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Morphological studies of *Pedicularis* L. from Hazara Division, Pakistan

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Abstract

Pedicularis L. belongs to Scrophulariaceae, one of the largest genera of angiosperm with 800 species. This genus is distributed in the moist Northern Hemisphere including the Himalayan region. In current study, this genus has been morphologically revised from Hazara division, in the province of Khyber Pakhtunkhwa, Pakistan. Frequent field visits were conducted from the month of June till September. Plant samples were collected and properly identified and voucher specimens were deposited in the Hazara University Herbarium Pakistan (HUP). Eleven species are recognized from the area of study, mostly confined to mountainous areas at high altitudes between 2000m to 4000m. Habit-wise, of these, one was annual and ten were perennial herbs.

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Introduction

The hemiparasitic genus *Pedicularis* L. belongs to the family Scrophulariaceae. This genus is one of large genera of flowering plants with 800 species (Mill, 2001) Habitat-wise, members of the *Pedicularis* are mostly found in the moist Northern Hemisphere (Yang *et al.*, 1998). The highest diversity is in eastern Asia, and 364 species reported from China alone (Yu *et al.*, 2011). Infrageneric classification of *Pedicularis* has been proposed by many taxonomists based on morphology of corolla, as it exhibits maximum variation among species especially in the shape of upper corolla lip (galea) and the length of corolla tube. Species may be divided into four different corolla shapes viz., (i) galea beakless and a toothless with short corolla tube, (ii) galea toothed with a short corolla tube, (iii) galea beaked with a short corolla tube, and (iv) galea beaked with a long corolla tube (Ree, 2005). Li (1948, 1949) proposed his classification based on leaf characters and general habit, as these characters are more prominent to classify the genus, instead of corolla forms. While, Tsoong (1955) suggested that both phyllotaxy and corolla characters should be used in the infra-generic classification. Classification of *Pedicularis* is important not only from taxonomic point of view but also from pharmacognostic point of view as the plant contains many important constituents, like phenols, flavonoids, iridoids and alkaloids, etc. (Yatoo *et al.*, 2017). Stewart (1972).

Reported 31 species and 7 sub-species of *Pedicularis* from Pakistan and Kashmir, while 15 species have been reported from Hazara division. Edinburgh *et al.*, (2015) reported 32 species for the Flora of Pakistan distributed in 15 series of *Pedicularis*, while 16 species have also been documented for Hazara division.

Hazara is the part of Khyber Pakhtunkhwa (KP) province of Pakistan. It lies between 33°-44' and 35°-35' North latitude and 72°-45' and 73°-75' East longitude, bounded on the North and East by the Gigit and Kashmir, to the South are the Islamabad (Capital Territory) and the province of Punjab, whilst to the West lays the rest of K.P. The river Indus runs through the division in a north-south line, forming much of the western border of the division. The total area of Hazara is 18,013 km², including agricultural, industrial, wasteland, forest and alpine range (Meyer, *et al.* 1908; Fig. 1). Altitudes range from 1100 feet on the Indus River near Tarbela to more than 15,000 feet at Alai, Battagram district. Hazara is mostly mountainous, mountain ranges (mostly Himalayan) spreading from north-east to south-west, Some prominent plain areas are Pakhli, Mangal, Rash, Haripur and Khanpur, mainly located in Haripur and Mansehra districts (Majid, 2015). Climate varies with altitude, (from 1100 ft. at plains to 16000 ft. at mountain top). Other factors may be rainfall, snowfall and temperature. Hazara is the wettest part of Pakistan because it lies immediately south of the main Himalaya Range, and is exposed to moist winds from the Arabian Sea. Amount of rainfall increases along elevation especially within the moist part of Hazara. Due to its location, Hazara has a bimodal rainfall regime, with one peak in February or March and another monsoonal peak in July and August. The driest months are October to December. Due to the high altitude, temperatures in Hazara are cooler than on the plains, with high temperature around 41°C and high humidity in June and July. In winter, temperatures are cold, with minima in January around 0°C and much lower in the high mountains. Snowfalls are common even at lower levels. In the wet temperate forests winter accumulation of snow may be up to 7 meters or more (Hussain and Ilahi, 1991). Vegetation of Hazara varies within the region. Dry subtropical sub-mountainous vegetation is found in Garhi-Habibullah, Terbela, Khanpur and foothills of Kaghan valley. Dry temperate forests are found in Kohistan. Moist temperate forests are present in Galiat and Shogran. Alpine and sub-alpine vegetation is found in upper Kaghan valley and Kohistan (Hussain, 1992).

As no taxonomical research work has been done so far for members of this genus from Hazara, Therefore, the current study was carried out to gather taxonomic attributes of the species belonging to genus

Pedicularis, occurring in the study area underconsideration.

Materials and methods

This study was conducted in the following phases:

Literature review

As a first step different relevant literatures were studied in order to gather information regarding the habit and habitat of different plants belonging to family Scrophulariaceae. For this purpose different floras were consulted and herbaria were visited to obtain information regarding distribution of different taxa with their altitudinal ranges.

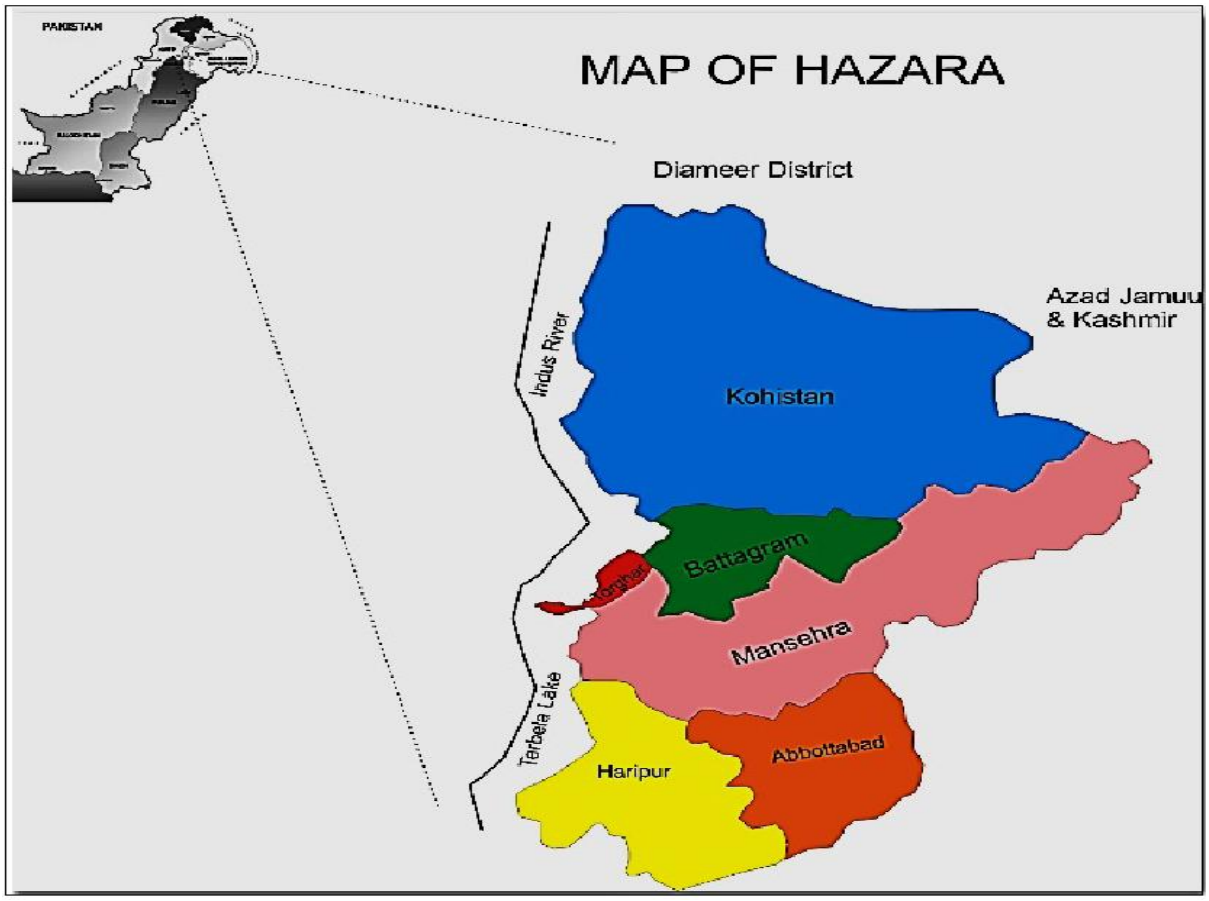

Fig. 1. Location Map of Hazara Division.

Planning

In the light of information gathered through literature review, study trips were scheduled to all parts of the region according to the blooming periods of the plants. The first trip was made in the last week of June, 2015. Further trips were made at an interval of 15-20 days, till September, 2017.

Field visits and Material Collection

Plant specimens with mature flowers were collected, properly pressed, dried and mounted on herbarium sheets. Voucher specimens of each plant were collected along with reproductive and vegetative parts. All information was recorded in the "Field Notebook". The plant specimens were identified by comparing it with already identified specimens in the herbarium or going through available literature, especially with Flora of Pakistan, family Scrophulariaceae (Edinburgh *et al.*, 2015). List of the collected species, taxonomically studied is presented as Table-I. Plants mounted on the Herbarium sheets and were deposited in the herbarium of Hazara University, Mansehra.

Photography

Pictures of plants belonging to genus *Pedicularis*

from Hazara division were taken with Canon 16.0 MP digital camera, and USB digital microscope, and are reproduced here.

Deposition of Voucher Specimens

At the end of research work, collected plant material was deposited in the Herbarium Hazara University Pakistan (HUP) for future records.

Results

About 15 specimens were collected from the study area. Based on these specimens, 11 species were recognized, found in mountainous areas. Morphology of these species is described here. Description, diagnostic keys and distribution of each species has been provided.

Pedicularis Linnaeus, Sp. Pl. 2: 607. 1753.

Plants are perennial or annual herbs. Stem is erect or ascending, usually unbranched, rarely branched. Radical leaves are often in cluster. Cauline leaves are alternate, opposite or whorled, petiolate, pinnately segmented. Inflorescence is usually racemose, many flowered, and flowers are pedicellate, having leaf like bracts. Calyx may be campanulate or tubular, bilabiate or 5 toothed, often with a deep anterior cleft. Corolla is purple, pink, white or yellow, bilabiate, upper lip (galea) hooded, enclosing stamens, bent at right angle and usually curved or coiled to form a beak, lower lip 3-lobed (labellum), spreading. Stamens 4, didynamous, filaments long, hairy or glabrous, anthers usually present at middle part of galea. Style long, emerging from galea, stigma capitate. Capsule lanceolate to ovoid, apex acute to acuminate, glabrous, seeds numerous, coat striate.11 species are found to occur in area of study.

Table 1. Checklist of Documented Species form along various parameters.

S. No	Specimen Name	Voucher No.	Locality	District	Flowering period	Fruiting period
1	*Pedicularis bicornuta* Klotzsch var. *bicornuta*	45(HUP)	Burawai	Mansehra	July- September	September-October
2	*Pedicularis gracilis* subsp. *stricta* (Prain) Tsoong	46(HUP)	Ayubia	Abbottabad	July- September	September-October
3	*Pedicularis kashmiriana* Pennell	38(HUP)	Battakundi	Mansehra	July- September	September-October
4	*Pedicularis multiflora* Pennell	51(HUP)	Battakundi	Mansehra	July- September	September-October
5	*Pedicularis murreeana* R. R. Mill	10(HUP)	Jhaffar	Abbottabad	July- September	September-October
6	*Pedicularis pectinata* subsp. *palans* Prain	54(HUP)	Dunga-gali	Abbottabad	July- September	September-October
7	*Pedicularis punctata* Decne.	34(HUP)	Sri	Mansehra	July- September	September-October
8	*Pedicularis pyramidata* Royle ex Benth.	53(HUP)	Lalazar	Mansehra	July- September	September-October
9	*Pedicularis roylei* Maxim.	43(HUP)	Babusar Top	Mansehra	July- September	August-September
10	*Pedicularis staintonii* R. R. Mill	56(HUP)	Lulusar lake	Mansehra	July- September	September-October
11	*Pedicularis stewartii* Pennell	57(HUP)	Thandiani	Abbottabad	July- September	September-October

Key to species

1 + Cauline leaves alternate.....2

- Cauline leaves opposite or whorled.....3

2 + Corolla yellow, galea inconspicuous, hidden by enlarged lateral lobes of lower lip.....1. *Pedicularis bicornuta*

- Corolla pink with white centre, galea conspicuous, in the form of coiled beak..... 7. *Pedicularis punctate*

3 + Galea of corolla beakless.....9. *Pedicularis roylei* - Galea with a prominent beak.....4

4+ Plants annuals.....2. *Pedicularis gracilis*

- Plants perennials.....5

5 + Cauline leaves opposite; galea beak more than

12mm long.....8. *Pedicularis pyramidata*
- Cauline leaves opposite and whorled; galea beak less than 12mm long.....6
6 + Cauline leaves opposite and in whorls of 3.....7
- Cauline leaves opposite and in whorls of 4.....9
7 + Calyx 4-lobed.....4. *Pedicularis multiflora*
- Calyx 5-lobed.....8
8 + Gale beak twisted downwards and inwards; calyx with prominent anterior cleft.....5. *Pedicularis murreeana*
- Gale beak twisted downwards and outwards; calyx with no anterior cleft.....6. *Pedicularis pectinata*
9 +Flowers in whorls of 2 in inflorescence; calyx with anterior cleft.....11. *Pedicularis stewartii*
-Flowers in whorls of 4 in inflorescence; calyx without anterior cleft.....10
10+Stem not swollen at nodes; calyx inflated; filaments hairy at distal ends only .....3. *Pedicularis kashmiriana* - Stem swollen at nodes; calyx not inflated; filaments hairy both at distal and proximal ends.....10. *Pedicularis staintonii*

Pedicularis bicornuta Klotzsch var. bicornuta Fig. 2-C

Perennial herbs, up to 20 cm tall, erect, unbranched. Cauline leaves alternate, petioles upto 2 cm long, hairy, lamina 6 cm, oblong, pilose, pinnately segmented, segments dentate.

Inflorescence many flowered, centrifugal. Pedicels hairy, 10 mm long. Bracts up to 35 mm long, linear-spathulate, margin crenate, hairy at distal end. Calyx 16 mm long, inflated, having deep anterior split, constricted at mouth, pale green, 5-toothed, teeth dentate, pilose at veins. Corolla 35 mm long, yellow, narrow tube 24 mm long, yellowish-white, pilose at upper part, lower lip 3-lobed, middle lobe rounded, lateral lobes almost covering galea and beak, margins of lobes ciliate, beak S-shaped, bifid at distal end, 2 halves are separated from each other. Anthers dorsifixed. Capsule 25 mm long, lanceolate-ovoid, straight on one side, apex acute, glabrous, seeds numerous, pale brown.

Pedicularis gracilis subsp. stricta (Prain) P. C. Tsoong Fig. 2-B

Annual herbs, 20-80 cm tall. Stem erect, quardangular, whitish hairy in lines along angles. Basal leaves usually deciduous. Cauline leaves in whorl of 3, lower ones petiolate, upto 15 mm long, upper ones sessile or subsessile, lamina ovate to ovate-oblong, upto 20 mm long, pinnatifid or pinnatisect, upto 7 pairs of segments, segments toothed, margin white callose. Inflorescence lax raceme, 2-4 pedicellate flowers in each whorl, arranged distantly. Bracts leaf like, 12 mm, glabrous, margin dentate, with whitish callose. Calyx cylindrical, slightly curved, 6 mm long, 5-lobed, pale green, margins ciliate. Corolla 18 mm, magenta, glabrous, tube white, longer than calyx, galea bent at 90° at point of anther pouch, beak straight, 9 mm long, bifid at tip. Stigma globose, protruding out of beak. Capsule ovoid, 7 mm long, seeds not seen.

Pedicularis kashmiriana Pennell. Fig. 3-B & 3-F

Perennial herbs, upto 100 cm tall. Stem erect, 1 to many, quardangular, hairy in lines along angles. Basal leaves with long petioles, usually deciduous. Cauline leaves opposite or in whorls of 4, upto 15 cm long, petioles winged, lamina pinnatsect, 9-12 pairs of segments, segments dentate, margin white callose, rachis winged. Inflorescence terminal upto 25 cm long, many flowered, 4 flowers in each whorl, axis whitish hairy, flowers sessile. Bracts lanceolate, 12 mm long, margin ciliate, dentate, apex violet. Calyx 10 mm, ovoid, 5-lobed, greenish mauve with darker ribs, hairy at veins, inflated in older flowers. Corolla pink, 30 mm long, lower lip 3-lobed, beak darker than galea, coiled like a question mark, 10 mm long. Filaments long, hairy at distal end. Capsule 10 mm long, ellipsoid, slightly shorter than calyx, blackish, apex acute, seeds 3.5 mm long, many, pale brown, surface reticulate.

Pedicularis multiflora Pennell. Fig. 2-E

Perennial herbs. Stem erect, upto 80 cm tall, quardangular, hairy in lines along angles. Basal leaves with long petioles, usually deciduous. Cauline leaves in whorls of 3, petioles upto 6 cm long, winged at

base, lamina upto 13 cm long, pinnatisect, 11-12 pairs of segments, segments dentate, margin white callose, rachis winged. Inflorescence spike or very shortly pedicellate, centripetal, 4 flowers in each whorl. Bracts 10 mm long, ovate-lanceolate, margin entire. Calyx upto 9 mm long, 4-lobed, light green tinged violet, with darker ribs, having 10 veins, hairy at veins, slight anterior cleft. Corolla 20 mm long, rose-pink, lower lip 3-lobed, beak is darker than rest of corolla, upto 9 mm long, coiled. Filaments long, hairy at distal end. Capsule 10 mm long, ellipsoid, slightly shorter than calyx, seeds many, 3.5 mm long, pale brown, oblong, surface reticulate.

Fig. 2. A, *Pedicularis pectinata* subsp. *palans;* B, *P. gracilis* subsp. *stricta;* C, *P. bicornuta* var. *bicornuta;* D, *P. stewartii*; E, *P. multiflora*; F, *P. pyramidata.*

Pedicularis murreeana R. R. Mill. Fig. 3-A

Perennial herbs. Stem upto 70 cm tall, erect, branched, especially in area of inflorescence. Basal leaves with petioles upto 80 mm long, lamina 90 mm long, ovate, pinnatisect, segments pinnatipartite or dentate-lobed. Cauline leaves opposite in lower part of stem, in whorls of 3 in upper part, petiolate, lamina upto 70 mm long, pinnatisect, upto 16 pairs of segments, rachis winged. Inflorescence many flowered, 2-3 flowers in each whorl. Lower bracts lanceolate, longer than calyx, margin pinnatifid, while upper ones dentate, pilose at margins. Calyx 10 mm long, campanulate, having deep anterior split, pale green with darker ribs, 5-lobed, hairy at veins. Corolla

25 mm long, pink to mauve, tube white, beak darker than rest of corolla, less than 9 mm, coiled downwards and inwards. Filaments densely hairy at both ends while glabrous in between, anthers yellow. Capsule 10 mm, ovoid, slightly shorter than or equal to calyx, glabrous, seeds not seen.

Pedicularis pectinata subsp. palans (Prain) Pennell. Fig. 2-A

Perennial herbs. Stem upto 65 cm tall, erect to ascending, unbranched, quardangular. Basal leaves with long petioles, upto 15 cm, and lamina pinnatisect, segments dentate. Cauline leaves opposite or in whorls of 3, petiolate, lamina 6 cm long, pinnatisect, segments dentate. Inflorescence lax raceme, 2-3 flowers in each whorl. Bracts lanceolate, hairy along margins and mid-line. Calyx 12 mm long, campanulate, 5-lobed, light green tinged purple, with darker ribs, no anterior cleft. Corolla upto 35 mm long, rose-pink with purple galea, lower lip 3-lobed, spreading, middle lobe much smaller, beak less than 9 mm, twisted downwards and outwards like a hook. Filaments hairy, anthers basifixed. Capsule 9 mm long, ovoid, glabrous, dark brown, seeds not seen.

Fig. 3. A, *Pedicularis murreeana,* habit; *P. kashmiriana,* B, habit, F, seeds*;* C, *P. roylei,* habit; *P. punctata,* D, flower, E, capsule.

Pedicularis punctata Decne. Fig. 3-D & E

Perennial herb, upto 25 cm tall. Stem decumbent, usually unbranched. Basal leaves with petioles 20-40 mm long, lamina pinnatisect, upto 50 mm long, upto 6 pairs of segments, margin serrate, hairy. Cauline leaves petiolate, lamina oblong, pinnatisect, upto 5 pairs of segments.

Inflorescence terminal raceme. Pedicels very short. Bracts leaf like, upto 8 mm long. Calyx tubular, 7-10 mm long, light green, bilabiate, deep anterior cleft, densely hairy.

Corolla 25-35 mm long, magenta with white centre, tube magenta, 2-3 times the length of calyx, hairy, lateral lobes orbicular, middle lobe ciliate, galea white, beak 7-9 mm long, coiled and curved like a sickle, split deeply at apex, gland dotted, magenta. Filaments glabrous. Capsule asymmetrically ovoid, longer than calyx, 13-16 mm long, having reticulate lines on surface, seeds oblong, 2.5 mm long, surface reticulate.

Pedicularis pyramidata Royle in Benth. Fig. 2-F

Perennial herbs, stout roortstock. Stem upto 90 cm tall, erect, branched, fistular, sparsely hairy in upper part. Basal leaves with long petioles. Cauline leaves opposite, petioles almost equal to lamina, lamina upto 80 mm long, pinnatisect, segments dentate, rachis winged. Inflorescence terminal raceme, 4 flowers in each whorl, axis hairy. Bracts upto 20 mm long, lanceolate, margin entire, ciliate at base.

Calyx 5-lobed, light green, with darker ribs, hairy at veins, inflated in older flowers. Corolla upto 35 mm long, pink, lower lip 3-lobed, galea darker than rest of corolla, beak is 12 mm long, coiled in the shape of question mark. Filaments hairy at apex, anthers ovoid, basifixed. Capsule upto 15 mm long, ovoid, slightly longer than calyx, glabrous, dark brown, seeds 3 mm long, many, oblong, light brown, surface reticulate.

Pedicularis roylei Maxim. Fig. 3-C

Perennial herbs. Stem upto 8 cm tall, erect, 1 to many, hairy. Basal leaves having upto 25 mm long petioles, lamina upto 30 mm long, linear, bipinnatisect, hairy, 7-12 pairs of segments, margin dentate. Cauline leaves few, in whorls of 3, petiole upto 5 mm long, lamina upto 12 mm long, pinnatisect. Inflorescence terminal raceme, 4 flowers in each whorl, flowers sessile. Bracts leaf like, hairy, pinnatifid. Calyx 5 mm long, campanulate, 5-lobed, purplish green, lobes darker than tube, margins serrate, densely hairy at veins. Corolla upto 20 mm long, purple-pink, lower lip 3-lobed, almost equal, spreading, galea purple, beakless, having truncate apex, darker than rest of corolla. Filaments glabrous. Capsule 12 mm long, ellipsoid, glabrous, apex acute, seeds 1.5 mm long, many, oblong, pale brown, surface reticulate.

Pedicularis staintonii R. R. Mill

Perennial herbs, upto 50 cm tall, stem suberect, glabrous below, hairy above, stem nodes swollen. Basal leaves not persistent. Cauline leaves in whorls of 4, having upto 20 mm long petioles, lamina upto 80 mm long, pinnatisect, 6-12 pairs of segments, margin dentate, glabrous.

Inflorescence racemose, flowers in whorls of 4. Bracts upto 15 mm long, with crenate margins in lower flowers, entire margins in upper flowers, elliptic, sparsely hairy. Calyx upto 10 mm long, campanulate, not inflated, 5-toothed, teeth mucronate, pale green. Corolla pink, 30 mm long, lower lip longer than galea, beak upto 11 mm long, coiled like question mark. Filaments hairy at distal and proximal parts only. Capsule 12 mm long, ovoid, dark brown, seeds not seen.

Pedicularis stewartii Pennell. Fig. 2-D

Perennial herbs, upto 85 cm tall, stem several, branched, somewhat ascending, quadrangular, glabrous below, hairy in lines along ridges in region of inflorescence. Basal leaves not persistent. Cauline leaves in whorls of 4, petioles upto 20 mm long, lamina upto 90 mm long, ovate- lanceolate, pinnatipartite, upto 21 pairs of segments, lobed or deeply dentate. Inflorescence branched, terminal lax raceme, flowers in whorls of 2. Floral axis brownish in

colour, with short hairs along ridges of stem. Pedicels 1-2 mm long. Bracts upto 15 mm long, leaf like in lower flowers, pinnatipartite, with dentate to crenate margins in upper flowers, sparsely hairy. Calyx 10 mm long, ovoid, purplish with greenish ribs, 5-toothed, deep anterior cleft. Corolla 30 mm long, purplish pink, darker at beak and margins of lower lip, lighter at base, lower lip 3-lobed, middle lobe much smaller than laterals, beak 8 mm long, slightly coiled downwards. Filaments hairy at distal and proximal parts, glabrous in between. Capsule 12 mm long, ovoid, seeds not seen.

Discussion

In present study 11 species (including 2 new reports, i.e. *Pedicularis multiflora* and *P. staintonii,* from study area) of *Pedicularis* L. were reported from Hazara division. Plants were perennial (mostly) or annual (less common) herbs, found at high altitudes (mountainous in habitat). Stem usually quadrangular and leaves were pinnately segmented. Corolla was bilabiate, upper lip (galea) is hooded, enclosing 4 stamens, bent at right angle and usually curved or coiled to form a beak, lower lip (labellum) was spreading. Plants were classified on the basis of vegetative characters like stem and leaf, particularly Phyllotaxy, i.e., leaves might be alternately arranged or oppositely (in whorls of two) or in whorls of 3 or 4. Similarly floral characters, like, inflorescense, calyx character, corolla, especially the shape of galea, filaments character, etc.

were also found to be of diagnostic value in delimitation of species. Like, *Pedicularis punctata* was differentiated from its closely related species, *Pedicularis rhinanthoides* on the basis of shape of calyx, the later was not found in the area of study.

Similarly, anterior cleft in calyx also played important role in distinguishing different closely allied species. Husain and Garg (2003) described 2 subspecies and 4 varieties of *Pedicularis gracilis,* to explain its complex nature, from Himalayas. One of these taxa (*Pedicularis gracilis* subsp. *gracilis* var. *stricta*) was described in present study as *Pedicularis gracilis* subsp. *stricta*. Both plants showed common features.

Conclusion

Macro-morphological characters of plants like habit, vegetative and floral characters, are helpful in delimitation of genus as well as species. Especially phyllotaxy and shape of corolla (particularly shape of galea) are crucial in infra-generic classification as well as species delimitation. Similarly calyx and stamen characters also play important role in distinguishing species from each other. Beta taxonomy needs special emphasis with respect of floristics of Hazara, as two species are reported first time from the area, while some species, reported earlier from area of study by different taxonomists, are not found in present study, mainly due to ecological reasons, particularly degradation of natural habitat.

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