Bräutigam and Schuhwerk 2002). Modern treatments are based substantially on a

simplification of the monograph of Zahn (1921-23), which enumerates 624 subspecies. The Zahn's (1930-39) concept of sections is adopted by (Mráz 2001). The morphologically intermediate species ("Zwischenarten" or species intermediae) between the main taxon ("Hauptart" – or species principalis) *H. alpinum* L. (1753) and other main taxa in the sense of Zahn are included in the sect. Alpina. Zahn added in the description of *H. nigrescens* Willd. (1803) a note: "verosimiliter *bifidum-alpinum*" (Zahn 1927).

From a systematic and biological viewpoint, the genus *Hieracium* is one of the most complex groups of the boreal flora. This is mainly due to the highly reticulate micromorphological differentiation caused by hybridization, results of which are conserved by apomictic reproduction (Gustaffson 1946-1947, Merxmuller 1975, Asker and Jerling 1992). On one hand, Scandinavian and British botanists accepted a narrow species concept; under species level no or few taxonomic ranks are recognized (Mráz 2001). While working on recently published accounts of the species of *Hieracium* and *H. Sect. Vulgata* of the SE Swedish provinces of Gotland and Östergötland the need to lectotypify as many as possible of the relevant names became apparent (Tyler 2002a, 2002b, 2003). Some of the names of taxa described from these provinces were lectotypified by Tyler (2000) and Sennikov (2003), but quite a number remains, and these are the focus by Tyler (2004).

Nomenclatural work in Nordic *Hieracium* presents some particular problems. However, these particularities have already been described and discussed thoroughly by Sennikov (2002) and Tyler (2000). While working on *Hieracium*, Tyler (2008), concluded that *H. incurrens* do indeed occur in central Sweden, namely in the Eastern coastal provinces closest to Finland. However, the relevant material has mostly been referred to *H. longilingua* Johansson, which is

here considered to be a latter synonym of *H. incurrens*. Material previously referred to *H. incurrens* from other parts of Sweden does, however, represent other taxa. Five accepted species of this affinity are described and discussed in some detail and one species, viz. *H. oestmanii* T. Tyler is described as new. In addition, the unrelated species *H. arnoldii* T. Tyler is described as new based on material from the provinces of Hälsingland and Medelpad. For Sennikov (2008), the only specimen suitable for typification of *Hieracium caesium* Fr. was discovered in Herbarium UPS and was designated as lectotype. This name appears to have been misapplied and superfluous when originally published at specific rank, but is legitimate according to Art. 52.3 of the International Code of Botanical Nomenclature. The 99 species of *Hieracium* known from Turkey were classified into 14 series by Sell & West (1975). A part of *Hieracium* species distributed in Turkey has been also recorded in the flora of other countries (Sell and West 1976).

The present paper is an introduction and first attempt to morphological, palynological and anatomical studies on *Hieracium* from Pakistan.

MATERIALS AND METHODS

Hieracium is most common in the North West Frontier Province and Punjab of Pakistan. Collections were made from eight sites (Fig. 1). Most of the material used for this study was collected directly from wild populations, and the voucher specimens for each of the samples studied have been placed in the herbarium of Pakistan Islamabad (ISL), Faculty of Biological Sciences, and Department of Plant Sciences, Quaid-i-Azam University Islamabad. The specimens were also studied from herbarium of Pakistan Museum of Natural History, Islamabad (PMNH) and National herbarium, Islamabad (RAW). The parts of the plants were measured with hard ruler or for finer details, under a dissecting microscope. Magnifiers of 5X, 10X,

20X were also used for observation of various parts. Ten specimens per species were used for assessment of morphological characters. Mature achenes from the peripheral florets of the capitulum were measured at low magnification under a stereomicroscope. The terminology of fruit-coat surface sculpturing follows Stearn (1973) and Font Quer (1979).

Pollen was removed from herbarium (ISL) sheets. General preparation consisted of acetolyzing mature pollen grains (Erdtman 1960), removal of undigested plant debris (Chissoe and Skvarla 1974, Chissoe and Skvarla 1996), and separating the samples for SEM. Whole pollen grains and fragments of pollen walls obtained by cryomicrotomy (Skvarla *et al.* 1988) were stained and dried using the repeat method of osmium and thiocarbohydrazide (i.e., OTOTO) as described by Chissoe *et al.* (1995). For each species ten randomly selected specimens were observed. Pollen was then mounted on double-stick tape and coating of gold was done using magnetron sputter coater model SC 7610 and Secondary electron images (SEI) were recorded using scanning electron microscope LE0440I (Chissoe and Skvarla 1996).

Leave samples were taken from the sixth/seventh nodes of the main stem at the full flowering. Dried leaves were placed in boiling water for few minutes to soften the leaf until they became unfolded and were ready for epidermal scrapping. Fresh leaves were used directly for anatomical studies. The fresh or dried leaves were placed in a test tube filled with 88% lactic acid kept hot in boiling water bath for about 50-60 minutes. Lactic acid softens the tissue of leaf due to which peeling off is made possible. For each plant species, randomly five slides were prepared from abaxial and adaxial surface. To prepare the abaxial surface, the leaf was placed keeping its adaxial surface upward and then it was flooded with 88% cold lactic acid. The adaxial epidermis was

cut across the leaf using a sharp scalpel blade and scrapped away together with the mesophyll cells until only the abaxial epidermis of the leaf remained on the tile. The epidermis was placed outside uppermost and mounted in clean 88% lactic acid. Same procedure was followed to prepare the adaxial epidermis. For anatomical studies, sections from fixed samples were taken by hand using a razor and their photographs were taken with a camera marked Nikon FDX-35 by examining them under a microscope. The length and width of the stomata were measured with an ocular micrometer using surface sections from the upper and lower parts of the leaf epidermis (Meinder and Mansfield 1968). The number of stomata was evaluated by preparing slides from the clear nail polish impression on both lower and upper epidermis of the leaves. The terminology of leaf epidermal anatomy follows Metcalfe and Chalk (1950). Stomata were counted and measured using 10X, 20X and 40X magnifications.

RESULTS

***Hieracium* L. Sp. Pl. 2: 799. 1753.**

Herb, perennial, 26-50 cm tall, stem cylindrical, glabrous. Basal stem leaves- sessile, spatulate, denticulate to dentate, apex obtuse, glabrous. Middle stem leaves sessile, similar to basal leaves. Upper stem leaves sessile, linear-lanceolate, denticulate, apex obtuse, scabrous above and below. Capitula terminal, few. Involucre campanulate. Phyllaries in two rows, oblanceolate, hispid hairs above and below, margin entire, outer phyllaries apex acute, inner phyllaries apex obtuse. Florets yellow. Achene dark brown, with 6 ribs, columnar, beakless. Pappus white, long deciduous. The characters and differences may be best described in a dichotomous key as below.

Key to the species of *Hieracium* collected in Pakistan

1. Stem with scabrous hairs, basal leaf blade acute to acuminate 2

1. Stem with stellate hairs, basal leaf blade obtuse 3
2. Basal leaves sessile, phyllaries in two rows *H. bichlorophyllum*
2. Basal leaves absent, phyllaries in three rows *H. umbellatum*
3. Phyllaries in four rows, ten ribs on each face, pappus persistent *H. virosum*
3. Phyllaries in two rows, six ribs on each face, pappus deciduous 4
4. Involucre size 8-11 x 7-11 mm, basal leaf blade elliptic-lanceolate to ovate-lanceolate, outer phyllaries linear lanceolate ... *H. vulgatum*
4. Involucre size 12-14 x 8-10 mm, basal leaf blade spatulate, outer phyllaries oblanceolate *H. diaphanoides*

***Hieracium bichlorophyllum* (Druce & Zahn) Pugsley, J. Ecol. 33: 347. 1946.**

Herb, perennial, 25-50 cm tall, stem erect, cylindrical with scabrous hairs. Basal stem leaves sessile, ovate-lanceolate to oblong, 5.5-7.3 x 1-1.7 cm, denticulate, apex acute to shortly acuminate, leaves glabrous above and scabrous below. Middle stem leaves sessile, 6-10 x 1-1.8 cm, lanceolate to oblanceolate, denticulate, glabrous above and below, apex acute. Upper stem leaves sessile, oblanceolate, denticulate to dentate, apex acute, glabrous above and below. Capitula terminal, numerous, corymbose. Involucre campanulate, 1.6-1.8 x 0.6-1 cm. Phyllaries in 2 rows, with scabrous hairs; outer phyllaries lanceolate, 0.4-1 x 0.1-0.3 mm, denticulate, apex obtuse; inner phyllaries 0.9-1.2 x 0.1-0.3 mm, oblanceolate, entire, apex acuminate. Florets yellow. Achene dark brown, 0.3 x 0.1 mm, with 8 ribs, Columnar, beakless. Pappus 4 mm long, scabrous, persistent (Fig. 2).

FLOWERING AND FRUITING. May-August.

SPECIMENS EXAMINED. **Azad Kashmir and N.W.F.P.:** Gilgit, Hunza's Garden, 05-06-1977, Mir Ajab Khan & Afzal, 405, 57029 (ISL); Hazara, Puludian, 27-07-1978, Muqarrab Shah & Dilawar Khan, 2712, 100869 (ISL); Skardu, Ghazi Nallah, 30-07-1978, Mir Ajab Khan &

Nisar Ahmad, 2084, 98005 (ISL); Skardu, Sukh Village, Mir Ajab Khan & Nisar Ahmad, 1010, 99184 (ISL); Skardu, Kachura Village, 04-07-1978, Mir Ajab Khan & Nisar Ahmad, 1186, 96169 (ISL); Skardu, Ghurbache Khupb, 21-07-1978, Mir Ajab Khan & Nisar Ahmad, 1789, 96999 (ISL).

***Hieracium diaphanoides* Lindeb., Bot. Not.: 127. 1882.**

Herb, perennial, 26-50 cm tall, stem cylindrical, with numerous stellate and few simple eglandular hairs. Basal stem leaves sessile, oblong, 10-13.5 x 1.5-2.5 cm, denticulate to dentate, apex obtuse, eglandular hairs on both sides. Middle stem leaves sessile, 8-11.5 x 1.5-2 cm, similar to basal leaves. Upper stem leaves sessile, linear-lanceolate, denticulate, apex obtuse, scabrous above and below. Capitula terminal, corymbose, few. Involucre campanulate, 12-14 x 8-10 mm. Phyllaries in 2 rows, oblanceolate, with few stellate and numerous long glandular hairs above and below, margin entire; outer phyllaries 0.7-0.9 x 0.1-0.3 mm, apex acute; inner phyllaries 0.9 x 0.3 mm, apex obtuse. Florets yellow. Achene dark brown, 0.3 x 0.1 mm, with 6 ribs, columnar, beakless. Pappus white, 0.3 mm long, deciduous (Fig. 3).

FLOWERING AND FRUITING. June-September.

SPECIMENS EXAMINED. **Azad Kashmir and N.W.F.P.:** Dir, Saksair, 08-08-1977, Muqarrab Shah & Dilawar Khan, 2702, 62819 (ISL).

***Hieracium umbellatum* L., Sp. Pl. 2: 804. 1753.**

Herbs, perennial, 30-100 cm tall, stem basally pale purple, solitary to few fascicled, glabrous or with very sparsely and minutely echinulate and white minutely stellate hairs, rarely with long simple hairs. Basal stem leaves absent at anthesis. Middle stem leaves sessile, lanceolate, 3-10 x 0.4-2 cm, adaxially with sparse arachnoid hairs and abaxially hispidulous on veins, base narrowly cuneate, margin with

sparse and sharp teeth, apex acute to shortly acuminate. Upper stem leaves similar to middle stem leaves, gradually smaller towards stem apex. Capitula few to numerous, terminal, corymbose to corymbose-paniculate. Involucre campanulate 1.5-1.8 x 0.4-0.6 cm. Phyllaries in 3 rows, abaxially glabrous, sometimes base with minute stellate hairs, rarely abaxially with capitate stipitate glandular hairs on midvein, apex acute; outer phyllaries lanceolate, 3.5-4.5 x 0.8-1.2 mm; middle phyllaries lanceolate-linear, 4 x 1 mm; inner phyllaries long linear-elliptic 18 x 1 mm. Florets yellow. Achene dark, 3 x 1 mm, columnar, glabrous, with 10 ribs, apex truncate and beakless. Pappus 6 mm, pale yellow, scabrous, persistent (Fig. 4).

FLOWERING AND FRUITING. July-September.

SPECIMENS EXAMINED. **Azad Kashmir and N.W.F.P.:** Hazara, Lalazar, 02-09-1975, Iqbal Dar, Anjum Amin, Nisar Ahmad & Muhammad Arif, 244, 14821 (ISL); Hazara, Lalazar, 02-09-1975, Iqbal Dar, Anjum Amin, Nisar Ahmed & Muhammad Arif, 244, 14823 (ISL); Hazara, Chak Buri Nar, 12-08-1976, Shaukat & Nisar, 868, 36266 (ISL); Hazara, Batakundi, Shaukat & Nisar, 05-08-1976, 752, 36177 (ISL); Skardu, Totti Nallah, 29-07-1978, Mir Ajab Khan & Nisar Ahmad, 2066, 96118 (ISL); Skardu, Kachura Lake, 03-07-1978, Mir Ajab Khan & Nisar Ahmad, 1144, 96195 (ISL); Skardu, Ghazi Nallah, 30-07-1978, Mir Ajab Khan & Nisar, 2084, 98004 (ISL); Skardu, Kachura Nallah, 21-07-1977, Mir Ajab Khan & Muhammad Afzal, 1604, 65261 (ISL). **Balochistan:** Ghanche, Kalbung Khaplu, 30-07-1977, Mir Ajab Khan & M. Afzal, 1922, 65289 (ISL).

***Hieracium virosum* Pallas, Reise Russ. Reich. 1: 501. 1771.**

Herb, perennial, 50-150 cm tall, with thick rhizomes. Stem erect, basally purple, solitary to few fascicled, stout, basally hirsute and apically glabrous. Basal stem leaves absent at anthesis. Middle stem leaves sessile, ovate, ovate-

lanceolate, narrowly elliptic-lanceolate, 5-8 x 1.5-4 cm, only veins hirsute, base cordate and amplexicaul, margin dentate, and apex acute to shortly acuminate. Upper stem leaves similar to middle stem leaves but smaller. Capitula numerous, terminal, corymbose to long paniculate. Involucre campanulate, 1.1-1.4 x 0.2-0.3 cm. Phyllaries in 4 rows, abaxially glabrous, apex obtuse to acute; outer phyllaries lanceolate, linear or broadly linear, 3-5 x 1-1.2 mm, middle phyllaries lanceolate 4.5 x 1.5 mm; inner phyllaries lanceolate, 11 x 1 mm. Florets yellow. Achenes dark purple, Columnar, 3 x 1 mm, with 10 ribs, apex truncate and beakless. Pappus yellow, 6 mm, scabrous, persistent (Fig. 5).

FLOWERING AND FRUITING. June-October.

SPECIMENS EXAMINED. **Azad Kashmir and N.W.F.P.:** Naran, 09-09-1975, S. R. Saif, 85, 23228 (ISL); Gilgit Agency, Naltar, 05-08-1976, Shahzad Iqbal, Ashraf, Akram & Maqsood, 226, 36186 (ISL); Skardu, Ghanche Nallah, 29-07-1977, Mir Ajab Khan & M. Muhammad Afzal, 1901, 62746 (ISL).

***Hieracium vulgatum* Fr., Fl. Hall. Sect. 7 – 10: 128. 1819 [Nov. 1819].**

Herb, perennial, 60-100 cm tall, with stellate and simple eglandular hairs. Stem proximally pilose-hirsute. Basal stem leaves 4-18 x 1.5-5 cm, elliptic-lanceolate to ovate-lanceolate, subsessile leaves with simple eglandular hairs which are usually sparse above, sometimes with stellate hairs beneath, obtuse to acute, denticulate to dentate. Middle stem leaves sessile, 5-10 x 1.5-4 cm, similar to basal leaves. Upper stem leaves ovate-lanceolate, sessile, denticulate to dentate, lower surface is densely covered with hairs as compared to upper surface. Capitula numerous, corymbose, peduncles with dense stellate hairs, few to numerous simple eglandular hairs and often a few glandular hairs. Involucre campanulate, 8-11 x 7-10 mm. Phyllaries in 2 rows, obtuse to acute, with few to numerous stellate hairs,

numerous simple eglandular hairs and few to numerous glandular hairs; outer phyllaries linear-lanceolate, 8-10 x 2-4 mm, inner phyllaries lanceolate, 12 x 3 mm. Florets yellow. Achene 3 x 1.2 mm, blackish, columnar, 10-ribbed, smooth, beakless. Pappus, white, 5 mm long, deciduous (Fig. 6).

FLOWERING AND FRUITING. May-September.

SPECIMENS EXAMINED. **Azad Kashmir and N.W.F.P.:** Muzaffarabad, 05-06-1978, Shahzad Iqbal & Nisar, 1502, 88034 (ISL); Chikar, Bagh, 01-07-1952, Jan Muhammad, 1383, 16343 (ISL); Muzaffarabad, Pandu, 05-06-1978, Shahzad Iqbal & Nisar, 1452, 88040 (ISL); Muzaffarabad, Reshna, 17-06-1978, Shahzad Iqbal, Ijaz & Abbasi, 1400, 93571 (ISL); Muzaffarabad, Sudangali, 25-05-1978, Shahzad Iqbal, Nisar & Ghulam Farooq, 781, 87506 (ISL); Chitral, Golin Koh, 08-07-1977, Muqarrab Shah & Dilawar Khan, 1950, 61162 (ISL); Skardu, Kachura Lake, 03-07-1978, Mir Ajab Khan & Nisar Ahmad, 1145, 96194 (ISL); Hazara, Siran, 19-08-1976, Shaukat & Nisar Ahmad, 987, 36367 (ISL); Swat, Shangla, 11-06-1976, Muqarrab Shah & Dilawar Khan, 1393, 35833 (ISL); Swat, Yakhtangi, Muqarrab Shah & Dilawar Khan, 1198, 35310 (ISL); Hazara, Siran, 20-08-1976, Shaukat & Nisar, 981, 36369 (ISL). **Punjab:** Rawalpindi, 19-05-1975, Iqbal Dar, Muhammad Arif, Sarfraz Khan, 25, 14579 (ISL); Campbellpur, Burhan, 29-05-1975, Anjum Amin, Manzoor Hussain & Nisar Ahmad, 198, 14593 (ISL); Rawalpindi, Bansra gali, 19-05-1975, Iqbal Dar, Muhammad Arif & Sarfraz Khan, 25, 14579 (ISL).

PALYNOLOGY. Based on the sculpturing, *Hieracium* pollen investigated in the present study was echinate and scabrate. The pollen class was trizonocolporate in *H. bichlorophyllum* and *H. diaphanoides*, while it was tetrazonocolporate for the remaining taxa (Table 2). Dimension of the polar axis ranged from 16.5 μm (*H. bichlorophyllum*) to 35 μm (*H. diaphanoides*) and equatorial axis varied

between 15 μm (*H. vulgatum*) and 36 μm (*H. diaphanoides*). The ratio of polar to equatorial axis (P/E) varies between different taxa as 0.8 (*H. bichlorophyllum* and *H. vulgatum*) and 1.0 in the remaining species. The exine thickness ranged from 1.6 μm (*H. umbellatum*) to 8 μm (*H. diaphanoides*). Spines are present in *H. diaphanoides* (Fig. 8) and *H. viosum* (Fig. 9) and absent in the other taxa (Fig. 7). Pollen spines show an impressive variation, which is of significance at the specific and generic level and has also been helpful to understand the process of spine evolution within the tribe Lactuceae. Spine length ranged from 4.7 μm (*H. viosum*) to 6.9 μm (*H. diaphanoides*). The number of spine rows between colpi varies from 5 to 12 in *H. viosum*.

LEAF EPIDERMAL ANATOMY. Most of the species had staurocytic stomata, except in *Hieracium umbellatum* (Table 3). All the species had stomata on both surfaces, except *H. viosum* which do not possess stomata on the lower epidermis. The percentage of each type in abaxial and adaxial surface is 100%. Numbers of stomata and epidermal cells vary 4-12 /mm² and 32-45 / mm², respectively.

The size of epidermal cell ranges from 23 μm (*H. vulgatum*) to 78 μm (*H. diaphanoides*). The size of stomatal complex varies from 68 μm (*H. vulgatum*) to 204 μm (*H. umbellatum*). The percentage of open stomata varies from 51.72% (*H. diaphanoides*) to 85.7% (*H. diaphanoides* and *H. viosum*) and that of close stomata ranges from 14.28% (*H. diaphanoides* and *H. viosum*) to 48.27% (*H. diaphanoides*). The crystals were found to be absent in abaxial surfaces of *H. bichlorophyllum* and *H. viosum*, whilst present in the other species studied. The length of trichome varies from 48 μm (*H. umbellatum*) to 1442 μm (*H. viosum*) and the base of trichome ranges from 21 μm to 441 μm (*H. umbellatum*). Trichomes were absent in *H. bichlorophyllum*, *H. diaphanoides* and in

abaxial surfaces of *H. viosum* and *H. vulgatum* (Table 4).

The length of guard cells varies from 23 μm (*H. vulgatum*) to 36 μm (*H. diaphanoides*), while the width of guard cells varies from 9 μm (*H. vulgatum*) to 21 μm in *H. diaphanoides*. The length of stomatal pores ranges from 16 μm (*H. bichlorophyllum*) to 24 μm (*H. diaphanoides*), while the width of stomatal pores varies from 2 μm to 6 μm . The microhairs were found to be absent on both the abaxial and adaxial surfaces of leaf epidermis (Table 5).

DISCUSSION

Literature on the taxonomy of the genus *Hieracium* and even on the tribe Lactuceae within Asteraceae from Pakistan has not been published yet. Therefore the studies were based on material available in the herbaria of Pakistan. Observations on the species were recorded in their habitats.

The main morphological characters which are useful in distinguishing and describing the species are habit, height of plant, stem surface, basal leaves, middle and upper stem leaves, capitula, inflorescence, phyllaries, achene size, shape, number of ribs and surface between ribs, achene beak, and pappus. Plant morphology in all its aspects is important and the first step to plant identification. The stem surface possesses numerous stellate and few simple eglandular hairs in *H. diaphanoides* and *H. umbellatum*, while sparse echinulate and stellate hairs are also present in *H. umbellatum*. *Hieracium bichlorophyllum* contains scabrous hairs, while stellate hairs are present in *H. vulgatum*. *Hieracium viosum* is apically glabrous and basally hirsute.

Basal leaves are sessile in all species but subsessile in *H. vulgatum*. It was also found that the basal leaf blade is ovate-lanceolate to oblong in *H. bichlorophyllum*, oblong in *H. diaphanoides*, elliptic-lanceolate to ovate-

lanceolate in *H. vulgatum*, and absent in *H. umbellatum* and *H. viosum*. The middle and upper stem leaves are lanceolate in *H. umbellatum*, ovate-lanceolate to elliptic lanceolate in *H. viosum*, lanceolate to oblanceolate in *H. bichlorophyllum*, and oblanceolate in *H. bichlorophyllum*. In *H. diaphanoides* middle leaves are oblong and upper leaves linear-lanceolate. In *H. vulgatum*, the middle stem leaves are elliptic-lanceolate to ovate-lanceolate and upper stem leaves are ovate-lanceolate. Furthermore, it has been found that phyllaries are arranged in two rows in all species except *H. umbellatum*, in which three rows are present, and *H. viosum* with four rows. The middle phyllaries were lanceolate in *H. viosum*, lanceolate-linear in *H. umbellatum*, and absent in the rest of the species, while outer and inner phyllaries also vary in shape in different species (Table 1).

Achenes were columnar and the number of ribs in the achene is an important taxonomic character which varies in different species: Ten ribs in *H. umbellatum*, *H. viosum* and *H. vulgatum*, eight ribs in *H. bichlorophyllum*, and six ribs in *H. diaphanoides*. None of the species studied has a fruit beak. The pappus was deciduous in *H. diaphanoides* and *H. vulgatum*, while persistent in the remaining species (Fig. 2-6). According to Tyler (2007), *Hieracium incurrens* Saelan ex Norrl., originally described from Finland, has been reported from Sweden several times and independently by different authors. Still, however, its presence in Sweden has remained dubious and it has become obvious that the different reports are referable to different taxa and the name has thus been, at least partially, misapplied. In 1920, Johansson and Samuelsson described the new variety *H. incurrens* var. *oletatum* based on material from the province of Västmanland (Johansson and Samuelsson 1920). This taxon was raised to the rank of species by Tyler (2005a) and the name was lectotypified by Tyler (2006). However, when doing so, Tyler (2005a, 2005b) compared

the new species with a description of *H. incurrens* based mainly on material from the Swedish provinces Södermanland and Västmanland, rather than on authentic Finnish material of that species. A new species was described from Pakistan: *Hieracium sherwalii* Abedin & Zamarrud (2008). The new taxon is characterized by having many branched stems from the base with numerous leaves and capitula.

Systematic and evolutionary themes based on Asteraceae pollen were discussed by Wodehouse (1928, 1935). From an historical perspective, it is noteworthy that Steetz (1864) is credited as the first to employ pollen as a taxonomic character in the Asteraceae (Bentham and Hooker 1873, Robinson 1992a, 1992b). Wodehouse recognized four pollen morphological forms in the family: simple echinate, sub-echinolphate, echinolphate, and psilolphate together with many intermediates. Wodehouse (1928) found one morphological form to be present in the genus *Hieracium* tribe Lactuceae. Blackmore's (1986) study of lophate pollen recognized at least 23 different pollen types in the Asteraceae, and lophate patterning was most variable. The ultraviolet microscopy of Stix (1960) provided the foundation for interpreting structural types throughout the family. Robinson significantly extended the pollen morphological/taxonomic database (Robinson 1986, 1987a, 1987b, 1987c, 1988a, 1988b, 1988c, 1988d, 1990, 1992a, 1992b, 1999a, 1999b). The importance of pollen morphology in Asteraceae systematics is underscored by his comments (Robinson p. 349 1992a) "...pollen is one of a series of characters such as stylar bases and anther appendages, observable with the compound microscope, that prove useful in delimiting natural groups. The point has been reached where I believe every taxonomic treatment in the Lactuceae should include mention of pollen type".

As the pollen morphology results indicate, pollen grains in *Hieracium* are lophate. The spines are more or less similar in all cases, except for differences in their size and distribution. Wodehouse (1935) reported that pollen grains of Compositae were unique and true to form and he outlined the principles of morphological evolution of spine form of the family, in which he suggested the reduction series from long to minute spines. There seems to be a potential indicating the evolutionary processes of pollen spines in the Lactuceae. The peculiar spine character perhaps represents a climax in the apertural evolution. The occurrence of spines and its absence indicate a trend of evolution of spine reduction in the tribe Lactuceae. The reduction and the absence of spines are evolved characters in Lactuceae. Genera with spinate pollen, as *Hieracium*, exhibit a primitive feature as compared to the genera with spineless pollen, which are considered advanced within the tribe. The data may be used in establishing relationships at generic and specific levels of the tribe Lactuceae.

Sajo & Menezes (1994) observed that the Asteraceae species *Vernonia psilophylla* and *V. sessilifolia* had stomata on both surfaces, whilst *V. linearis* has stomata only on the abaxial epidermis. Metcalfe & Chalk (1950) reported that due to the diversity of habits, Asteraceae species show various anatomical structures and some present ecological specialization. Most of the species had staurocytic stomata, except in *H. umbellatum* (Fig. 14-15). All the species had stomata on both surfaces, except *H. virosum* which does not possess stomata on the lower epidermis. Castro *et al.* (1997) also presented a description of some types of trichomes occurring in some genera of Asteraceae and used them to elaborate an identification key.

The length of guard cells varies from 23 μm (*H. vulgatum*) to 36 μm (*H. diaphanoides*) (Fig. 12-13), while the width of guard cells varies from 9

μm (*H. vulgatum*) to 21 μm in (*H. diaphanoides*). The length of stomatal pores ranges from 16 μm (*H. bichlorophyllum*) to 24 μm (*H. diaphanoides*) while the width of stomatal pore varies from 2 μm to 6 μm . The microhairs were found to be absent on both the abaxial and adaxial surfaces of leaf epidermis (Table 5).

Our results so far indicate that plant morphology, pollen morphology, and leaf epidermal anatomy studies conducted in Pakistan provide important data for identification, as well as a contribution towards a better knowledge of the family Asteraceae.

ACKNOWLEDGEMENT

The authors wish to thank the Chairman, Department of Plant Sciences, Faculty of Biological Sciences Quaid-i-Azam University Islamabad for providing the plant material used for scanning electron microscopy, leaf epidermal anatomy, literature, language revision and critical comments, which improved the manuscript. The contribution is a part of the study of the corresponding author.

REFERENCES

- Abedin S, Zamarrud. 2008.** A new species of *Hieracium* L. (Asteraceae) from Pakistan. Pakistan Journal of Botany 40(1): 5-8.
- Asker SE, Jerling L. 1992.** Apomixis in Plants. CRC Press. Boca Raton.
- Bate-Smith EC, Sell PD, West C. 1968.** Chemistry and taxonomy of *Hieracium* L. and *Pilosella* Hill. Phytochemistry. 7(7): 1165-1169.
- Beaman JH. 1990.** Revision of *Hieracium* in Mexico and Central America. Syst. Bot. Monogr. 29: 1-77.
- Bentham G, Hooker JD. 1873.** Tribus I. *Vernonieae*. Genera Plant. 2: 223-238.
- Birdsall J, Quimby PC. 1996.** Hawkweeds. In: Rees, N. et al. (Eds.), Biological Control of

- Weeds in the West. Western Society of Weed Science in Cooperation with USDA Agricultural Research Service. Montana Department of Agriculture and Montana State University, Bozeman.
- Blackmore S. 1986.** The identification and taxonomic significance of lophate pollen in the Compositae. *Can. J. Bot.* 64: 3101-3112.
- Bräutigam S, Schuhwerk F. 2002.** *Hieracium* L. Habichtskraut. In: Jäger, E.J. and Werner, K. (eds), Rothmaler, Exkursionsflora von Deutschland 4. Gefäßpflanzen, Kritischer Band, 9. Auflage. Spektrum Akademischer Verlag, Heidelberg and Berlin, pp. 709-734.
- Castro MM, Leitão-Filho HF, Monteiro WR. 1997.** Utilização de estruturas secretoras na identificação dos gêneros de Asteraceae de uma vegetação de cerrado. *Rev. Brasil. Bot.* 20: 163-174.
- Chisoe WF, Skvarla JJ. 1974.** Sucrose density pads for concentration and purification of pollen grains. *Stain Technol* 49: 123-124.
- Chisoe WF, Skvarla JJ. 1996.** Combining sputter coating with OTOTO treatment to eliminate charging artifacts in pollen preparations. *Proc. Okla. Acad. Sci.* 78: 83-85.
- Chisoe WF, Vezey EL, Skvarla JJ. 1995.** The use of osmiumthiocarbohydrazide for structural stabilization and enhancement of secondary electron images in scanning electron microscopy of pollen. *Grana* 34: 317-324.
- Erdtman G. 1960.** The acetolysis method. A revised description. *Svensk Botanisk. Tidskrift* 54: 561-564.
- Fernald ML. 1950.** Gray's Manual of Botany. A Handbook of the Flowering Plants and Ferns of the Central and Northeastern United States and Adjacent Canada, Eighth (Centennial) Edition Illustrated, American Book Company, New York.
- Font Quer P. 1979.** Diccionario de Botánica. Barcelona: Labor.
- Gottschlich G. 1996.** *Hieracium*. In: Sebold, O., Seybold, S., Philippi, G., Wörz, A. (Eds.), Die Farn- und Blütenpflanzen Baden-Württembergs, Band 6: Teil (Spermatophyta, Asteridae) Valerianaceae bis Asteraceae. Verlag Eugen Ulmer, Stuttgart, 393-535.
- Gustaffson A. 1946-1947.** Apomixis in higher plants I-III. *Acta Univ. Lund. N.S.* 42: 1-67; 43: 69-179; 43: 181-371.
- Hunter G. 1991.** The distribution of Hawkweeds (*Hieracium*) in the South Island, indicating a problem status. *J NZ Mountain Lands Inst.* 48: 1-10.
- Johansson K, Samuelsson G. 1920.** Hieraciumfloran in Västmanland. *Ark. Bot.* 16 no. 14.
- Krahulcová A, Krahulec F, Chapman HM. 2000.** Variation in *Hieracium* subgen. *Pilosella* (Asteraceae): What do we know about its sources? *Folia Geobot.* 35: 319-338.
- McNeill J, Barrie FR, Burdet HM, Demoulin V, Hawksworth DL, Marhold K, Nicolson DH, Prado J, Silva PC, Skog JE, Wiersema JH, Turland NJ. 2005.** International Code of Botanical Nomenclature (Vienna Code) adopted by the Seventeenth International Botanical Congress Vienna, Austria, July 2005. *Regnum Vegetabile.* 146 A.R.G. Gantner Verlag KG. ISBN 0080-0694.
- Meinder H, Mansfield TA. 1968.** Physiology of Stomata. McGraw-Hill, London.
- Merxmüller H. 1975.** Diploide *Hieracien*. *Anales Inst. Bot. Cavanilles.* 32: 189-196.
- Metcalf CR, Chalk L. 1950.** Anatomy of the Dicotyledons: Leaves, Stem, and Wood in Relation to Taxonomy with Notes on Economic Uses. V.2. Clarendon Press, Oxford.

- Mráz P. 2001.** Chromosome numbers in selected species of *Hieracium* sec. *Alpina* (Asteraceae) from Central and Eastern Europe. *Folia Geobotanica*. 36: 321-332.
- Nägeli C, Peter A. 1885.** Die Hieracien Mitteleuropas. Monographische Bearbeitung der Piloselloiden mit besonderer Berücksichtigung der mitteleuropäischen Sippen. München.
- Peter A. 1881.** Vortrag über einige rotblühende Hieracien. *Flora*. 64: 123-126.
- Petrović SD, Gorunović MS, Wray V, Merfort I. 1999.** A taraxasterol derivative and phenolic compounds from *Hieracium gymnocephalum*. *Phytochemistry*. 50: 293-296.
- Robinson H. 1987a.** Studies of the *Lepidaploa* complex (*Vernonieae*: Asteraceae): 1. The genus *Stenocephalum* Sch. Bip. *Proc. Biol. Soc. Wash.* 100: 578-583.
- Robinson H. 1987b.** Studies in the *Lepidaploa* complex (*Vernonieae*: Asteraceae): II. A new genus, *Echinocoryne*. *Proc. Biol. Soc. Wash.* 100: 584-589.
- Robinson H. 1987c.** Studies of the *Lepidaploa* complex (*Vernonieae*: Asteraceae): III. Two new genera, *Cyrtocymura* and *Eirmocephala*. *Proc. Biol. Soc. Wash.* 100: 844-855.
- Robinson H. 1988a.** Studies of the *Lepidaploa* complex (*Vernonieae*: Asteraceae): IV. The new genus, *Lessingianthus*. *Proc. Biol. Soc. Wash.* 101: 929-951.
- Robinson H. 1988b.** Studies of the *Lepidaploa* complex (*Vernonieae*: Asteraceae): V. The new genus *Chrysolaena*. *Proc. Biol. Soc. Wash.* 101: 952-958.
- Robinson H. 1988c.** Studies of the *Lepidaploa* complex (*Vernonieae*: Asteraceae): VI. A new genus *Aynia*. *Proc. Biol. Soc. Wash.* 101: 959-965.
- Robinson H. 1988d.** A new combination for *Vernonia libertadensis* S. B. Jones, with notes and descriptions of additional Andean species of *Baccharis*. *Phytologia* 65: 34-46.
- Robinson H. 1990.** Studies of the *Lepidaploa* complex (*Vernonieae*: Asteraceae): VII. The genus *Lepidaploa*. *Proc. Biol. Soc. Wash.* 103: 464-498.
- Robinson H. 1992a.** The Asteraceae of the Guianas: III. *Vernonieae* and the restoration of the genus *Xiphochaeta*. *Rhodora*. 94: 348-361.
- Robinson H. 1992b.** *Mesanthophora*, a new genus of *Vernonieae* (Asteraceae) from Paraguay. *Novon.* 2: 169-172.
- Robinson H. 1999a.** Generic and subtribal classification of American *Vernonieae*. *Smithson. Contrib. Bot.* 89: 1-116.
- Robinson H. 1999b.** Revisions and ? palaeotropical *Vernonieae* (Asteraceae). *Proc. Biol. Soc. Wash.* 112: 220-247.
- Rose AB, Basher LR, Wiser SK, Platt KH, Lynn IH. 1998.** Factors predisposing short-tussock grasslands to *Hieracium* invasion in Marlborough, New Zealand. *NZ J Ecol.* 22: 121-140.
- Royal Botanic Gardens Kew. 1993.** Index Kewensis on Compact Disc. Oxford University Press, Oxford.
- Sajo MG, Menezes NL. 1994.** Considerações sobre a anatomia foliar de espécies de *Vernonia* Scrib. (Compositae) da Serra do Cipó, MG. *Naturalia*. 19: 161-172.
- Schuhwerk F. 1996.** Published chromosome counts in *Hieracium*. Available from <<http://www.botanik.biologie.uni-muenchen.de/botsamml/projects/chrzlit.html>>.
- Sell PD, West C. 1975.** *Hieracium* L. In: Davis PH, Matthews VA, Kupicha FK, Parris BS, eds. *Flora of Turkey and the East Aegean Islands* 5. Edinburgh: Edinburgh University Press, 696-746.

- Sell PD, West C. 1976.** *Hieracium* L. In: Tutin TG, Heywood VH, Burgess NA, Moore DM, Valentine DH, Walters SM, Webb DA, (eds) Flora Europaea, Vol. 4, Plantaginaceae to Compositae (and Rubiaceae). Cambridge University Press: Cambridge, pp. 358-410.
- Sennikov AN. 2002.** Bibliographic catalogue of *Hieracium* and *Pilosella* names published by Finnish authors. *Norrinia*. 9: 1-109.
- Sennikov AN. 2003.** Typification of some *Hieracium* (Asteraceae) names published by Swedish authors. *Ann. Bot. Fennici*. 40: 219-231.
- Sennikov AN. 2008.** A taxonomic and nomenclatural note on *Hieracium caesium* (Asteraceae). *Nordic Journal of Botany*. 23(3): 305-313.
- Skvarla JJ, Rowley JR, Chisoe WF. 1988.** Adaptability of scanning electron microscopy to studies of pollen morphology. *Aliso*. 12: 119-175.
- Stearn WT. 1973.** *Botanical Latin*. London: David and Charles.
- Steetz J. 1864.** Crystallopollen und Ambassa. In: Peters, C. (ed.), *Naturwissenschaftliche Reise nach Mossambique auf Befehl seiner Majestät des Königs Friedrich Wilhelm IV, Part 6*. *Botanik*. 2: 363-364.
- Stix E. 1960.** Pollen morphologische Untersuchungen an Compositen. *Grana Palynol*. 2: 41-104.
- Švehliková V, Mráz P, Piacente S, Marhold K. 2002.** Chemotaxonomic significance of flavonoids and phenolic acids in the *Hieracium rohacsense* group (*Hieracium* sect. *Alpina*; Lactuceae, Compositae). *Biochememical Systematics and Ecology*. 30: 1037-1049.
- Tyler T. 2000.** Lectotypification of names of South Swedish *Hieracium* species (Asteraceae). *Nordic Journal of Botany*. 20: 93-103.
- Tyler T. 2002a.** Östergötlands skogsfibblor. *Bot. Notiser*. 135(2): 1-52.
- Tyler T. 2002b.** Gotlands hag-och skogsfibblor. *Rindi*. 22(2-3): 47-90.
- Tyler T. 2003.** Östergötlands hagfibblor. *Bot. Notiser*. 136(2): 1-36.
- Tyler T. 2004.** Lectotypifications of names of species of *Hieracium* known from the Swedish provinces Gotland and Östergötland. *Ann. Bot. Fennici*. 41: 79-83.
- Tyler T. 2005a.** New species and combinations in *Hieracium* (Asteraceae) from Southern Sweden. *Ann. Bot. Fenn.* 42: 399-403.
- Tyler T. 2005b.** Hökfibblor in Mälardalskapen. *Daphne* 16: 2-103.
- Tyler T. 2006.** Lectotypification of names of *Hieracium* sect. *Hieracium* and sect. *Vulgata* based on material from Southern Sweden. *Compositae Newslett*. 44: 38-57.
- Tyler T. 2007.** On *Hieracium incurrens* (Asteraceae) and similar species in Central Sweden. *Nordic Journal of Botany*. 25: 152-160.
- Tyler T. 2008.** On *Hieracium incurrens* (Asteraceae) and similar species in Central Sweden. *Nordic Journal of Botany*. 25(3-4): 152-160.
- Wilson LM, Callihan RH. 1999.** Meadow and orange hawkweed. In: Sheley, R.L., Petroff, J.K. (eds.), *Biology and Management of Noxious Rangeland Weeds*. Oregon State University Press. Corvallis, 238-248.
- Wodehouse RP. 1928.** Phylogenetic value of pollen characters. *Ann. Bot.* 42: 891-934.
- Wodehouse RP. 1935.** *Pollen Grains*. McGraw-Hill, New York, 574.
- Zahn KH. 1921-23.** *Compositae-Hieracium*. In: Engler A. (ed.) *Das Pflanzenreich*. IV: 1-576 (4.II.1921), 577-1146 (18.X.1921), 1147-1705

(27.II.1923).Verlag von Wilhelm Engelmann,
Leipzig.

Zahn KH. 1927. Beiträge zur Kenntnis der
Hieracien Ungarns und der Balkanländer VII.
Magyar Bot. Lapok. 25(1926): 283-394.

Zahn KH. 1930-39. *Hieracium*. In: Graebner P.F.
(ed.), Synopsis der mitteleuropäischen Flora,
XII/1-3 + Registerband, Leipzig.

Recibido: 14 Setiembre, 2009.

Aceptado: 26 Noviembre, 2009.

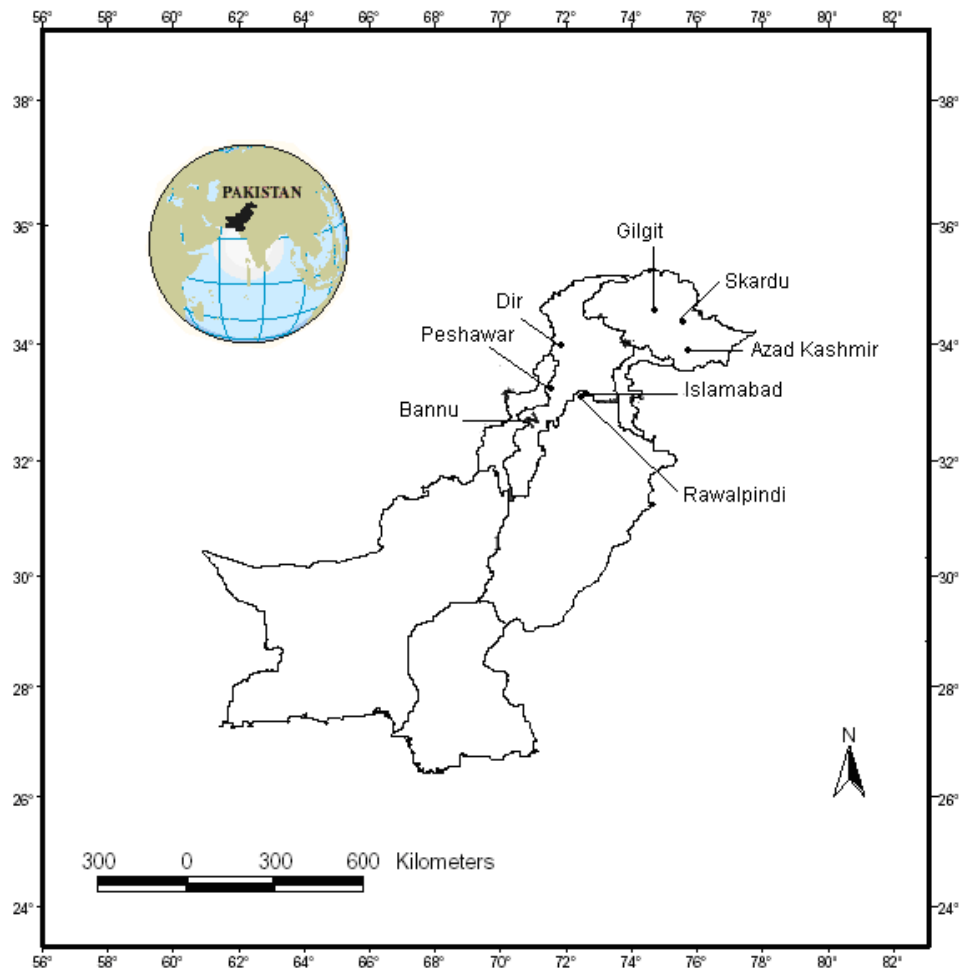


Figure 1. Location of *Hieracium* sampling sites from Pakistan.



Figures 2-4. 2. *Hieracium bichlorophyllum*; 3. *H. diaphanoides*; 4. *H. umbellatum*.

5



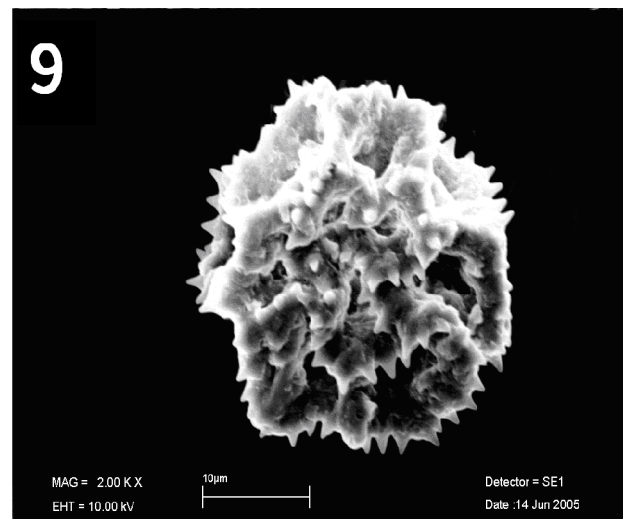
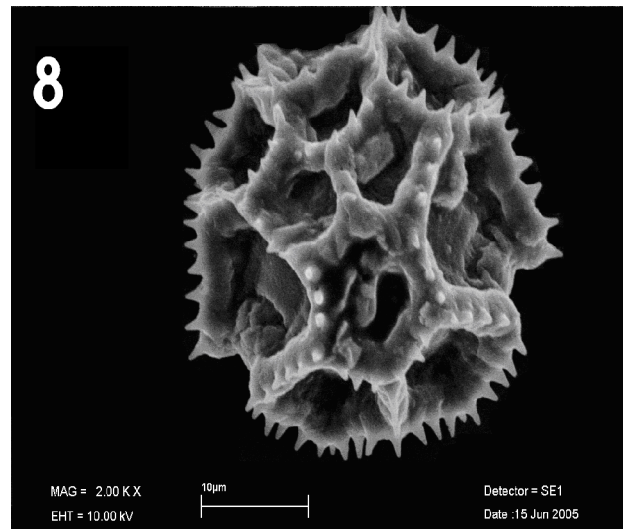
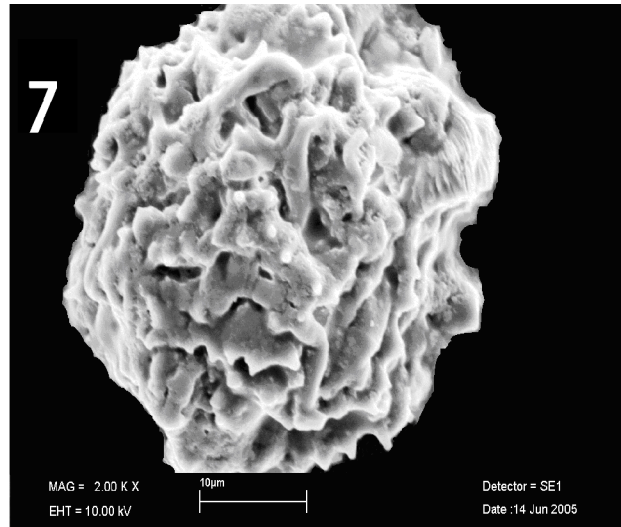
HERBARIUM OF PAKISTAN
ISLAMABAD UNIVERSITY
No. 1901 Date 29.7.1977
Name: *Hieracium virosum* Pall.
Family: Compositae
Locality: Gharche Sallah Alt. 1500m
District: Swat Province: North West
Remarks: Herb. hairy, fls. yellow, rose
seed. rocky
Collected by Mir. Syed A. M. Syed
Determined by: Ravinder Kaur

6

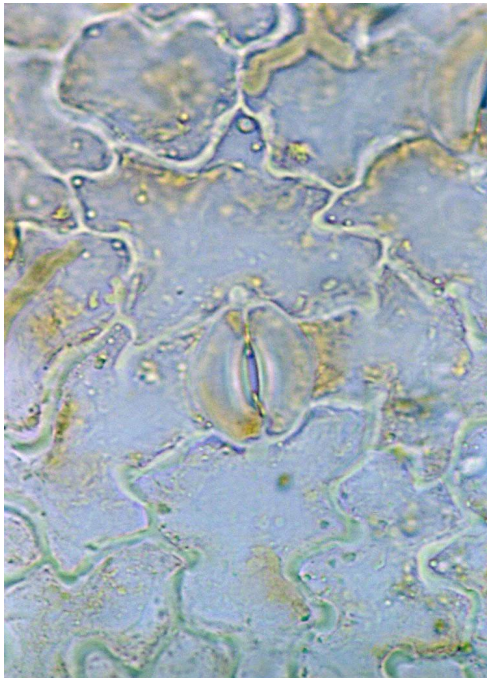


HERBARIUM OF PAKISTAN
ISLAMABAD UNIVERSITY
No. 987 Date 19.8.1976
Name: *Hieracium vulgatum* Koch
Family: Compositae Base.
Locality: Swat Alt. 4500
District: Hazara Province: NWFP
Remarks:
Collected by: Shaukat and Nisar
Determined by: Miss Tanzeel Anjum

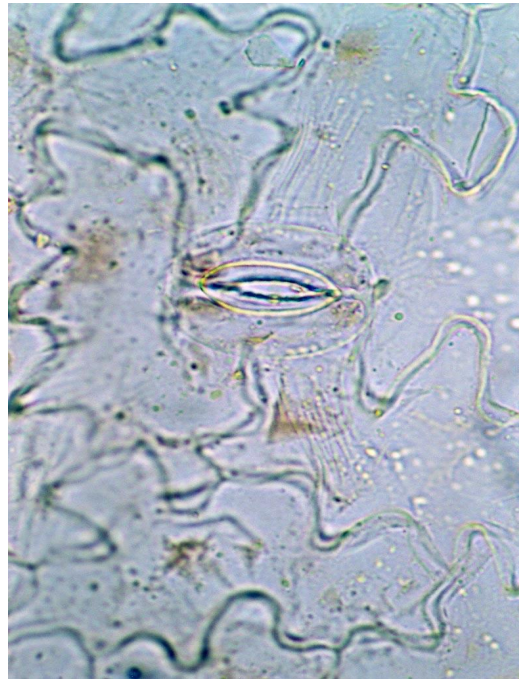
Figures 5-6. **5.** *H. virosum*; **6.** *H. vulgatum*.



Figures 7-9. Scanning Electron Micrographs (SEM) of pollen grains of *Hieracium* species of Pakistan. 7. *H. bichlorophyllum*, equatorial view; 8. *H. diaphanoides*, polar view; 9. *H. virosum*, subpolar view.



10



11



12

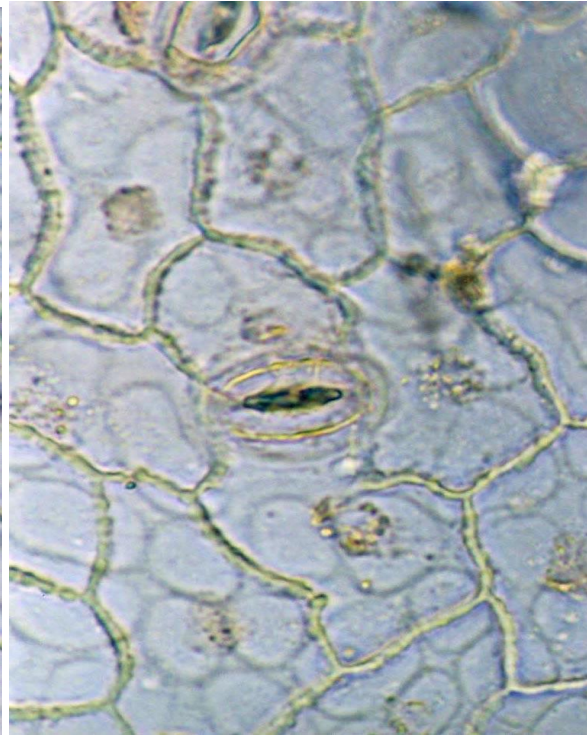


13

Figures 10-11. *Hieracium bichlorophyllum* **10**. Adaxial side at 40X; **11**. Abaxial side at 40X.
Figures 12-13. *Hieracium diaphanoides* **12**. Adaxial side at 40X; **13**. Abaxial side at 40X.



14



15

Figures 14-15. *Hieracium umbellatum* **14.** Adaxial side at 40X; **15.** Adaxial side at 40X.

Table 1. Differences between related species of *Hieracium*.

Character	<i>Hieracium bichlorophyllum</i>	<i>H. diaphanoides</i>	<i>H. umbellatum</i>	<i>H. virosum</i>	<i>H. vulgatum</i>
Habit	Perennial	Perennial	Perennial	Perennial	Perennial
Height of plant	25-50 cm	26-50 cm	30-100 cm	50-150 cm	60-100 cm
Stem Surface	Scabrous hairs	With numerous stellate and few simple eglandular hairs	Glabrous or sparsely echinulate & stellate hairs	Apically glabrous & basally hirsute	Stellate hairs
Basal leaves	Sessile	Sessile	Absent	Absent	Subsessile
Basal leaf blade	Ovate-lanceolate to oblong	Oblong	Absent at anthesis	Absent at anthesis	Elliptic-lanceolate to ovate-lanceolate
Middle stem leaves	Lanceolate to oblanceolate	Oblong	Lanceolate	Ovate-lanceolate to elliptic lanceolate	Elliptic-lanceolate to ovate-lanceolate
Upper stem leaves	Oblanceolate	Linear-lanceolate	Lanceolate	Ovate-lanceolate to elliptic lanceolate	Ovate-lanceolate
Phyllaries	2 rows	2 rows	3 rows	4 rows	2 rows
Outer phyllaries	Lanceolate	Oblanceolate	Lanceolate	Lanceolate to broadly linear	Linear lanceolate
Middle phyllaries	Absent	Absent	Lanceolate-linear	Lanceolate	Absent
Inner phyllaries	Oblanceolate	Oblanceolate	Linear-elliptic	Lanceolate	Lanceolate
Inflorescence	Corymbose	Corymbose	Corymbose	Corymbose to Paniculate	Corymbose
Achene	Columnar	Columnar	Columnar	Columnar	Columnar
Size of Achene (L X W)	0.3 x 0.1 mm	0.3 x 0.1 mm	3 x 1 mm	3 x 1 mm	3 x 1.2 mm
No. of ribs on each face	8 ribs	6 ribs	10 ribs	10 ribs	10 ribs
Achene beak	Beakless	Beakless	Beakless	Beakless	Beakless
Pappus	Persistent	Deciduous	Persistent	Persistent	Deciduous
Size of Pappus	4 mm long	0.3 mm long	6 mm long	6 mm long	5 mm long

Table 2. Measurements of equatorial diameter, polar diameter, P/E ratio, exine thickness, spine length, spine rows, shape and sculpturing features of pollen grains of *Hieracium* species of tribe Lactuceae.

Taxon	Equatorial Diameter (µm)	Polar Diameter (µm)	P/E	Exine Thickness (µm)	Spine Length (µm)	Number of Spine rows b/w colpi	Shape in polar view	Shape in Equatorial view	Aperture type	Pollen Class	Sculpturing
<i>H. bichlorophyllum</i>	20-26.5 22.9±1.1	16.5-22 18.5±0.9	0.8	2.2-3.7 3.1±0.2	Spines absent	Spines absent	Semiangular	Spheroidal	Lacunate	Trizonocolporate	Scabrate
<i>H. diaphanoides</i>	32-36 34±0.6	31-35 33±0.6	1.0	5-8 6.6±0.5	5-7 6.2±0.3	5-7 6.2±0.3	Semicircular	Spheroidal	Nonlacumate	Trizonocolporate	Echinate
<i>H. umbellatum</i>	16-28 21.2±2.2	17-27 21.6±1.6	1.0	1.6-3.8 2.6±0.4	Spines absent	Spines absent	Semicircular	Prolate - spheroidal	Nonlacumate	Tetrazonocolporate	Scabrate
<i>H. viosum</i>	26-31 29.1±0.8	26-31.4 28.5±0.8	1.0	2.8-5 3.7±0.4	5-12 8.4±1.2	5-12 8.4±1.2	Semiangular	Spheroidal	Nonlacumate	Tetrazonocolporate	Echinate
<i>H. vulgatum</i>	15-32.4 22.1±2.8	17-19.6 18.4±0.4	0.8	2.6-4.7 3.3±0.3	Spines absent	Spines absent	Semiangular	spheroidal, perprolate to spheroidal	Nonlacumate	Tetrazonocolporate	Scabrate

Table 3. Percentage of different types of stomata, and epidermal cells in the upper (U.E.) and lower (L.E.) epidermis of *Hieracium*.

Name	Type of Cell Wall		Type of Stomata		% of Each Type		No. of Stomata /mm ²		No. of Epidermal cell/mm ²	
	U.E.	L.E.	U.E.	L.E.	U.E.	L.E.	U.E.	L.E.	U.E.	L.E.
<i>H. bichlorophyllum</i>	Undulate	Undulate	Staurocytic	Staurocytic	100	100	8	7	39	32
<i>H. diaphanoides</i>	Undulate	Undulate	Staurocytic	Staurocytic	100	100	4	5	34	45
<i>H. umbellatum</i>	Undulate	Straight, Tubular, Angular	Staurocytic	Amphianisocytic	100	100	12	5	37	43
<i>H. viosum</i>	Undulate	Undulate	Staurocytic	Absent	100	Absent	7	Absent	36	34
<i>H. vulgatum</i>	Undulate	Undulate	Staurocytic	Staurocytic	100	100	5	6	32	34

Table 4. Dimension and state of epidermal cell, stomatal complex and percentage of open and close stomata of *Hieracium* species.

Name	Size of Epidermal Cell (µm)		Size of Stomatal Complex (µm)		% of Open Stomata		% of Close Stomata		Crystals		Length of Trichomes (µm)		Base of Trichomes (µm)	
	U.E.	L.E.	U.E.	L.E.	U.E.	L.E.	U.E.	L.E.	U.E.	L.E.	U.E.	L.E.	U.E.	L.E.
<i>H. bichlorophyllum</i>	34-89 61±8.8	36-102 73.4±10.8	84-132 111.2±7.6	78-98 88.6±3.3	55.17	41.93	44.82	+	Absent	Absent	Absent	Absent	Absent	Absent
<i>H. diaphanoides</i>	78-163 116.2±13.2	63-157 113±15.6	134-261 184±19.3	69-224 143.4±26.3	85.7	51.72	48.27	+	+	Absent	Absent	Absent	Absent	Absent
<i>H. umbellatum</i>	63-204 142.4±24.5	48-124 84.8±11.7	132-184 159.4±8.5	81-109 96.8±4.3	71.4	28.5	22.2	+	+	Absent	Absent	Absent	Absent	Absent
<i>H. viosum</i>	65-128 99±9.7	46-112 78.8±10.3	96-134 117±6.6	Absent	85.7	Absent	Absent	+	+	Absent	Absent	Absent	Absent	Absent
<i>H. vulgatum</i>	32-113 73.2±13	23-106 66.6±13.7	68-94 82.2±4.1	98-146 123.6±8.3	54.16	45.83	41.9	+	+	Absent	Absent	Absent	Absent	Absent

U.E. = Upper Epidermis L.E. = Lower Epidermis ± Standard Error

Table 5. Dimension and state of stomatal complex of *Hieracium* species.

Name	Length of Guard Cell (μm)		Width of guard Cell (μm)		Length of Stomatal Pore (μm)		Width of Stomatal Pore (μm)		Size of Microhairs (μm)	
	U.E.	L.E.	U.E.	L.E.	U.E.	L.E.	U.E.	L.E.	U.E.	L.E.
<i>H. bichlorophyllum</i>	31	28	14	11	16	19	2	4	Absent	Absent
<i>H. diaphanoides</i>	36	36	14	21	21	24	6	2	Absent	Absent
<i>H. umbellatum</i>	31	34	12	11	22	21	3	2	Absent	Absent
<i>H. virosum</i>	24	Absent	11	Absent	21	Absent	2	Absent	Absent	Absent
<i>H. vulgatum</i>	23	26	12	9	19	18	2	3	Absent	Absent

U.E. = Upper Epidermis L.E. = Lower Epidermis